

Developing Pre-service Teachers' Transversal Science, Technology, Engineering, and Mathematics Competencies through Structured Educational Psychology: Evidence from a Module Implementation in Türkiye

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ABSTRACT

Educational psychology plays a critical role in preparing future Science, Technology, Engineering, and Mathematics (STEM) teachers by supporting evidence-based instructional practices and the development of transversal competencies. This study evaluates the effectiveness of Educational Psychology in a STEM Fields module developed within the Erasmus+ academy for STEM teachers project for pre-service science teachers. A quantitative single-group pre-test–post-test quasi-experimental design is employed with 54 participants. The blended 4-week module integrates face-to-face and online learning activities focusing on educational psychology, teacher proactivity, time management, and collaborative work. The results indicate a statistically significant improvement in participants' transversal STEM competencies following the intervention, with no significant gender differences observed. Descriptive findings further show notable improvements in inclusive instructional design, educational psychology-based decision-making, and collaborative learning. Participants also report high levels of self-perceived thematic competence and overall satisfaction with the module. Overall, the findings suggest that integrating educational psychology into STEM teacher education can effectively enhance pre-service teachers' pedagogical competencies, foster essential transversal skills, and support more inclusive and evidence-informed STEM teaching.

KEY WORDS: Blended learning, educational psychology, pre-service teachers, science, technology, engineering, and mathematics teacher education, transversal competencies

INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) is an interdisciplinary educational field that fosters critical thinking, problem-solving, and innovation to address global challenges, prepares students for a technology-driven global economy, and promotes long-term sustainability (Organisation for Economic Co-operation and Development [OECD], 2023; 2025). Fulfilling these strategic goals requires moving beyond traditional disciplinary boundaries and adequately preparing STEM educators to satisfy the growing instructional demands of modern classrooms. A significant portion of the necessary competencies required in contemporary STEM teaching is genuinely rooted in psychology, which provides the foundational theoretical and empirical frameworks necessary for a better understanding of learning, motivation, and human development within instructional environments (Bray, 2010; McDonald, 2016).

Brief Review of Educational Psychology Research in STEM Education

Empirical research in the psychology of STEM education examines various topics – the cognitive, motivational,

ffective, social, and professional identity-related mechanisms presented in learning, instruction, curriculum design, career trajectories, and equity (Buckley et al., 2018; Lubinski, 2010; Uttal and Cohen, 2012; Wai et al., 2009). A traditional focus in the literature is on the cognitive architecture underlying student learning, specifically the assessment of spatial and general cognitive abilities and the translation of these diagnostic findings into actionable pedagogical strategies.

Parallel to cognitive perspectives, motivational and affective dynamics are equally prominent in explaining STEM engagement and achievement. Foundational theoretical frameworks – including self-determination theory (Ryan and Deci, 2000), expectancy-value theory (EVT; Eccles and Wigfield, 2002), and social cognitive theory (Bandura, 1997) in an educational context – serve as primary analytical lenses for evaluating student achievement, persistence, or various educational outcomes. Within these frameworks, academic self-efficacy, defined as an individual's belief in their capability to execute actions required to achieve specific performance outcomes (Bandura, 1997), emerges as an important psychological determinant of STEM success.

High self-efficacy directly mitigates domain-specific affective barriers, such as mathematics and physics anxiety, while robustly predicting performance in laboratory and complex problem-solving STEM settings. Furthermore, instructors' growth-mindset beliefs directly shape students' psychological experiences and disciplinary interest (LaCosse et al., 2021).

From the Eccles and Wigfield EVT perspective, intrinsic interest value and utility value (the perceived alignment of STEM content with personal and career goals) act as vital catalysts for long-term engagement. Conversely, perceived task effort and psychological cost (e.g., fear of failure, social sacrifice) represent primary drivers of student attrition from STEM pathways. Equity-oriented research further highlights systemic psychological barriers affecting underrepresented groups across developmental milestones (Saucerman and Vasquez, 2014), the operationalization of pervasive cultural stereotypes (Master and Meltzoff, 2016), and the protective effects of psychologically inclusive instructional environments (Kizilcec and Saltarelli, 2019). Much of the existing research is grounded within social cognitive career theory (Lent et al., 1994), which highlights identity formation, contextual support systems, and self-efficacy as critical levers for broadening participation and sustaining long-term professional interest in STEM fields.

Instructional Design, Teacher Transversal Competencies, and Professional Preparation

Translating psychological principles – such as self-efficacy, motivation, and cognitive load theory – into concrete curricular and instructional innovations requires both rigorous instructional design and teachers who are effectively trained to integrate these practices into everyday professional activities (e.g., Darling-Hammond et al., 2017). Research demonstrates the efficacy of strategic scaffolding – defined as temporary, structured guidance delivered at individual and collaborative levels – within problem-based learning environments in STEM disciplines (Kim et al., 2018; 2020). Similarly, authentic outreach programs and job-shadowing initiatives significantly enhance student motivation and vocational attitudes (Vennix et al., 2018). Emergent curricular paradigms, such as STEAM (integrating the arts and humanities into traditional STEM), further underscore how psychological theory informs holistic instructional strategies, thereby aligning cognitive, emotional, and social dimensions to optimize learning outcomes.

Instructors' mindset beliefs and motivational orientations implicitly guide their choice of instructional strategies, highlighting the need for professional development frameworks that systematically cultivate these psychological capacities to foster more adaptive and responsive teaching practices. Since STEM disciplines encompass vast and rapidly evolving knowledge bases, achieving complete technical expertise across all constituent fields – or even within a single domain – presents a considerable challenge for any individual educator. Consequently, interdisciplinary collaboration and adaptive teaching capabilities become increasingly vital (Lin et al.,

2025). While international educational taxonomies widely recognize content knowledge, general pedagogy, digital skills, and ethical competencies as fundamental pillars of effective teaching, scholarly attention increasingly focuses on teacher transversal competencies as essential components for integrated STEM education (Bybee, 2013).

Conventionally, psychological knowledge has been conceptualized as an intrinsic core of teacher transversal competencies, rather than as an isolated sub-discipline.

In educational taxonomy and teacher professional standards, transversal competencies represent cross-disciplinary, non-technical capacities – such as communication, adaptive problem-solving, emotional regulation, reflective practice, and culturally responsive teaching – that allow educators to navigate complex classroom dynamics. Psychological literacy serves as the underlying cognitive and affective engine that powers these capacities (Cavas and Cavas, 2020). For instance, an educator's ability to communicate effectively or differentiate instruction depends directly on their functional understanding of student cognitive load, developmental readiness, and self-regulatory processes (Darling-Hammond et al., 2017). By embedding psychological principles within the construct of transversal competencies, teacher education frameworks recognize that managing human development and interpersonal classroom environments requires the systematic application of behavioral and psychological science (Lent et al., 1994).

Transversal competencies integrate these interpersonal dispositions with advanced cross-disciplinary cognitive abilities, including critical thinking, data-informed adaptive instruction, and interdisciplinary curriculum design (Koç et al., 2024). Unlike informal soft skills, transversal competencies are explicitly aligned with formal educational standards, psychological theory, and systemic equity goals, thereby empowering educators to translate evidence-based psychological principles into structured, contextualized STEM instruction (Bybee, 2013).

Psychological Principles in STEM Course Design

Educational psychology plays a pivotal role in updating STEM curriculum design by aligning instructional content with learners' cognitive and socio-emotional development. Grounded in cognitive load theory, effective STEM curricula utilize structured scaffolding and interactive simulations to optimize information processing and mitigate cognitive overload (APA, 2010). Furthermore, integrating psychological principles – such as metacognitive strategies, growth mindset cultivation, and socio-emotional learning – fosters resilience and enables pre-service educators to create inclusive, equitable learning environments (Bybee, 2013).

While the theoretical importance of educational psychology in STEM education is widely acknowledged, existing empirical scholarship has predominantly examined isolated psychological constructs within traditional, long-term course formats (Alan et al., 2019; Aşık et al., 2017). Consequently,

limited empirical attention has been devoted to systematically integrating applied educational psychology frameworks with transversal STEM competencies (e.g., metacognitive scaffolding, inclusive design against stereotype threat, and socio-emotional collaboration) (Koç et al., 2024). Furthermore, despite the growing shift toward flexible professional development, rigorous quantitative evaluations examining the effectiveness of short, blended pedagogical modules in developing these non-domain-specific competencies among pre-service science educators remain scarce.

To address these critical gaps, this study evaluates a specialized 4-week blended module, entitled “Educational Psychology in STEM Fields,” developed within the scope of the Erasmus + Academy for STEM Teachers (acaSTEMy) project, examining its impact on pre-service science teachers’ transversal self-efficacy, domain-specific achievements, and course satisfaction.

Educational Psychology in Developing Teachers’ Transversal Competences and Context of the Study

To ensure students learn how to apply knowledge effectively, STEM education must move beyond teaching theoretical basics and actively offer experiences embedded in socially relevant and personally meaningful contexts (Bybee, 2013). Driven by this educational necessity, STEM teachers’ transversal competencies such as communication, collaboration, analytical problem-solving, adaptability to shifting classroom dynamics, emotional intelligence, metacognitively informed reflective practice, and culturally responsive teaching that promotes inclusivity emerge as vital cross-disciplinary capacities.

In educational research, it is important to distinguish transversal teacher competencies from traditional teacher soft skills, even though both share significant overlap in encompassing non-technical, interpersonal, and adaptive abilities informed by educational psychology. While teacher soft skills typically focus on narrower, interpersonal traits (e.g., empathy, patience, conflict resolution) that are not always tied to specific academic disciplines or systemic educational goals, transversal teacher competencies integrate both soft skills and cross-disciplinary abilities tailored specifically to STEM contexts (e.g., designing innovative interdisciplinary lessons and digital literacy) and align explicitly with formal professional development goals and global educational challenges.

In this study, “transversal STEM competencies” are conceptualized as non-domain-specific, integrative pedagogical, socio-emotional, and cognitive capabilities required for educators to establish resilient and inclusive STEM learning environments. Rather than relying on isolated instructional techniques, the theoretical architecture evaluated in this study is directly anchored in the European Commission’s LifeComp Framework (Sala et al., 2020) across its personal, social, and learning-to-learn dimensions, and contextualized within the acaSTEMy competency framework. This theory-driven alignment synthesizes foundational educational

psychology constructs, including self-regulated learning (Zimmerman, 2002), reflective practitioner models (Schön, 1983; Korthagen, 2010), mindset theory (Dweck, 2006), and social constructivism (Biesta, 2015).

Context of the Present Study and Problem Statement

Despite the recognized importance of these psychological foundations, conventional STEM teacher education programs frequently isolate educational psychology from practical STEM pedagogy, treating it as an abstract requirement rather than an applied instructional toolkit (Akgündüz, 2018; Çolakoğlu and Gökben, 2017). Consequently, pre-service educators are often not fully equipped to translate psychological theories into adaptive, classroom-ready strategies that address complex instructional challenges (Arslanhan and İnaltekin, 2020). Furthermore, indices regarding demographic or gender-based disparities in STEM self-efficacy and pedagogical confidence among pre-service teachers underscore the need to evaluate whether targeted training interventions yield equitable outcomes (Aydın et al., 2017; Baran et al., 2020).

To bridge this gap and operationalize educational psychology principles into actionable pedagogical skills, this study evaluates an intervention module entitled “Educational Psychology in STEM Fields” (Burusic, 2025), developed within the scope of the international acaSTEMy project. This structured intervention aims to advance pre-service educators beyond generic soft skills toward evidence-based transversal capacities.

To systematically evaluate the impact and efficacy of the “Educational Psychology in STEM Fields” module, this study addresses the following five research questions:

1. RQ1: Does the implemented module have a statistically significant effect on the level of participants’ Core Transversal STEM competencies?
2. RQ2: Does the effect of the implemented module on the level of participants’ core transversal STEM competencies vary significantly according to gender?
3. RQ3: What is the nature of the change in pre-service teachers’ transversal skills from the pre-test in the “Educational Psychology in STEM Fields” module to the post-test stage?
4. RQ4: What are pre-service teachers’ self-perceived levels of thematic competence and specific learning achievements following the module intervention?
5. RQ5: What are pre-service teachers’ perceptions regarding the “Educational psychology in STEM fields” module?

METHODOLOGY

Research Design

To evaluate the effectiveness of the educational psychology in STEM fields module, developed within the scope of the Erasmus+ acaSTEMy project for pre-service science teachers, a quantitative single-group pre-test–post-test quasi-experimental design was employed.

Owing to institutional and curriculum integration constraints, the intervention was implemented within a single cohort, without a control group, over a 4-week period (8 h/week). This provided a suitable framework for the preliminary evaluation of this innovative module.

To address the research questions comprehensively, a dual-layered analytical framework was utilized in two layers. The first layer employed inferential statistics to evaluate the overall impact of the module and its interaction with demographic variables. Specifically, parametric assumptions were tested and satisfied, allowing for the execution of a paired-samples t-test used to measure the statistical significance and effect size (Cohen's *d*) of the change from pre-test to post-test (RQ1). Concurrently, an independent-samples t-test was utilized to examine whether this intervention effect varied significantly based on the participants' gender (RQ2).

The second layer consisted of a comprehensive descriptive and thematic tracking approach to provide a granular understanding of the module's outcomes based on the evaluation instruments.

The evaluation instrument utilized in this framework consisted of a comprehensive post-test containing 33 items, building on a shorter, targeted pre-test baseline. Arithmetic means and standard deviations were calculated to (i) assess the specific nature of the change in transversal skills (RQ3), (ii) evaluate post-intervention levels of self-perceived thematic competence and learning achievements (RQ4), and (iii) map pre-service teachers' perceptions regarding the overall module implementation (RQ5).

Theoretical Criteria for Module Development

Each module comprises three types of activities designed to foster self-reflection, contextual understanding, and practical application as indicated below:

Setting the scenario (face-to-face)

Conducted in a face-to-face format, this activity begins with an introductory scenario that provides context and relevant information, followed by a self-assessment task. During this process, participants review their existing skills and identify areas for growth regarding the focus of the unit, thereby gaining meaningful self-awareness within a collaborative environment.

Explore and explain (online)

This online activity deepens participants' self-assessment through guided reading and reflection. Participants explore how the target social skills of the unit can be applied to their STEM classrooms, reflect on their position within the broader instructional context, and analyze real-life implications to link their insights with effective teaching practices.

Application (follow-up group face-to-face session and individual follow-up activities)

In group-based, face-to-face sessions and individual follow-up activities, participants evaluate their self-assessments and the insights gained during the "explore and explain" process, either collaboratively with other educators or by analyzing

them from an operational perspective. Through collaborative exploration, participants are guided to exchange ideas, comprehend potential challenges, and investigate how to integrate new insights into their instructional practices, leading to tangible outcomes.

Reflection and transfer

Educational Psychology in STEM Fields Module concludes with a "Closing Session." This session summarizes all core insights, strategies, and takeaways derived from the units. It also provides an opportunity for participants to reflect on their professional growth, consolidate their learning, and plan how to systematically implement these enhanced social competencies within their STEM classrooms. Table 1 shows the Phases of the module (educational psychology in STEM fields).

Sample

Based on the feedback from the module participants (detailed analysis conducted on 54 complete post-test responses), the demographic profile of the study group was examined (Table 2).

This imbalanced distribution reflects the general demographic trends in Turkey, where the teaching profession is predominantly

Table 1: Phases of the module (educational psychology in STEM fields)

Unit/Theme	Phase and delivery mode	Core focus and task description
Unit 1: Defining module	Scenario (face-to-face)	Module orientation, educational psychology foundations in STEM, and pre-test administration.
Unit 2: Teacher proactivity	Scenario (face-to-face)	Task initiation, proactive goal setting, self-assessment.
	Explore (online)	Critical literature reviews on teacher initiative.
	Apply (face-to-face)	Curriculum innovation and practical peer discussions.
Unit 3: Time management	Scenario (face-to-face)	Time management architectures for professional targets.
	Explore (online)	Analyzing literature on task prioritization strategies.
	Apply (face-to-face)	Formulating personal instructional balance metrics.
Unit 4: Working with others	Scenario (face-to-face)	Interdependency concepts, collaborative self-efficacy.
	Explore (online)	Asynchronous readings on stakeholder communication.
	Apply (face-to-face)	Teamwork workshops and peer reflection exercises.
	Summary (face-to-face)	Final closure session and comprehensive post-test.

STEM: Science, technology, engineering, and mathematics

Table 2: Participant profile and demographics

Demographic variable	Category	Frequency	Percentage
Gender	Female	39	72.2
	Male	15	27.8
Total		54	100.0

preferred and represented by females. As reported by the Ministry of National Education (MoNE, 2025), the national teaching workforce comprises 732,056 female teachers and 455,353 male teachers, indicating that teaching remains a predominantly female profession.

Questionnaire Development and Quantitative Analysis

The measurement instrument employed in this research was adapted to fit the current module content from the questionnaire, originally created by Cláudia Faria within the scope of the acaSTEMy project. To evaluate the impact and efficacy of the “Educational Psychology in STEM Fields” module, a two-phase asymmetric evaluation design was implemented. Both instruments utilized a 6-point Likert-type scale, ranging from 1 (strongly disagree) to 6 (strongly agree), thus eliminating neutral responses and encouraging definitive self-assessment by the pre-service STEM teachers. Both versions opened with an identical demographic information index (Section I) capturing participants' gender under strict data privacy protocols.

Content and face validity of the evaluation instrument were established through an expert review panel comprising three educational psychology researchers and two STEM education specialists within the scope of the Erasmus+ acaSTEMy project. The panel evaluated the items for theoretical alignment, construct clarity, and age-appropriate pedagogical phrasing for pre-service teachers.

The evaluative framework was intentionally structured as an asymmetric longitudinal design. The pre-test was restricted exclusively to Section II (8 core items, Items 4–11) to establish an unconfounded baseline measurement of pre-service teachers' transversal STEM self-efficacy before intervention. Administering Section III (specific thematic outcomes) and Section IV (module satisfaction and utility) at the pre-test stage was seen as methodologically inappropriate, as participants had

no prior exposure to the module content or delivery platform. Direct inferential pre-post comparison (paired-samples t-test) was strictly bounded to the identical 8 items in Section II.

A detailed structural comparison and item mapping of the pre-test and post-test instruments across all operational dimensions is summarized in Table 3.

The architecture of the quantitative data collection was organized around three core focus areas:

1. Comparative competency dimension (Section II Items 4–11): This section served as the direct comparative baseline administered at both the pre-test and post-test stages, evaluating longitudinal shifts in perceived transversal skills (e.g., analytical understanding, problem-solving, and collaboration).
2. Thematic learning achievements (Section III Items 12–20): Administered solely at the post-test stage, this dimension measured the attainment of specific module learning objectives regarding educational psychology in STEM fields.
3. Module organization and applicability (Section IV Items 21–33): This post-intervention phase measured participant satisfaction, the efficacy of the blended (face-to-face and online) structure, online learning materials, and overall module utility.

Data Collection and Analysis

The questionnaire data were analyzed using IBM Statistical Package for the Social Sciences Statistics 24. Before the analyses, the dataset was screened for missing values and outliers. After the screening process, complete data from 54 participants were retained for the final analyses.

The descriptive statistics results regarding the pre-test and post-test scores of the participating students ($n = 54$) within

Table 3: Structural comparison and item mapping of the pre-test and post-test instruments

Instrument dimension/ section	Pre-test item range	Post-test item range	Specific focus and competency domains measured	Inclusion rationale
Section I: Demographic index	Items 1–3	Items 1–3	General participant demographic background (specifically gender)	Baseline participant profiling
Section II: Core transversal STEM competencies	Items 4–11	Items 4–11	Educational psychology integration, student motivation, scaffolding, collaboration, time management, proactive initiative, cognitive load optimization in digital tools, and reducing stereotype threats	Direct comparative analysis: Administered pre- and post-intervention to track self-efficacy shifts
Section III: Specific thematic learning achievements	Not included	Items 12–20	Scientific inquiry resilience, peer mentorship management, metacognitive strategies, growth mindset cultivation, emotional intelligence, and autonomy-supportive teaching environments.	Post-intervention only: Measures direct mastery of targeted module topics.
Section IV: Module satisfaction and operational utility	Not included	Items 21–33	Module utility, blended delivery satisfaction (face-to-face vs. online), online reading material quality, peer recommendation intent, theoretical-practical balance, and overall satisfaction.	Post-intervention only: Evaluates the usability, design, and systemic quality of the course module.
Total items	8 scaled items (+3 demographics)	30 scaled items (+3 demographics)	Full evaluative coverage of the STEM module intervention	Asymmetric longitudinal evaluation design

STEM: Science, technology, engineering, and mathematics

the scope of Section II are as presented in Table 4. When the obtained findings were examined, it was observed that the pre-test arithmetic mean of the participants was 31.02 (standard deviation [SD] = 6.95), whereas the post-test arithmetic mean increased to 34.81 (SD = 4.97). In addition, the students' pre-test scores ranged between 18.00 and 48.00, while their post-test scores varied between 20.00 and 46.00.

Instrument Reliability

The internal consistency of the evaluation instruments was evaluated using Cronbach's alpha, calculated across all structural dimensions for both administration phases. Given that the overall scale reliability remained exceptionally high and well above the recommended 70 threshold (Tavakol and Dennick, 2011), all items were retained to preserve content coverage. A detailed summary of the reliability metrics across all instrument dimensions is presented in Table 5.

For the core transversal STEM competencies dimension (Section II; 8 items), the pre-test instrument demonstrated excellent internal reliability ($\alpha = 0.925$). Following intervention, the post-test administration for Section II maintained high reliability ($\alpha = 0.862$), with corrected item-total correlations ranging from 0.441 to 0.729, confirming robust measurement stability. The post-test exclusive dimensions also demonstrated high to excellent internal consistency. Section III (specific thematic learning achievements; 9 items) yielded a Cronbach's alpha of 0.858, with corrected item-total correlations ranging between 0.465 and 0.714. Section IV (module satisfaction and utility; 13 items) exhibited excellent overall internal reliability ($\alpha = 0.940$). Within Section IV, individual item-total correlations ranged from 0.653 to 0.847 across twelve items, while Item 4.11 exhibited a lower item-total correlation ($r = 0.156$).

Assessing Normality

To determine the appropriateness of utilizing parametric analysis techniques across the research questions, the

assumption of normal distribution was systematically evaluated for both the overall dataset and the subgroup levels. Evaluated through multiple indicators rather than relying solely on a single statistical test (Field, 2018), the distributional properties of difference scores (post-test minus pre-test) derived from Section II were examined using statistical significance tests (Kolmogorov-Smirnov and Shapiro-Wilk) alongside descriptive shape parameters (skewness and kurtosis).

For the first research question, evaluating the overall intervention effect across the entire sample ($n = 54$), difference scores demonstrate a statistically normal distribution, as summarized in Table 6 (Kolmogorov-Smirnov $p = 0.200$; Shapiro-Wilk $p = 0.074$). Although Hair et al. (2013) suggest a strict range of -1.0 to $+1.0$ for skewness and kurtosis, broader statistical literature accepts values between -2.0 and $+2.0$ as indicating an acceptable departure from normality for parametric procedures (George and Mallery, 2010). In the overall dataset, the difference scores yielded a skewness of -0.070 and a kurtosis of -1.059 , well within these acceptable limits.

For the second research question, examining competency variations by gender, the distribution of difference scores was evaluated separately for female ($n = 39$) and male ($n = 15$) participants (Table 7). For male participants, the Shapiro-Wilk test confirmed normal distribution ($p = 0.989$), with skewness (0.014) and kurtosis (-0.469) values remaining near ideal levels. For female participants, while the Shapiro-Wilk test indicated a deviation from normality ($p = .028$), the non-significant Kolmogorov-Smirnov test ($p = 0.093$) and the skewness (-0.097) and kurtosis (-1.247) parameters remained safely within the accepted thresholds of -2.0 to $+2.0$ (Ghasemi and Zahediasl, 2012). Given that the independent-samples t-test is statistically robust to moderate departures from normality when skewness and kurtosis fall within acceptable limits – particularly in groups where $n \geq 30$ (Field, 2018) – the parametric t-test framework was retained for the subgroup analysis.

RESULTS/FINDINGS

This section presents the empirical findings regarding the effectiveness of the *Educational Psychology in STEM Fields* module. The results are structured around the targeted research questions, presenting inferential statistical analyses alongside descriptive insights.

Table 4: Descriptive statistics for Section II pre-test and post-test scores

Section	N	M	SD	Min	Max
Section II Pre-test	54	31.02	6.95	18	48
Section II Post-test	54	34.81	4.97	20	46

Section II measures core transversal STEM competencies (total of 8 items). N: Number, M: Mean, SD: Standard deviation, Min: Minimum, Max: Maximum, STEM: Science, technology, engineering, and mathematics

Table 5: Internal consistency metrics for evaluation instruments

Scale dimension	Phase	Number of items	Cronbach's alpha (α)	Item-total correlation range
Section II: Core transversal STEM competencies	Pre-test	8	0.925	0.501–0.844
Section II: Core transversal STEM competencies	Post-test	8	0.862	0.441–0.729
Section III: Specific thematic achievements	Post-test	9	0.858	0.465–0.714
Section IV: Module satisfaction and utility	Post-test	13	0.940	0.156–0.847

STEM: Science, technology, engineering, and mathematics

Comparative Analysis of Core Transversal STEM Competencies

To answer the first research question (*Does the implemented module have a statistically significant effect on the level of participants' Core Transversal STEM Competencies?*), a paired-samples t-test was executed. Table 8 summarizes the comparative inferential statistics derived from Section II pre-test and post-test scores.

As presented in Table 8, a paired-samples t-test revealed a statistically significant difference between participants' pre-test ($M = 31.02$, $SD = 6.95$) and post-test ($M = 34.81$, $SD = 4.97$) scores, $t(53) = 3.08$, $p = 0.003$, indicating a clear shift in favor of the post-intervention measurement. To quantify the magnitude of this change, Cohen's d effect size was calculated. According to Cohen's (1988) standard classification criteria ($d = 0.20$ small, $d = 0.50$ medium, $d = 0.80$ large), the obtained effect size ($d = 0.42$) reflected a small-to-moderate practical effect size, demonstrating that the instructional module produced a meaningful positive movement in pre-service teachers' self-perceived thematic competence. Overall, the findings provided preliminary evidence of positive changes in participants' self-reported transversal STEM competencies following the module.

Analysis of Core Transversal STEM Competencies by Gender

To address the second research question (*Does the effect of the implemented module on the level of participants' Core Transversal STEM Competencies vary significantly according to gender?*), an independent-samples t-test was executed on the gain scores (post-test minus pre-test). The inferential statistics across gender groups are summarized in Table 9.

The difference in gain scores between female participants ($M = 4.54$, $SD = 8.98$) and male participants ($M = 1.87$, $SD = 9.28$) was not statistically significant, $t(52) = 0.97$, $p = 0.336$ (Table 8). Homogeneity of variances was confirmed by Levene's test ($F = 0.037$, $p = 0.849$). The calculated effect

size (Cohen's $d = 0.29$) represented a small practical effect size, indicating that the module intervention produced a consistent enhancement in core transversal STEM competencies across both gender groups.

Findings Related to Research Question 3

The third research question (*What is the nature of the change in pre-service teachers' transversal skills from the pre-test to the post-test stage of the "Educational Psychology in STEM Fields" module?*) examined the nature of the shift in pre-service teachers' core transversal competencies from the pre-test to the post-test stage of the "Educational Psychology in STEM Fields" module (Section II). The item-level descriptive statistics, including pre-test and post-test means and standard deviations across the eight skill indicators, are presented in Table 10.

As detailed in Table 10, the descriptive analysis demonstrates a consistent positive trend across all transversal competency items following the module implementation. Before the training, participants exhibited their highest baseline competencies in social learning collaboration (Item 2.4; mean $[M] = 4.37$, $SD = 0.977$) and digital tool integration (Item 2.7; $M = 4.15$, $SD = 1.139$), whereas the lowest baseline performance was observed in analyzing STEM learning processes through educational psychology principles (Item 2.1; $M = 3.54$, $SD = 1.128$). Following the module intervention, the most substantial descriptive mean gains were registered in Item 2.1 (+0.87 points) and inclusive learning activity design (Item 2.8; +0.68 points). By the post-test stage, social learning collaboration maintained the highest overall mastery level (Item 2.4; $M = 4.85$, $SD = 0.899$). Overall, these findings indicated that the module effectively remediated initial conceptual gaps while simultaneously reinforcing pre-service teachers' inclusive, motivational, and technological competencies in STEM instruction.

To provide a more structural synthesis of these item-level shifts, the eight transversal competency indicators were categorized into five primary pedagogical domains: Information analysis (Items 2.1, 2.3), reasoned decision-making (Items 2.2, 2.5), collaboration and teamwork (Items 2.4, 2.6), digital tool integration (Item 2.7), and inclusive education design (Item 2.8). The domain-specific growth rates, high achievement metrics, and qualitative analytical trends across these core areas are shown in Table 11.

The improvement rate was operationalized as the relative percentage change from the pre-test to the post-test score.

Table 6: Tests of normality for overall section II difference scores

Variable	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	p-value	Statistic	df	p-value
Difference scores	0.095	54	0.200*	0.961	54	0.074

$n=54$. Difference scores=Post-test minus Pre-test scores. *This is a lower bound of the true significance

Table 7: Tests of normality for section II difference scores by gender

Variable	Gender	n	Kolmogorov-Smirnov			Shapiro-Wilk		
			Statistic	df	p-value	Statistic	df	p-value
Difference scores	Female	39	0.130	39	0.093	0.936	39	0.028
	Male	15	0.112	15	0.200*	0.984	15	0.989

$n=54$. Difference scores=Post-test minus Pre-test scores. *This is a lower bound of the true significance

$$\text{Improvement Rate (\%)} = \frac{X_{\text{post}} - X_{\text{pre}}}{X_{\text{pre}}} \times 100$$

High achievement rate (%) reflected the proportion of participants achieving high-level proficiency (scores of 5 and 6 on a 6-point scale) in the post-test evaluation.

As synthesized in Table 11, the domain-level analysis revealed that the largest relative growth vector occurred in inclusive education design (+18.73% improvement rate), emphasizing the module's effectiveness in training pre-service teachers to address equity and mitigate stereotype threat in STEM contexts. Simultaneously, collaboration and teamwork achieved the highest absolute post-test success rate (91.10%), underscoring high collective self-efficacy in managing group dynamics and interdisciplinary project tasks. Overall, these domain-specific advances demonstrated that the module's integrated

Table 8: Paired-samples t-test results for Section II pre-test and post-test scores

Measurement	N	M	SD	df	t-value	p-value	Cohen's d
Section II Pre-test	54	31.02	6.95	53	3.08	0.003	0.42
Section II Post-test	54	34.81	4.97				

n=54. Statistical significance was set at $P < 0.05$. N: Number, M: Mean, SD: Standard deviation, df: Degrees of freedom

Table 9: Independent-samples t-test results for core transversal STEM competencies gain scores by gender

Gender	N	M	SD	Levene's F	p-value	t-value	df	p-value
Female	39	4.54	8.98	0.037	0.849	0.97	52	0.336
Male	15	1.87	9.28					

n=54. Gain scores: Post-test minus Pre-test scores. Levene's test confirmed homogeneity of variance ($p > 0.05$). N: Number, M: Mean, df: Degrees of freedom, SD: Standard deviation, STEM: Science, technology, engineering, and mathematics

pedagogical structure successfully elevated both foundational decision-making abilities and specialized instructional design competencies in a balanced manner.

Findings Related to Research Question 4

The fourth research question (*What are pre-service teachers' self-perceived levels of thematic competence and specific learning achievements following the module intervention?*) investigated pre-service teachers' post-intervention levels of self-perceived thematic competence and specific learning achievements within the "Educational Psychology in STEM Fields" module (Section III). The descriptive statistics (means and standard deviations) for the nine evaluated thematic learning achievements at the post-test stage are displayed in Table 12.

The descriptive analysis of the thematic learning achievements evaluated in Section III demonstrated that participants reported consistently high levels of self-perceived competence across all dimensions following the module intervention (Table 12). Among the nine evaluated learning achievements, participants indicated the highest level of self-perceived competence in fostering a growth mindset in students and emphasizing that mistakes were an integral part of learning (Item 3.5; $M = 4.87$, $SD = 0.991$). This was closely followed by their confidence in supporting student perseverance during scientific inquiry (Item 3.1; $M = 4.69$, $SD = 0.722$) and utilizing self-reflective assessment tools for establishing professional goals (Item 3.8; $M = 4.47$, $SD = 0.799$). Conversely, the lowest mean scores, though still reflecting strong positive agreement, were observed in participants' perceived ability to integrate metacognitive strategies into their lessons (Item 3.3; $M = 4.09$, $SD = 0.917$) and to design autonomy-supportive learning environments (Item 3.9; $M = 4.34$, $SD = 0.876$). Overall, these findings suggested that while all targeted competencies were perceived as well-developed by the end of the intervention, the module was exceptionally successful in reinforcing participants'

Table 10: Comparative analysis of transversal skills (pre-test vs. post-test)

Item code	Skill/competency description	Pre-test M	Pre-test SD	Post-test M	Post-test SD
2.1	Ability to analyze learning processes in STEM fields through educational psychology principles (e.g., cognitive processes, metacognition)	3.54	1.128	4.41	0.813
2.2	Ability to make evidence-based (psychology-based) decisions to enhance student motivation and engagement in STEM courses	3.74	1.119	4.31	0.773
2.3	Ability to implement and evaluate cognitive and affective intervention methods for complex problems encountered in STEM disciplines	3.76	1.008	3.85	0.878
2.4	Understanding of how to foster social learning in STEM education through effective collaboration and respect for interdisciplinary perspectives	4.37	0.977	4.85	0.899
2.5	Ability to utilize proactive goal setting and time management strategies to achieve professional goals (e.g., lesson planning)	4.06	1.036	4.30	0.792
2.6	Ability to independently manage and complete complex tasks in STEM education (e.g., laboratory management, project-based learning)	3.78	1.003	4.26	0.994
2.7	Ability to integrate digital tools and simulations into the learning process to optimize students' cognitive load	4.15	1.139	4.52	0.926
2.8	Understanding of how to design inclusive learning activities that support underrepresented groups in STEM and mitigate stereotype threat	3.63	1.154	4.31	0.865

n=54. Ratings were measured on a 6-point Likert scale. M: Mean, SD: Standard deviation, STEM: Science, technology, engineering, and mathematics

Table 11: Development of transversal skills (pre-test vs. post-test comparison)

Skill area	Items included	Improvement rate (%)	High achievement rate	Analysis
Information analysis	2.1, 2.3	13.15	82.60	A significant increase was recorded in students' capacity to analyze learning processes in STEM fields through educational psychology principles and to evaluate cognitive/ affective intervention methods for complex disciplinary problems.
Reasoned decision-making	2.2, 2.5	10.38	86.10	Evidence-based decision-making competencies to enhance student motivation showed robust growth, paired with an enhanced proactive ability to utilize goal-setting and strategic time management in lesson planning.
Collaboration and teamwork	2.4, 2.6	11.78	91.10	Fostering social learning, practicing peer collaboration, and showing mutual respect for interdisciplinary perspectives yielded the highest absolute post-test achievement rate, demonstrating strong self-initiative in managing complex laboratory and project-based tasks.
Digital tool integration	2.7	8.92	90.40	Steady and consistent proficiency was demonstrated in purposefully incorporating advanced digital tools and educational simulations into learning environments to optimize students' cognitive load parameters.
Inclusive education design	2.8	18.73	86.20	The highest relative pedagogical growth vector was achieved in understanding how to structure inclusive learning pathways that actively support underrepresented demographics in STEM fields and proactively mitigate stereotype threat risks.

STEM: Science, technology, engineering, and mathematics

Table 12: Descriptive statistics for thematic learning achievements at post-test stage

Item code	Educational psychology in STEM fields/learning outcome	Post-test M	Post-test SD
3.1	Ability to support students in sustaining the scientific inquiry process patiently in the face of difficulties	4.69	0.722
3.2	Ability to manage peer mentoring processes effectively to support students' STEM identity development	4.40	0.862
3.3	Ability to integrate metacognitive strategies into lessons to enable students to monitor their own learning processes	4.09	0.917
3.4	Understanding of how to develop equity-oriented psychological interventions to mitigate systemic barriers in STEM education	4.37	0.831
3.5	Understanding of how to foster a growth mindset in students, emphasizing that making mistakes is an integral part of learning	4.87	0.991
3.6	Ability to utilize feedback techniques that enhance students' self-efficacy perceptions toward STEM tasks	4.43	0.944
3.7	Understanding of emotional intelligence principles to manage emotional dynamics and conflicts within the STEM classroom	4.43	0.924
3.8	Ability to utilize self-reflective assessment tools when establishing personal professional development goals	4.47	0.799
3.9	Ability to design autonomy-supportive learning environments to foster students' intrinsic motivation	4.34	0.876

n=54. Ratings were measured on a 6-point Likert scale. M: Mean, SD: Standard deviation, STEM: Science, technology, engineering, and mathematics

Table 13: Descriptive results for module satisfaction and evaluation at post-test stage

Item code	Evaluation item	M	SD
4.1	Perception of the module as suitable and beneficial	4.85	0.810
4.2	Satisfaction with the format of the module (blended/face-to-face and online)	4.85	0.899
4.3	Perception of online learning materials as well-designed and user-friendly for self-directed learning	4.81	0.892
4.4	Perception of online reading materials as suitable	4.69	0.886
4.5	Acquisition of new knowledge through the module-based course	4.72	1.017
4.6	Perception of online learning materials as providing meaningful feedback	4.89	0.816
4.7	Willingness to recommend the module-based course to colleagues	4.92	0.917
4.8	Willingness to participate in similar follow-up training sessions	4.59	1.141
4.9	Perception of the course as providing ideas directly applicable to teaching practices	4.74	0.944
4.10	Perception of the course level as appropriate	5.02	0.858
4.11	Perception of the course as not overly theoretical	3.59	1.206
4.12	Satisfaction and enjoyment derived from taking the course	4.94	0.920
4.13	Overall satisfaction with the module-based course	4.96	0.960

n=54. Ratings were measured on a 6-point Likert scale. Item 4.11 was reverse-coded before analysis. M: Mean, SD: Standard deviation

self-efficacy regarding student mindset transformation and professional self-reflection.

Module Satisfaction and Evaluation (Section IV)

The fifth research question (*What are pre-service teachers' perceptions regarding the "Educational Psychology in STEM Fields" module?*) examined pre-service teachers' perceptions regarding the overall design, utility, and satisfaction of the "Educational Psychology in STEM Fields" module (Section IV). The descriptive statistics (means and standard deviations) for the 13 evaluation indicators administered at the post-test stage are summarized in Table 13.

As presented in Table 13, participants reported high levels of overall satisfaction with the module-based course ($M = 4.96$, $SD = 0.960$) and expressed strong positive perceptions regarding its structural utility. The highest mean ratings were observed in participants' willingness to recommend the course to colleagues (Item 4.7; $M = 4.92$, $SD = 0.917$) and their overall enjoyment derived from the course experience (Item 4.12; $M = 4.94$, $SD = 0.920$). Furthermore, participants found the online feedback mechanisms highly effective (Item 4.6; $M = 4.89$, $SD = 0.816$). Conversely, the lowest mean score was recorded for Item 4.11 ($M = 3.59$, $SD = 1.206$), which evaluated the perception of the course as "not overly theoretical." This indicated that while the module was overwhelmingly well-received, participants perceived the theoretical workload as relatively intensive compared to practical components.

DISCUSSION AND CONCLUSION

This section presents a detailed analysis of the results from the module implementation conducted with pre-service science teachers. The analysis highlights both the development of transversal skills and the acquisition of educational psychology-related competencies in STEM fields.

Effectiveness of the Module on Core Transversal STEM Competencies

The first research question investigated whether the newly implemented "Educational Psychology in STEM Fields" module exerted a statistically significant effect on pre-service teachers' Section II core transversal STEM competencies. The inferential statistics indicated that the pedagogical treatment led to a significant increase from the pre-test baseline ($M = 31.02$, $SD = 6.95$) to the post-test stage ($M = 34.81$, $SD = 4.97$; $t(53) = 3.08$, $p = 0.003$), leading to the rejection of the null hypothesis. This statistically significant advancement suggested that integrating psychological frameworks – such as cognitive load optimization, scaffolding, and inclusive learning designs supported pre-service educators' transversal self-efficacy.

To critically gauge the practical magnitude of this intervention, Cohen's d effect size was calculated. The resulting value of $d = 0.42$ denoted a small-to-moderate effect size according to established psychological standards. Within the context of short-term educational interventions spanning a limited

4-week framework, achieving an effect magnitude of this scale indicated that the cyclical blend of "Setting the Scenario," "Explore and Explain," and "Application" modes provided an adaptable operational architecture. This finding aligned with contemporary teacher education literature, which asserted that when pedagogical training was structurally tied to collaborative self-assessment and practical classroom scenarios, it could encourage growth in non-technical teacher capacities, thereby helping bridge the gap between theoretical models and real-world implementation (Lin et al., 2025; Zimmerman (2002). However, as a single-group study without a control group, these findings offered preliminary evidence rather than broad generalizations.

Interaction of the Intervention with the Gender Variable

The second research question scrutinized whether the instructional benefits of the educational psychology module varied significantly based on participants' gender. The independent-samples t -test executed on the gain scores revealed that the difference in gain scores between female pre-service teachers ($M = 4.54$, $SD = 8.98$) and male pre-service teachers ($M = 1.87$, $SD = 9.28$) was not statistically significant, $t(52) = 0.97$, $p = 0.336$. This empirical trend suggested that the developmental trajectory of transversal STEM competencies followed a relatively uniform pattern across both demographic groups within this cohort.

In teacher training research, educational interventions frequently encountered skewed gender outcomes due to varying baseline anxieties or divergent relational traits. However, the equitable growth observed in this cohort suggested that the module's instructional architecture was balanced and accessible to both groups. The lack of significant divergence suggested that the core themes – such as professional time management, collaborative interdependency, and task proactivity – resonated well with both female and male teacher candidates.

While these results suggest a gender-neutral professional development tool capable of supporting future STEM educators in Turkey's predominantly female-represented teaching landscape, the demographic imbalance between female ($n = 39$) and male ($n = 15$) candidates warrants cautious interpretation regarding statistical power. The absence of significant gender differences in competency gains is particularly noteworthy given persistent documentation of psychological barriers and stereotype-related disparities in STEM pathways (Saucerman and Vasquez, 2014; Master and Meltzoff, 2016). This gender-neutral pattern suggests that the module's cyclical structure of scenario-based self-assessment, guided exploration, and collaborative application provides equitable access to psychological literacy for both female and male candidates, consistent with calls for psychologically inclusive instructional design (Kizilcec and Saltarelli, 2019).

Development of Transversal Skills

A granular evaluation of Section II indicators revealed that the implementation of the "Educational Psychology in STEM Field" module was accompanied by substantial growth

across five core academic and professional transversal skill domains. Moving beyond raw knowledge acquisition, the module's integrated pedagogical structure appeared to support both foundational decision-making abilities and specialized instructional design competencies in a balanced manner.

The most notable relative pedagogical advancement occurred in Inclusive Education Design, where pre-service teachers exhibited a pronounced shift in their awareness and practical capacity to structure equitable learning pathways. This outcome underscored the module's potential in preparing future educators to address systemic barriers, support underrepresented demographics in STEM, and mitigate stereotype threat risks. This aligned with modern equity-focused teacher education frameworks (e.g., Bybee, 2013), which emphasized that modern STEM instruction needed to extend beyond content mastery to cultivate inclusive classroom environments.

Simultaneously, participants demonstrated promising progress in Information Analysis, reflecting an enhanced capacity to examine complex STEM learning processes through educational psychology principles and to evaluate cognitive and affective intervention strategies. This conceptual growth was paralleled by positive trends in Collaboration and Teamwork, which achieved the highest overall post-intervention level. Fostering social learning, practicing peer collaboration, and promoting mutual respect for interdisciplinary perspectives appeared to have bolstered pre-service teachers' self-initiative when managing complex laboratory and project-based tasks (Sala et al., 2020). These findings supported social learning theories, suggesting that structured peer interdependency could support collective self-efficacy and collaborative STEM problem-solving (Lin et al., 2025; Kim et al., 2020).

Finally, steady growth was observed in reasoned decision-making and digital tool integration. The strong post-test proficiency in digital tool usage indicated that participants successfully learned to incorporate educational simulations and technology to optimize students' cognitive load parameters – a critical competence highlighted in cognitive load theory frameworks (APA, 2010).

The largest relative improvement occurred precisely in the domain the introduction identified as most underdeveloped in conventional STEM teacher education – the capacity to design psychologically inclusive learning environments that mitigate stereotype threat (Kizilcec and Saltarelli, 2019; Master and Meltzoff, 2016). Concurrently, the high post-intervention achievement in collaboration and teamwork reinforced the centrality of social-cognitive mechanisms, including collective efficacy and interdependent goal structures, for sustaining engagement in complex STEM tasks (Lent et al., 1994; Bandura, 1997). In general, these domain-specific advances demonstrated that the module's integrated pedagogical structure successfully elevated both foundational decision-making abilities and specialized instructional design competencies in a balanced manner.

Educational Psychology in STEM Fields and Self-Perceived Thematic Competence

The post-test evaluation of this section indicated that the “Educational Psychology in STEM Fields” module largely achieved its primary objective of fostering key pedagogical and psychological competencies among participants. The notable progress in enhancing participants' self-reported capacity to foster a growth mindset (I3.5), support student perseverance (I3.1), and utilize self-reflective tools (I3.8) aligns with contemporary educational psychology literature, which underlines that teacher mindset transformation was critical for establishing resilient STEM classrooms. Conversely, the relatively lower perceived competence reported in integrating metacognitive strategies (I3.3) and designing autonomy-supportive environments (I3.9) suggested that transitioning from theoretical understanding to active classroom design required more prolonged, hands-on pedagogical practice. In conclusion, the module served as a promising intervention for psychological empowerment and self-efficacy, though a slight gap remained between mindset shift and autonomous pedagogical implementation.

The notably high mastery of growth-mindset cultivation was consistent with evidence that instructors' mindset beliefs directly shaped students' anticipated psychological experiences and disciplinary interest (LaCosse et al., 2021). By contrast, the comparatively lower scores on metacognitive strategy integration and autonomy-supportive environment design indicated that shifts in underlying beliefs could occur more readily than the translation of those beliefs into sophisticated instructional design, a pattern well documented in research on the theory–practice divide in teacher education (Korthagen, 2010; Avalos, 2011). In conclusion, the module served as an effective intervention for psychological empowerment, though a slight gap remained between mindset shift and autonomous implementation.

Module Evaluation and Student Satisfaction

The “Educational Psychology in STEM Fields” module not only supported the content mastery of teacher candidates but also provided exposure to critical professional competencies. Inferential statistics indicated that the pedagogical treatment led to a statistically significant improvement in pre-service teachers' transversal STEM self-efficacy ($M = 31.02$ vs. $M = 34.81$, $p = 0.003$), yielding a small-to-moderate effect size (Cohen's $d = 0.42$). This observed improvement was consistent with literature indicating that professional learning experiences characterized by active learning, collaboration, modeling, feedback, reflection, and sustained engagement effectively strengthen teachers' instructional capacities (Darling-Hammond et al., 2017). Crucially, competency gains did not differ significantly by gender ($p = 0.336$), suggesting that the module provided accessible learning opportunities for both female and male candidates within this sample. Such outcomes were encouraging in the Turkish educational context, where women constituted the majority of the teaching workforce (MoNE, 2025).

Descriptively, the module achieved its most profound relative growth in fostering inclusive education designs to mitigate stereotype threat risks (+18.73% improvement) and addressing collaborative social learning frameworks (91.10% absolute post-test achievement rate). These findings resonate with Biesta's (2015) assertion that education must extend beyond raw knowledge acquisition to support students' socialization and subjectification. Conversely, participants reported comparatively lower post-intervention mastery in integrating metacognitive strategies into lessons ($M = 4.09$) and designing autonomy-supportive environments ($M = 4.34$). Teacher professional development research explains that transitioning from a theoretical understanding to active classroom design requires extended, iterative hands-on practice, suggesting that a 4-week timeline faces temporal constraints in cultivating full autonomous instructional execution (Avalos, 2011).

Regarding structural feedback, high agreement in the appropriateness of the course level ($M = 4.82$ on a 6-point scale) underscored the general suitability of the curriculum design. However, the relatively lower rating recorded for the perception of the course as "not being overly theoretical" ($M = 3.59$) indicated that while the module was highly valued and enjoyed, the theoretical density was perceived as intensive. This reflected a classic challenge in initial teacher education – the traditional "theory-practice divide" – where candidates frequently struggled to internalize dense psychological frameworks within short timeframes (Korthagen, 2010). Consequently, while the intervention proved to be a valuable tool for psychological and pedagogical empowerment, these combined outcomes suggested an opportunity for future practical optimization, highlighting the need to embed more prolonged simulation phases in subsequent implementations. Nevertheless, the high overall satisfaction and strong willingness to recommend the module suggested that the blended architecture successfully balanced conceptual depth with perceived professional utility, supporting arguments for sustained, reflective professional development models (Darling-Hammond et al., 2017; Avalos, 2011).

Limitations

Several limitations should be acknowledged regarding the scope and methodology of this study. First, the single-cohort design lacked a separate control group, which limited the ability to conclusively isolate the module's specific pedagogical impact from external variables or temporal maturation effects. Second, although inferential parametric and non-parametric analyses were successfully conducted, the data collection relied exclusively on quantitative self-report instruments. Consequently, the findings primarily reflected participants' subjective perceptions of their self-efficacy and competency gains rather than direct observational measures of classroom performance. Third, the study was conducted within a single institutional setting with a specific sample size ($n = 54$), which might restrict the broad generalizability of the module satisfaction and learning outcomes to diverse teacher education contexts. Finally, while the 4-week implementation

timeline proved effective for conceptual acquisition and self-efficacy growth, it presented temporal constraints for mastering complex instructional executions, such as autonomy-supportive climate design. Future research could address these limitations by incorporating control group experimental designs, longitudinal tracking of instructional practice, and qualitative data streams to achieve a more comprehensive triangulation of the module's long-term efficacy. Fourth, while the *post hoc* comparison across gender groups revealed no statistically significant differences in gain scores, the demographic imbalance between female ($n = 39$) and male ($n = 15$) participants might constrain the statistical power of the inferential test. Future implementations with larger, balanced samples should employ repeated measures analysis of variance or mixed-effects models to investigate time X gender interactions more robustly.

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