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Beyond Hardware: How Teacher Attitudes and Self-Efficacy Override Resources in Shaping ICT and Computational Thinking Practices

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Abstract

The 21st-century classroom is saturated with technology, yet a persistent "implementation gap" reveals that providing hardware is not enough. Why do some teachers seamlessly integrate digital tools while others struggle, despite equal resources? This large-scale, cross-national study investigates the psychological drivers behind this gap, moving beyond resource-centric explanations to explore teachers' attitudes and confidence. Drawing on data from over 48,000 teachers across diverse educational systems in ICILS 2023, we tested a mediation model examining how teachers' positive views on ICT and their perceptions of school resources influence classroom practices—both in general ICT use and the more demanding domain of Computational Thinking (CT) instruction.Our findings deliver a clear message: teachers' internal belief systems are the true catalysts for technology integration. While positive attitudes directly and indirectly predicted greater emphasis on ICT and CT, perceived resource availability showed no significant effect. This confirms that confidence outweighs material provisions. Furthermore, these mechanisms operate differently for male and female teachers, revealing that a one-size-fits-all professional development approach is insufficient. For policymakers and educators, the conclusion is transformative: to build future-ready classrooms, we must invest first in cultivating confident, positively disposed, and psychologically empowered teachers. Sustainable technology integration is not about hardware; it is about humanware.

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Introduction

The pervasive integration of Information and Communication Technologies (ICT) has catalyzed a profound transformation in education, shifting from a peripheral option to a central imperative for modernizing systems and equipping students with essential competencies (Voogt & Roblin, 2012). Within this landscape, educators face a dual mandate: to leverage ICT tools to enhance pedagogy and to foster 21st-century skills such as Computational Thinking (CT). Defined as a problem-solving process involving abstraction, decomposition, and algorithmic thinking, CT is now regarded as a foundational literacy in a technology-saturated society (Wing, 2006; Yadav et al., 2016). Equipping students with these skills is therefore a central priority for contemporary education systems. However, the mere presence of technology in classrooms has not automatically translated into improved practices or student competencies. This persistent 'implementation gap' demonstrates that providing resources is a necessary but insufficient condition for effective technology integration. The critical question facing policymakers is no longer *if* schools have technology, but *why* integration so often fails to meet its potential (Ertmer & Ottenbreit-Leftwich, 2010). Understanding the core drivers of effective use has thus become an urgent priority. This study addresses this urgency by moving beyond simplistic resource-based explanations to investigate the deeper psychological mechanisms—teachers' attitudes, beliefs, and self-efficacy—that ultimately determine whether technological investments yield meaningful educational returns. By leveraging a large-scale, cross-national dataset, we provide robust evidence to guide policies toward a more sustainable, human-centered approach to technology integration.

In response to the digital shift, educational policies worldwide have prioritized investments to close the "first-level digital divide"—the gap in physical access to hardware and connectivity (DiMaggio & Hargittai, 2001). However, as schools have become equipped, a more nuanced "second-level digital divide" has emerged: disparities in the skills, confidence, and pedagogical strategies required to use technology transformatively (Hargittai, 2001). This compels a critical shift in research focus from infrastructure to the psychological dispositions of teachers (Teo, 2008). Factors such as teachers' attitudes toward technology's educational value and their ICT self-efficacy—their confidence in using technology effectively—are powerful determinants of classroom behaviors (Bandura, 1997; Comi et al., 2017). Positive attitudes and high self-efficacy are consistently linked to a greater willingness to experiment with digital tools and integrate them in student-centered ways (Pozas & Letzel, 2023). Therefore, this study operates on the premise that while environmental factors like resource availability are relevant, their influence is filtered through teachers' internal belief systems. A confident teacher may overcome resource limitations, whereas a teacher with low confidence may fail to utilize even advanced technologies. This positions ICT self-efficacy not merely as a direct predictor, but as a crucial mediating mechanism that channels the influence of both external resources and internal attitudes into concrete classroom action. Although the individual significance of these psychological and contextual factors is well established, much of the existing literature examines them in isolation or within narrowly defined national contexts (Sang et al., 2010). Studies often focus solely on direct relationships between attitudes and ICT use (Teo, 2008) or highlight structural barriers (Tondeur et al., 2007). Other contributions, while valuable, are restricted by their contextual scope, such as single-country settings like Ghana (Arhin et al., 2025) or Indonesia. Even when integrative frameworks like the Technology Acceptance Model (TAM) are employed, their application is frequently confined to specific subpopulations, such as preschool teachers in China (Hong et al., 2021) or secondary teachers in Vietnam (Granić & Marangunić, 2019), limiting broader applicability. Consequently, a critical gap persists: the comprehensive, cross-national examination of how teachers' attitudes and perceived resources jointly shape classroom practices, particularly through the mediating role of ICT self-efficacy. Few studies have empirically tested this mediation using large-scale international data. To address this gap, the present study proposes and tests a partial mediation model using data from the International Computer and Information Literacy Study (ICILS) 2023. This study investigates the extent to which teachers' positive attitudes toward ICT and their perceptions of school-level resources predict their ICT- and CT-related instructional practices, and whether ICT self-efficacy mediates these relationships. By simultaneously modeling these pathways, the study offers robust, large-scale empirical evidence on the relative importance of individual beliefs versus structural conditions, informing evidence-based policies for effective technology integration across diverse educational contexts.

Theoretical Framework and Hypotheses Development

The conceptual model is grounded in two complementary theoretical streams: Social Cognitive Theory (SCT; Bandura, 1986), which explains the reciprocal interactions among personal, behavioral, and environmental factors, and Technology Acceptance Models (TAM; Davis et al., 2024), which elucidate the mechanisms driving technology adoption. Together, these theories offer a robust foundation for understanding how teachers' internal beliefs and external environments jointly shape their instructional practices.

Social Cognitive Theory: The Centrality of Self-Efficacy

SCT explains human behavior through triadic reciprocal determinism—a dynamic interaction among personal factors (e.g., beliefs), environmental influences (e.g., resources), and behaviors (Bandura, 1986). Among its core constructs, self-efficacy stands out: an individual's belief in their capability to execute actions necessary to achieve specific outcomes. Crucially, self-efficacy is not about the skills one possesses, but about the confidence in using those skills effectively.

The explanatory power of self-efficacy has been validated across disciplines, from organizational performance with technology (Harrison et al., 1997) to health behaviors (Anderson et al., 2007). In education, self-efficacy is a malleable belief that can be enhanced through targeted interventions (Roberts et al., 2001), and it remains the most consistently powerful predictor of technology integration intentions and practices, with validity confirmed in cross-cultural contexts (Huang et al., 2020; Perkmen et al., 2023). Applying this framework, ICT self-efficacy emerges as a key explanatory variable. High levels are associated with a greater willingness to experiment with new tools, persistence in overcoming challenges, and more innovative pedagogical approaches (Ertmer & Ottenbreit-Leftwich, 2010). Importantly, SCT provides the rationale for positioning self-efficacy as a central mediator: the influence of external factors (like resources) and internal beliefs (like attitudes) on behavior is often channeled through self-efficacy beliefs (Compeau & Higgins, 1995). Therefore, this study operationalizes personal factors as teachers' positive attitudes and ICT self-efficacy, and environmental factors as perceived resource availability, positing that these jointly influence the emphasis on instructional practices focused on ICT and CT.

Technology Acceptance Models: From Attitudes to Action

While SCT explains the role of internal beliefs, it does not fully account for the attitudinal determinants of adopting specific technologies. To address this, TAM, grounded in the Theory of Reasoned Action (Fishbein & Ajzen, 1975), introduced two universal belief constructs: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). PU—the belief that using a system enhances job performance—aligns conceptually with positive views on technology, which increase intentions to use it (Davis, 1989; Scherer et al., 2019). PEOU—the belief that using a system is free of effort—is theoretically linked to self-efficacy, as technologies perceived as easier to use enhance confidence (Bandura, 1997). Over three decades, TAM has evolved into extended versions (TAM2, TAM3, UTAUT), yet the original constructs remain foundational (Davis et al., 2024).

Extending Technology Integration to Computational Thinking (CT)

Building on these models, this study focuses on a specialized, future-oriented competency: CT. Popularized by Wing (2006), CT is a fundamental problem-solving process involving decomposition, pattern recognition, and abstraction (Shute et al., 2017). Integrating CT into K-12 education presents a distinct pedagogical challenge compared to general ICT use. While the latter often involves applying ready-made tools like word processors, fostering CT requires guiding students through a cognitively demanding process grounded in logic and algorithms (Shute et al., 2017). This distinction is pedagogically significant: the factors influencing a teacher's readiness to use presentation software may differ from those shaping their confidence to teach algorithmic reasoning. This distinction is critical because fostering higher-order thinking like CT may be even more dependent on a teacher's confidence in their own abilities than the application of routine ICT tools. Therefore, this study explicitly models Emphasis on ICT Capabilities and Emphasis on CT-related Tasks as distinct outcome variables, hypothesizing that the foundational drivers—attitudes, perceived resources, and ICT self-efficacy—will predict both practices within a unified framework grounded in SCT and TAM. Additionally, the study tests the moderating role of gender, given the complex landscape of gender differences in technology-related attitudes (Venkatesh & Morris, 2000; Cai et al., 2017; Scherer et al., 2019), to ensure a robust and generalizable understanding.

Purpose of the Study and Research Questions

To date, research has often examined the drivers of technology integration in isolation or within single-country contexts (Lee & Lee, 2021; Rubach et al., 2023), hindering the development of a comprehensive, generalizable framework. The present study addresses this gap by testing an integrated structural model on a large-scale, cross-national dataset from ICILS 2023. Our primary objective is to disentangle the relative influence of external conditions (perceived resources) and internal beliefs (attitudes, ICT self-efficacy) on teachers' instructional practices related to both general ICT use and CT. Specifically, we aim to provide robust empirical evidence on a central, under-tested hypothesis: that the impact of resources is mediated by teachers' psychological dispositions. By testing the invariance of this model across gender, we aim to deliver a widely applicable framework to guide evidence-based professional development and technology integration policies worldwide.

The Hypothesized Model and Study Hypotheses

Drawing on SCT and TAM, a partial mediation model was specified (see Figure 1). The model posits that teachers' positive attitudes toward ICT and their perceptions of available resources influence their instructional emphasis on ICT and CT, both directly and indirectly through the mediating role of ICT self-efficacy.

Based on this framework, the following hypotheses were formulated:

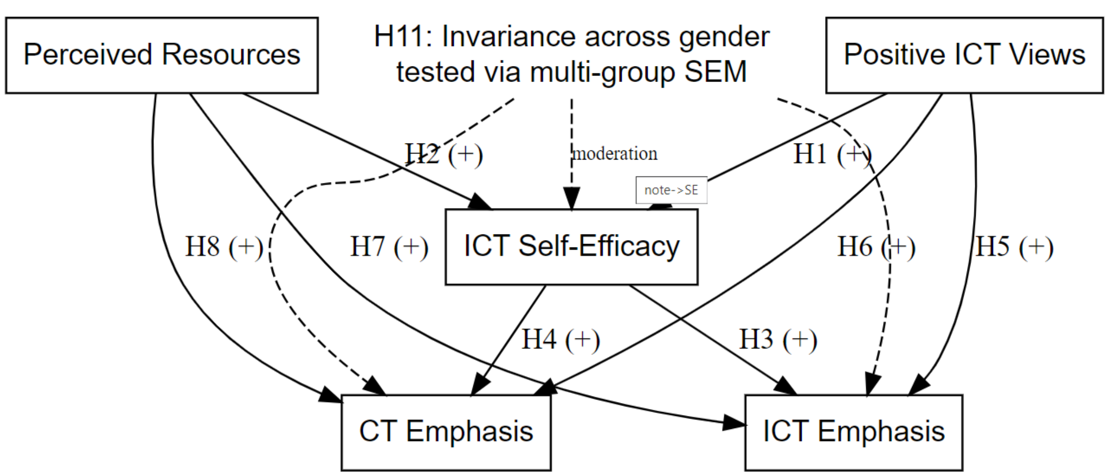

Fig. 1: The partial mediation model

Relationships with the Mediator (ICT Self-Efficacy):

H1: Teachers› positive views on using ICT will be positively associated with their ICT self-efficacy.

H2: The perceived availability of computer resources will be positively associated with teachers› ICT self-efficacy.

Effects on Classroom Practices (Outcome Variables):

H3: Higher ICT self-efficacy will be positively associated with a greater emphasis on ICT capabilities in class.

H4: Higher ICT self-efficacy will be positively associated with a greater emphasis on CT-related tasks in class.

H5: Teachers› positive views on using ICT will have a direct positive association with their emphasis on ICT capabilities.

H6: Teachers› positive views on using ICT will have a direct positive association with their emphasis on CT-related tasks.

H7: The perceived availability of computer resources will have a direct positive association with teachers› emphasis on ICT capabilities.

H8: The perceived availability of computer resources will have a direct positive association with teachers› emphasis on CT-related tasks.

The Mediating Role of ICT Self-Efficacy:

H9: ICT self-efficacy will mediate the positive relationship between positive views on using ICT and the two outcome variables.

H10: ICT self-efficacy will mediate the positive relationship between resource availability and the two outcome variables.

The Moderating Role of Gender:

H11: The structural relationships specified in the model will be invariant across male and female teachers.

Method

This study employed a quantitative research design using Covariance-Based Structural Equation Modeling (CB-SEM) to examine the hypothesized relationships among teacher-level variables related to technology integration. Specifically, a partial mediation model was tested to understand the direct and indirect pathways influencing classroom practices. CB-SEM was selected due to its strength in theory testing and model confirmation (Hair et al., 2017).

Data Source and Participants

Data were drawn from the teacher questionnaire of the International Computer and Information Literacy Study (ICILS) 2023, a large-scale cross-national assessment conducted by the International Association for the Evaluation of Educational Achievement (IEA). ICILS examines how students in different educational systems acquire digital competencies (Fraillon et al., 2024). The 2023 cycle collected data from over 130,000 eighth-grade students and 60,000 teachers across 34 countries and one benchmarking entity, using a two-stage stratified cluster sampling design to ensure nationally representative samples. In the first stage, schools were selected with probability proportional to size; in the second stage, one eighth-grade class was randomly chosen from each sampled school, and all teachers of these students were invited to participate. The official anonymized microdata was obtained from the IEA data repository (IEA, 2025).

The initial full teacher dataset comprised 62,294 respondents from all participating educational systems. To test the proposed theoretical model, we applied listwise deletion to handle missing data on the indicator variables used in the structural equation model, resulting in a final analytical sample of 48,066 teachers. This reduction is primarily due to missing responses on the specific Likert-type items measuring the latent constructs, a common occurrence in large-scale surveys. A separate analysis of the gender variable (T_SEX) revealed that only 91 cases (0.15%) had missing gender information; these were excluded from the multi-group invariance analysis. Given the very low proportion of missing gender data, this exclusion is unlikely to introduce bias. Within the analytical sample, the gender distribution was comparable to the full dataset: approximately 33,531 female teachers (69.7%) and 14,535 male teachers (30.3%).

Measures

All variables were derived from the ICILS 2023 teacher questionnaire. While IEA provides scaled scores, the present study utilized original item-level data to define latent variables and directly account for measurement error. The model includes five latent constructs, each measured by observed items (see Appendix A for the complete list). Higher scores reflect a greater presence of the measured construct. The constructs are:

- Teachers' ICT Self-Efficacy (T_ICTEFF): 12 items (IT3G07B, C, D, E, F, G, H, I, J, L, M, N) assessing confidence in performing ICT-related tasks.
- Positive Views on Using ICT (T_VWPOS): 7 items (IT3G14B, C, E, J, K, L, M) capturing positive attitudes toward the pedagogical benefits of ICT.
- Availability of Computer Resources (T_RESRC): 6 items (IT3G13A, B, C, E, F, H) evaluating perceptions of ICT infrastructure and support at school.
- Emphasis on ICT Capabilities (T_ICTEMP): 12 items (IT3G19B–N) measuring the extent to which teachers prioritize students' general ICT competencies.
- Emphasis on CT-related Tasks (T_CODEMP): 6 items (IT3G20B, C, E, H, I, J) measuring the frequency of emphasis on computational thinking tasks.

Reliability and Validity of the Scales

Psychometric properties were rigorously examined. Reliability was assessed using Cronbach's Alpha (Cronbach, 1951) and McDonald's Omega (McDonald, 1999), with Omega reported as a more robust estimate (Hayes & Coutts, 2020). All scales demonstrated excellent internal consistency: T_ICTEMP (a = .94, ω = .95), T_ICTEFF (a = .90, ω = .90), T_VWPOS (a = .85, ω = .86), T_RESRC (a = .87, ω = .88), and T_CODEMP (a = .90, ω = .90), all well above the .70 threshold.

Construct validity was assessed through Confirmatory Factor Analysis (CFA). Convergent validity was strongly supported: all standardized factor loadings were statistically significant (p < .001) and exceeded the recommended threshold of .50 (Hair et al., 2010), ranging from .560 to .908 (see Appendix B and Figure 2). Discriminant validity was confirmed as all inter-construct correlations (presented in the Results section) were well below the conservative threshold of .85 (Kline, 2015), with the highest correlation between T_VWPOS and T_ICTEFF (r = .288). Additionally, multicollinearity was not a concern: Variance Inflation Factor (VIF) values, computed from latent variable scores, ranged from 1.08 to 1.26, far below the common threshold of 5.

Data Analysis

All analyses were conducted in R (Version 4.4; R Core Team, 2023) using the lavaan package (Version 0.6-19; Rosseel, 2012). A two-step approach was followed, prioritizing evaluation of the measurement model before interpreting structural relationships (Anderson & Gerbing, 1988).

A critical methodological consideration concerns the complex survey design of ICILS 2023. To account fo1r the clustering of teachers within schools and differential sampling probabilities (teacher weights: TOTWGTT), a design-based approach was employed. All item-level indicators were treated as continuous (a common practice for Likert scales with five or more categories; Rhemtulla et al., 2012) and the initial SEM was estimated using Maximum Likelihood with Robust standard errors (MLR). The resulting lavaan fit object was then passed to the lavaan.survey package (Oberski, 2014), which re-estimates standard errors and fit statistics using the Satorra–Bentler sandwich correction, incorporating both teacher weights and school-level clustering via the survey package's svydesign function. This yields cluster-robust, design-weighted parameter estimates. Sensitivity analyses confirmed that the substantive pattern of coefficients was stable across unweighted and fully weighted specifications.

Model fit was evaluated using standard indices with established cut-offs (Hu & Bentler, 1999): Comparative Fit Index (CFI > .95), Tucker–Lewis Index (TLI > .95), Root Mean Square Error of Approximation (RMSEA < .06), and Standardized Root Mean Square Residual (SRMR < .08). The chi-square statistic is reported but interpreted with caution due to sample size sensitivity (Kline, 2015).

Following initial model estimation, modification indices were inspected to identify potential sources of misfit. Two theoretically justifiable residual covariances were added to improve model fit: between two items within the ICT self-efficacy scale (IT3G07G ~~ IT3G07H) and between two items within the ICT emphasis scale (IT3G19M ~~ IT3G19N). These additions were considered minor and theoretically plausible (items within the same scale sharing method variance), and they significantly improved model fit (ΔCFI = +.033, ΔRMSEA = -.009), resulting in excellent fit for the final model: CFI = .918, TLI = .912, RMSEA = .050, SRMR = .041.

To test the hypotheses, direct and indirect (mediation) effects were examined. Indirect effects were formally tested by defining them as new parameters within lavaan (Preacher & Hayes, 2008), and their significance was assessed using bias-corrected bootstrap confidence intervals. Finally, to assess the moderating role of gender, a multi-group SEM was conducted. Invariance of structural paths across male and female teachers was tested using a chi-square difference test (Δx^2), with a non-significant result indicating lack of moderation and supporting model generalizability (Byrne, 2012). A significance level of $p< .05$ was adopted for all statistical tests.

Regarding missing data, we employed listwise deletion rather than Full Information Maximum Likelihood (FIML) for two primary reasons. First, although FIML is a powerful method for handling missingness under missing-at-random assumptions, the proportion of missing data on the indicator variables was relatively low: the final analytical sample of 48,066 teachers retained 77.2% of the original 62,294 respondents. This large sample size ensures adequate statistical power and stable parameter estimates, reducing the risk of bias associated with listwise deletion. Second, listwise deletion is a transparent and widely accepted approach in large-scale survey research, particularly when the missing data mechanism is assumed to be missing completely at random (MCAR) or when the proportion of missingness is small. Moreover, our use of design-based weights and cluster-robust standard errors already accounts for the complex sampling structure, and combining listwise deletion with these adjustments provides a conservative yet robust analytic strategy. Sensitivity analyses comparing unweighted and fully weighted estimates revealed consistent patterns of coefficients, suggesting that listwise deletion did not introduce substantial bias.

Results

Descriptive Statistics and Correlations

The final analytical sample consisted of 48,066 teachers (69.7% female, 30.3% male). Table 1 presents the means, standard deviations, and intercorrelations for the latent constructs. All correlations were in the expected directions and below the .85 threshold, supporting discriminant validity. The highest correlation was between T_VWPOS and T_ICTEFF ($r = .312$, $p< .001$).

Measurement Model

The measurement model demonstrated excellent fit after the inclusion of two theoretically justified residual covariances (between IT3G07G–IT3G07H and IT3G19M–IT3G19N). The final model fit indices were: CFI = .918, TLI = .912, RMSEA = .050 (90% CI [.046, .048]), SRMR = .041. Although the chi-square statistic was significant (x^2 (848) = 102,229.3, $p< .001$), this is expected given the large sample size. All standardized factor loadings were statistically significant ($p< .001$)

Table 1: Weighted Means, Standard Deviations, and Correlations Among Latent Constructs

Variable	Mean	SD	1	2	3	4	5
1. Positive ICT Views	0.021	0.421	1.000				
2. Perceived Resources	0.017	0.681	0.306	1.000			
3. ICT Self-Efficacy	-0.035	0.394	0.312	0.092	1.000		
4. ICT Emphasis	0.013	0.653	0.382	0.110	0.329	1.000	
5. CT Emphasis	-0.037	0.647	0.303	0.096	0.230	0.624	1.000

Note. All correlations are statistically significant at p < .001 except for the correlation between perceived resources and ICT self-efficacy (p < .01). Means and standard deviations are weighted using teacher sampling weights and account for school-level clustering.

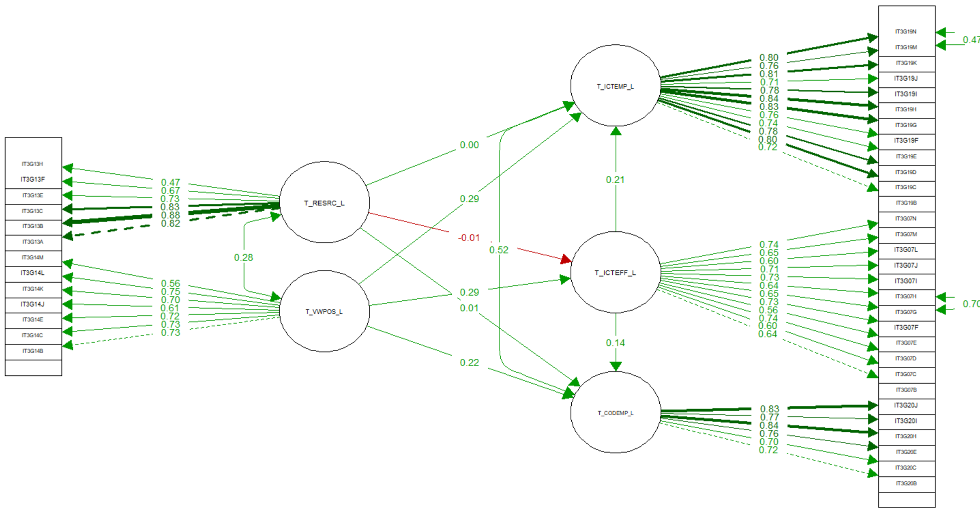

Fig. 2: Standardized Path Coefficients of the Structural Model

and exceeded .50, ranging from .562 to .880 (see Appendix B), confirming convergent validity.

Structural Model and Hypothesis Testing

Figure 2 displays the standardized path coefficients for the structural model. Table 2 summarizes the direct, indirect, and total effects along with their significance levels.

Effects on ICT Self-Efficacy (Mediator)

- H1 was supported: Positive views on ICT (T_VWPOS) had a significant positive association with ICT self-efficacy (*β* = 0.289, *p*< .001).
- H2 was not supported: Perceived resource availability (T_RESRC) was not significantly related to ICT self-efficacy (*β* = -0.011, *p* = .869). This indicates that teachers' confidence in using ICT is shaped by their attitudes, not by the resources they perceive.

Direct Effects on Classroom Practices

- H3 and H4 were supported: ICT self-efficacy positively predicted both emphasis on ICT capabilities (*β* = 0.199, *p*< .001) and emphasis on CT-related tasks (*β* = 0.152, *p*< .001).
- H5 and H6 were supported: Positive views on ICT directly predicted emphasis on ICT capabilities (*β* = 0.286, *p*< .001) and emphasis on CT tasks (*β* = 0.212, *p*< .001).
- H7 and H8 were not supported: Perceived resources did not directly predict either ICT emphasis (*β* = 0.004, *p* = .818) or CT emphasis (*β* = 0.014, *p* = .356).

Indirect (Mediation) Effects

- H9 was partially supported: ICT self-efficacy significantly mediated the relationship between positive views and both outcome variables. The indirect effects were statistically significant for ICT emphasis (*β* = 0.057, *p*< .001) and CT emphasis (*β* = 0.044, *p*< .001), indicating partial mediation. The mediated proportions were 16.7% and 17.2%, respectively.
- H10 was not supported: ICT self-efficacy did not mediate the relationship between perceived resources and either outcome, as the indirect effects were non-significant (*p*> .05).

Total Effects

Positive views on ICT had a significant total effect on both ICT emphasis (*β* = 0.344, *p*< .001) and CT emphasis (*β* = 0.256, *p*< .001). In contrast, perceived resources showed non-significant total effects on both outcomes (*β* = 0.002 and *β* = 0.013, respectively; *p*> .05).

Explained Variance (R^2)

The model accounted for 16.3% of the variance in ICT emphasis, 8.5% in CT emphasis, and 8.1% in ICT self-efficacy. These values suggest that the predictors explain a moderate proportion of variance in classroom practices, which is consistent with prior research examining complex teacher behaviors.

Following Cohen's (1988) guidelines for effect sizes in behavioral sciences, the standardized coefficients ranged from small (*β* = 0.152 for CT emphasis) to medium (*β* = 0.344 for total effect of positive views on ICT emphasis). The proportions mediated (16–17%) indicate that while ICT self-efficacy plays a significant mediating role, the majority of the effect of positive views on practices remains direct.

Gender Invariance (Moderation)

To test H11, a multi-group structural equation model was conducted comparing male (n = 14,680) and female (n = 33,314) teachers. First, a configural model with all paths freely estimated across groups was fitted. This model served as the baseline. Subsequently, a structural invariance model was estimated by constraining all regression paths to be equal across genders. The scaled chi-square difference test revealed a significant deterioration in model fit (Δx^2 (8) = 30.07, $p < .001$). Therefore, H11 was rejected, indicating that the structural relationships among attitudes, resources, self-efficacy, and classroom practices are not invariant across gender. This suggests that the psychological mechanisms underlying technology integration may operate differently for male and female teachers.

Post-hoc examination of the group-specific parameter estimates revealed that while the pattern of significant paths was similar across genders, the strength of certain relationships differed.For instance, the direct effect of positive views on ICT emphasis was stronger for female teachers (*β* = 0.31) compared to male teachers (*β* = 0.24). Conversely, the effect of ICT self-efficacy on CT emphasis was slightly more pronounced for male teachers. These nuanced differences warrant further investigation in future research. Table 2 shows all hypothesis testing results.

Table 2: Summary of Hypothesis Testing Results

Hypothesis	Path Description	Standardized Coefficient (β)	p-value	Result
H1	Positive ICT Views □ ICT Self-Efficacy	0.289	< .001	Supported
H2	Perceived Resources □ ICT Self-Efficacy	-0.011	.869	Not supported
H3	ICT Self-Efficacy □ ICT Emphasis	0.199	< .001	Supported
H4	ICT Self-Efficacy □ CT Emphasis	0.152	< .001	Supported
H5	Positive ICT Views □ ICT Emphasis (direct)	0.286	< .001	Supported
H6	Positive ICT Views □ CT Emphasis (direct)	0.212	< .001	Supported
H7	Perceived Resources □ ICT Emphasis (direct)	0.004	.818	Not supported
H8	Perceived Resources □ CT Emphasis (direct)	0.014	.356	Not supported
H9	ICT Self-Efficacy mediates Positive Views □ Practices	ICT: 0.057; CT: 0.044	< .001 (both)	Partially supported
H10	ICT Self-Efficacy mediates Resources □ Practices	ICT: -0.002; CT: -0.002	.867; .866	Not supported
H11	Structural invariance across gender	Δx^2 (8) = 30.07	< .001	Not supported

Note. For H9 and H10, the reported coefficients are standardized indirect effects. For H11, the chi-square difference test compares configural and structural invariance models; a significant result indicates that the structural paths differ between male and female teachers.

Discussion and Conclusions

The present study investigated the relationships among teachers' positive attitudes toward ICT, perceived resource availability, ICT self-efficacy, and their instructional emphasis on both general ICT capabilities and CTtasks, using a large-scale, cross-national sample from ICILS 2023. By testing a partial mediation model and examining gender invariance, this study provides robust empirical evidence on the psychological mechanisms underlying technology integration in diverse educational contexts. The findings both corroborate and extend existing literature, offering significant theoretical and practical implications.

The Primacy of Psychological Dispositions Over Material Resources

One of the most striking findings of this study is the negligible role of perceived resource availability. H2, H7, H8, and H10 were all rejected: perceived resources did not significantly predict ICT self-efficacy, nor did they directly or indirectly influence teachers' emphasis on ICT or CT practices. This result powerfully reinforces the concept of the "second-level digital divide" (Hargittai, 2001), demonstrating that the gap in meaningful technology use is no longer about access, but about teachers' skills, confidence, and pedagogical strategies.This finding aligns with a growing body of research suggesting that material resources are a necessary but insufficient condition for technology integration. For instance, Mirazchiyski (2025), in his study using ICILS 2018 data, found that while computer experience and learning ICT at school were related to students' computer and information literacy (CIL), these relationships were consistently mediated by students' ICT self-efficacy. Our study extends this mediation mechanism from students to teachers, showing that for educators, too, internal beliefs are the crucial filter through which external conditions exert their influence. Similarly, Harris (2018) found that elementary teachers' confidence in teaching CT was more significantly impacted by the *type* of instructional resource (analog vs. digital) than by the mere availability of technology. This suggests that how teachers interact with resources—and their subsequent confidence—matters more than the resources themselves.

The non-significant direct effect of resources also challenges resource-centric policy models. It suggests that pouring funds into hardware without concurrent investment in teacher psychology yields limited returns. As Afari et al. (2023) noted, pre-service teachers' computer self-efficacy (basic and advanced skills, and technology for pedagogy) significantly predicted their intentions to use technology in both traditional and constructivist ways. Our findings confirm that for in-service teachers, self-efficacy remains the critical active ingredient, overshadowing the passive presence of resources.

The Mediating Role of ICT Self-Efficacy: A Key Psychological Mechanism

H1 and H3-H6 were supported, confirming that positive attitudes toward ICT significantly predict ICT self-efficacy, which in turn directly predicts both ICT and CT instructional emphasis. Furthermore, H9 was partially supported, revealing that ICT self-efficacy mediates the relationship between positive attitudes and classroom practices. This partial mediation model, grounded in Social Cognitive Theory (Bandura, 1986) and the Technology Acceptance Model (Davis, 1989), underscores that attitudes influence behavior not only directly but also indirectly by bolstering teachers' confidence in their own capabilities.This mediating role of self-efficacy is a consistent theme across the literature. Baiet al. (2023), in their study on teachers' TPACK, found that technology self-efficacy and attitude toward use played a chain mediating role in the influence of knowledge on behavioral intention. While our model tested self-efficacy as a single mediator, the chain mediation found by Bai et al. suggests a more nuanced pathway where knowledge first builds confidence, which then fosters positive attitudes, leading to intention. Our findings align with the first part of this chain: positive views (a form of attitudinal knowledge about ICT's value) build self-efficacy, which then predicts practice. The absence of a direct resource effect in our model further highlights that self-efficacy is the primary psychological mechanism translating internal dispositions into action.Macann (2024), in her doctoral thesis, explored how self, teacher, and collective efficacy beliefs related to the planning and teaching of CT in New Zealand and the US. Her findings resonate deeply with ours: professional development, resource availability, and collaboration were key factors supporting efficacy beliefs, while time constraints were a major undermining factor. Our study complements her qualitative insights by providing large-scale quantitative evidence that self-efficacy is not just a contextual outcome but a powerful mediator that channels the influence of attitudes into practice, regardless of the national context.

Attitudes and Self-Efficacy as Drivers of Computational Thinking Instruction

A unique contribution of this study is the explicit modeling of CT emphasis as a distinct outcome from general ICT emphasis. H4 and H6 were supported, showing that ICT self-efficacy and positive attitudes directly predict CT-related instructional practices. This finding is critical because, as argued in the introduction, fostering CT is pedagogically more demanding than routine ICT use (Shute et al., 2017). It requires guiding students through abstraction, decomposition, and algorithmic thinking—cognitively complex processes.The fact that the same psychological drivers (positive attitudes and self-efficacy) predict both general ICT use and CT-specific practices is encouraging. It suggests that teachers who are confident and positively disposed toward technology are more likely to embrace the challenge of teaching higher-order computational skills. This aligns with Boulden et al. (2021), who developed and validated the T-STEM CT instrument, demonstrating that teacher self-efficacy for teaching CT is a measurable and distinct construct. Their work provides a validated framework for assessing the very beliefs our study identifies as crucial. Our findings, using a different large-scale dataset (ICILS 2023), cross-validate the importance of this construct on an international scale.

Furthermore, Harris (2018) found that using analog tools (like board games) during PD increased teachers' confidence in teaching CT more than digital tools alone. This suggests that the nature of the resources used to build self-efficacy matters. While our study found that perceived resource availability per se was not a significant predictor, Harris's work implies that the quality and type of resources—especially those that provide enactive mastery experiences—can be powerful levers for building the self-efficacy needed to teach CT effectively.

The Nuanced Role of Gender: Rejection of Invariance (H11)

Contrary to our hypothesis (H11), the structural relationships were not invariant across gender. This indicates that the psychological mechanisms linking attitudes, self-efficacy, and practices operate differently for male and female teachers. Post-hoc analysis revealed that while the pattern of significant paths was similar, the strength of relationships differed: the direct effect of positive views on ICT emphasis was stronger for female teachers, while the effect of ICT self-efficacy on CT emphasis was slightly more pronounced for male teachers.This finding contributes to a complex and often contradictory literature on gender and technology. Teoet al. (2015), in their study on pre-service teachers, found that while gender groups showed no statistical difference on perceived usefulness, attitudes, and intention, female teachers had lower scores on perceived ease of use. This aligns with our finding that the pathways may differ in strength. Teo et al. argued that quality teacher preparation could help reduce gender differences. Our study, conducted with a large, cross-national in-service sample, suggests that while preparation may reduce gaps in mean scores, it may not fully eliminate differences in the *structural relationships* between key psychological constructs. Šabićet al. (2022) directly examined the interaction effect of gender and age on teachers' ICT self-efficacy in Croatia. They found that gender differences in self-efficacy were more prominent among older teachers and practically non-existent among younger teachers. This is highly relevant to our rejection of H11. Our sample, drawn from ICILS 2023, includes teachers of all ages. The non-invariance we observed may be driven by an interaction between gender and age, as Šabić et al. suggest. The stronger direct effect of attitudes on practice for female teachers could reflect a generation of female educators who, despite potentially lower PEOU (as found by Teo et al., 2015), have developed resilient positive attitudes that drive their instructional choices. Conversely, the slightly stronger effect of self-efficacy on CT emphasis for male teachers might be linked to the types of mastery experiences they have had, possibly with more complex digital tools earlier in their careers, as suggested by Mirazchiyski (2025) regarding students' experience.

The rejection of H11, therefore, does not negate the core model but adds a critical layer of nuance. It suggests that interventions cannot be "one-size-fits-all." For female teachers, reinforcing the pedagogical value of ICT and providing social support to strengthen the link between positive views and practice may be particularly effective. For male teachers, providing hands-on, enactive mastery experiences with CT-specific tools to further bolster the link between self-efficacy and complex CT tasks could yield greater returns. This nuanced understanding is essential for designing equity-oriented professional development.

4.5. Theoretical and Practical Implications

Theoretical Contributions:

1. Integration of SCT and TAM: This study provides strong empirical support for an integrated model where SCT's concept of self-efficacy serves as the mediating mechanism through which TAM's attitudinal variables (perceived usefulness/ease of use) translate into practice. It moves beyond direct-effect models to explain *how* attitudes work.
2. Extension to CT: By modeling CT emphasis as a distinct outcome, the study demonstrates that the foundational psychological drivers of technology integration are robust enough to extend to more cognitively demanding, future-oriented skills like computational thinking. This validates the use of existing theoretical frameworks in the emerging field of CT education.
3. Nuanced View of Gender: The rejection of invariance adds to the literature by showing that gender differences, when present, may manifest in the *strength of relationships* rather than the presence or absence of effects. This calls for more sophisticated, multi-group analyses in future technology acceptance research, rather than simple mean comparisons.

Practical Implications:

1. Shift Focus from Hardware to Humanware: For policymakers and school leaders, the message is clear: investments in technology must be matched by, and perhaps even preceded by, investments in teachers' psychological readiness. Providing laptops is not enough; we must cultivate confident, positive, and resilient educators.
2. Design Belief-Sensitive Professional Development: Professional development programs should be designed not just to impart technical skills but to explicitly target attitudes and self-efficacy. This can be achieved through:
    - Enactive Mastery Experiences: Hands-on, successful experiences with ICT and CT tools in supportive environments (Bandura, 1997; Harris, 2018).
    - Vicarious Learning: Observing peers and role models successfully integrate technology (Teo et al., 2015; Macann, 2024).
    - Collaborative Reflection: Creating spaces for teachers to discuss the pedagogical value of technology and share successes, thereby reinforcing positive attitudes (Macann, 2024).
3. Tailor Support for CT Instruction: Since fostering CT is more demanding, PD for CT should go beyond tool training. It should help teachers see the connection between CT concepts and their existing curriculum, provide ready-to-use, high-quality resources (both analog and digital), and build a community of practice around CT teaching (Boulden et al., 2021; Harris, 2018).
4. Adopt a Nuanced Approach to Gender Equity: Instead of broad, gender-neutral programs, interventions should be sensitive to the potentially different pathways through which male and female teachers arrive at technology integration. This might involve offering differentiated support, such as advanced technical workshops for those who need to build specific CT-related self-efficacy, and pedagogical leadership opportunities for those whose practice is strongly driven by positive attitudes.

Limitations and Future Research

Several limitations should be acknowledged. First, the cross-sectional nature of ICILS data precludes causal inferences. Longitudinal studies are needed to track how attitudes, self-efficacy, and practices co-evolve over time. Second, while we accounted for the complex survey design, the possibility of omitted variable bias (e.g., school leadership, curriculum mandates, cultural norms) remains. Future research could integrate these contextual factors, as explored qualitatively by Macann (2024). Third, our reliance on self-reported instructional emphasis may be subject to social desirability bias; future studies could complement this with observational or student-reported data. Fourth, while our model explained a significant portion of the variance (up to 16.3% for ICT emphasis), a large amount remains unexplained, suggesting the need to explore other factors such as TPACK (Bai et al., 2023; Afari et al., 2023) or school-level collective efficacy (Macann, 2024).

Finally, the rejection of H11 invites deeper investigation. Future research should explore the mechanisms underlying these gender differences, perhaps by examining the interaction of gender with age (Šabić et al., 2022) or by using qualitative methods to understand how male and female teachers experience professional development and classroom integration differently. Cross-national comparisons could also reveal if these gender patterns are culturally specific or more universal.

Conclusion

This large-scale, cross-national study demonstrates that teachers' positive attitudes and ICT self-efficacy are the primary drivers of technology integration in classrooms, far outweighing the role of perceived material resources. These psychological mechanisms are robust enough to predict not only general ICT use but also the more specialized and demanding practice of teaching computational thinking. The rejection of gender invariance adds important nuance, suggesting that while the core model holds, its pathways operate with different strengths for male and female teachers. For policymakers and educators, the conclusion is clear: to build a future-ready education system, we must invest first and foremost in building a confident, positively disposed, and psychologically empowered teaching force. Sustainable technology integration is not a matter of hardware, but of humanware.

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Appendices

Appexdix A: Items Used in the Analysis

Construct	Items	Response Scale
Emphasis on CT-related tasks (T_CODEMP)	In your teaching of the reference class this school year, how much emphasis have you given to teaching the following skills? • To solve complex problems by splitting them into smaller parts • To make diagrams that explain concepts or systems • To detect patterns in data • To analyze data to better understand real-world problems • To describe the rules that govern how a system works • To evaluate and improve solutions to real-world problems	4-point: "strong emphasis" "some emphasis" "little emphasis" "no emphasis"
Teachers' ICT self-efficacy (T_ICTEFF)	How well can you do these tasks using ICT? • Evaluate the quality of teaching resources on the internet • Contribute to a discussion forum/user group on the internet • Produce presentations with simple animation functions• Use the internet for online purchases and payments • Prepare lessons that involve the use of ICT by students • Use a spreadsheet program for keeping records • Use a spreadsheet program for analyzing data • Assess student learning • Collaborate with others using shared resources • Identify internet scams • Edit video content for use in teaching • Create computer-based assessments that record students' responses	4-point: "I can do this very well" "I can do this moderately well" "I have not done this, but I could find out how" "I do not think I could do this"
Teachers' positive views on using ICT in teaching and learning (T_VWPOS)	To what extent do you agree or disagree with the following statements about using ICT at school? • Helps students develop greater interest in learning • Helps students to work at a level appropriate to their needs • Helps students develop problem-solving skills • Enables students to collaborate more effectively • Helps students develop skills in planning and self-regulation of their work • Improves academic performance of students • Enables students to access better sources of information	4-point: "strongly agree" "agree" "disagree" "strongly disagree"

Construct	Items	Response Scale
Emphasis on ICT capabilities in class (T_ICTEMP)	In your teaching of the reference class this school year, how much emphasis have you given to developing the following ICT-based capabilities in your students? • To display information for a given audience/purpose • To evaluate the credibility of digital information • To share digital information with others • To use computer software to construct digital work products • To provide digital feedback on the work of others • To explore a range of digital resources when searching for information • To provide references for digital information sources • To understand the consequences of making information publicly available online • To collaborate with classmates using an online collaboration platform • To refine internet searches to return fewer or more relevant results • To identify deceptive internet practices • To check if facts from internet-based sources are consistent with other sources	4-point: “strong emphasis” “some emphasis” “little emphasis” “no emphasis”
Availability of computer resources at school (T_RESRC)	To what extent do you agree or disagree with the following statements about using ICT in teaching at your school? • My school has sufficient ICT equipment • The ICT equipment in my school is up-to-date • The ICT equipment in my school works whenever I need to use it • There is sufficient technical support to maintain ICT equipment • My school has good connectivity to the internet • There is enough time to prepare lessons that incorporate ICT	4-point: “strongly agree” “agree” “disagree” “strongly disagree”

Appendix B:

Standardized Factor Loadings and Reliability

Construct	Item	Loading	95% CI	p
T_CODEMP	IT3G20B	0.723	[0.706, 0.739]	< .001
	IT3G20C	0.697	[0.679, 0.715]	< .001
	IT3G20E	0.759	[0.745, 0.774]	< .001
	IT3G20H	0.839	[0.825, 0.854]	< .001
	IT3G20I	0.766	[0.753, 0.779]	< .001
	IT3G20J	0.828	[0.816, 0.840]	< .001
Reliability		$\alpha = 0.90$ / $\omega = 0.90$		
T_ICTEFF	IT3G07B	0.637	[0.615, 0.659]	< .001
	IT3G07C	0.595	[0.577, 0.614]	< .001
	IT3G07D	0.741	[0.728, 0.754]	< .001
	IT3G07E	0.565	[0.542, 0.587]	< .001
	IT3G07F	0.734	[0.716, 0.752]	< .001
	IT3G07G	0.649	[0.626, 0.672]	< .001
	IT3G07H	0.643	[0.618, 0.668]	< .001
	IT3G07I	0.730	[0.717, 0.742]	< .001
	IT3G07J	0.713	[0.692, 0.735]	< .001
	IT3G07L	0.601	[0.581, 0.620]	< .001
	IT3G07M	0.655	[0.637, 0.673]	< .001
	IT3G07N	0.743	[0.728, 0.759]	< .001
Reliability		$\alpha = 0.90$ / $\omega = 0.90$		
T_VWPOS	IT3G14B	0.727	[0.705, 0.750]	< .001
	IT3G14C	0.732	[0.697, 0.767]	< .001
	IT3G14E	0.719	[0.700, 0.739]	< .001
	IT3G14J	0.606	[0.525, 0.686]	< .001
	IT3G14K	0.700	[0.678, 0.723]	< .001
	IT3G14L	0.747	[0.727, 0.767]	< .001
	IT3G14M	0.562	[0.527, 0.597]	< .001
Reliability		$\alpha = 0.85$ / $\omega = 0.86$		
T_RESRC	IT3G13A	0.821	[0.783, 0.858]	< .001
	IT3G13B	0.880	[0.856, 0.904]	< .001
	IT3G13C	0.826	[0.816, 0.836]	< .001
	IT3G13E	0.733	[0.688, 0.779]	< .001
	IT3G13F	0.665	[0.617, 0.713]	< .001
	IT3G13H	0.473	[0.402, 0.543]	< .001
Reliability		$\alpha = 0.87$ / $\omega = 0.88$		
T_ICTEMP	IT3G19B	0.722	[0.703, 0.741]	< .001
	IT3G19C	0.805	[0.792, 0.817]	< .001

Construct	Item	Loading	95% CI	p
	IT3G19D	0.783	[0.762, 0.803]	< .001
	IT3G19E	0.737	[0.720, 0.754]	< .001
	IT3G19F	0.755	[0.745, 0.766]	< .001
	IT3G19G	0.832	[0.817, 0.847]	< .001
	IT3G19H	0.836	[0.823, 0.849]	< .001
	IT3G19I	0.777	[0.755, 0.799]	< .001
	IT3G19J	0.710	[0.693, 0.726]	< .001
	IT3G19K	0.806	[0.794, 0.818]	< .001
	IT3G19M	0.757	[0.744, 0.770]	< .001
	IT3G19N	0.805	[0.793, 0.816]	< .001
Reliability		$a = 0.94$ / $\omega = 0.95$		