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Investigating Mathematics Teachers' Technology Acceptance and Self-Efficacy for Technology Integration: A Structural Equation Modeling Approach

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Abstract

The effective integration of technology into educational environments is closely related to teachers' digital skills and their willingness to use these tools in teaching processes. In this respect, the study aimed to examine the relationship between mathematics teachers' acceptance levels towards technology and their self-efficacy beliefs about technology integration. The study was designed using the relational survey model and the data were analyzed with structural equation modeling (SEM). The research sample consisted of 381 mathematics teachers working in different school types. The Technology Acceptance Scale (TAM) and Self-Efficacy Perception Scale for Technology Integration (S-ET) were used as data collection tools. The results of the analyses revealed that there was a statistically significant and moderately positive relationship between technology acceptance and self-efficacy towards technology integration (r = 0.541; β = 0.42; p < .001). The findings showed that teachers' positive attitudes towards technology supported their self-efficacy towards technology integration. However, it is concluded that positive attitudes alone are not sufficient for effective technology integration; teacher education programs should be structured to strengthen practical skills and pedagogical approaches to technology use. It is also suggested that contextual factors (infrastructure, technical support, in-service training) should be taken into consideration.

Keywords:

Technology Acceptance Model, Self-Efficacy, Technology Integration, SEM, mathematics teachers

Introduction

Digital technologies are rapidly transforming educational environments and opening new possibilities for teaching and learning. This is especially evident in mathematics, where abstract concepts benefit from visualization and interactive engagement. However, the effectiveness of technological integration in the classroom depends significantly on teachers' attitudes towards technology, their willingness to adopt it, and their competencies in applying it to real teaching scenarios (Ertmer & Ottenbreit-Leftwich, 2010).

Today's education systems are being profoundly shaped by ongoing digital transformation, which increasingly requires teachers to continuously develop both their professional expertise and their technological skills. As technology becomes more integral to teaching and learning, educators are expected not only to master digital tools but also to integrate them effectively into their instructional practices. Simply having access to digital tools is insufficient; teachers must also possess the knowledge and confidence required to use them effectively (Ursavaş, Şahin&McIlroy, 2014).

For teachers to meaningfully incorporate digital tools into their instructional practices, they must possess not only technical proficiency but also pedagogical digital competence, which involves the ability to select, adapt, and apply technological resources in ways that genuinely support learning (McGarr, 2024). In mathematics education, technology is particularly valuable because it enables teachers to make abstract concepts more tangible, enhance students' problem-solving abilities, and foster interactive and engaging learning experiences (Weigand et al., 2024).

Consequently, the role of mathematics teachers extends far beyond simply delivering content through digital platforms. Teachers are increasingly expected to use technology as an intentional pedagogical strategy that transforms how mathematical concepts explored, discussed, and understood. Effective integration of technology, therefore, is not about using digital tools for their own sake but about leveraging them thoughtfully to enrich learning experiences and deepen students' conceptual understanding.

Research indicates that factors such as perceived usefulness, ease of use, and self-efficacy play a critical role in teachers' willingness to embrace technology and apply it effectively in their teaching practices (Davis, 1989; Teo, 2009). Positive attitudes among mathematics teachers linked to the successful integration of technology in their classrooms (Öksüz et al., 2009). Nevertheless, teacher candidates still lack sufficient knowledge, skills, and guidance regarding the pedagogical use of technology (Clark-Wilson et al., 2020; Liu et al., 2024).

This study aims to examine the relationship between technology acceptance (as described by the Technology Acceptance Model, or TAM) and self-efficacy beliefs related to technology integration among mathematics teachers. The study's significance lies in its potential to inform the design of more effective teacher education programs by illuminating how these two factors interact. Additionally, the findings are expected to shed light on the ways technology-based teaching practices contribute to the pedagogical development of future teachers.

Theoretical background

Technology Integration from the Teacher's Perspective

Technology's role in education has become a prominent focus of research and practice because of its ability to revolutionize the way teachers instruct and students learn. Its integration into classrooms offers opportunities for personalized learning, interactive teaching methods, and access to vast resources, redefining traditional educational environments. Mayer (2003) emphasized that multimedia learning improves understanding and recall of information. Similarly, a meta-analysis by Tamim et al. (2011) showed that students in technology-enhanced learning environments performed better than those in traditional environments.

By integrating technology into their classrooms, educators can create personalized and engaging learning experiences for their students. Educators can also lead their students to access rich sources of information by implementing innovative learning strategies. This change has redefined traditional educational models, paving the way for dynamic and collaborative environments that meet diverse learning needs. However, despite the long-standing emphasis on the transformative effects of technology, its full potential in classroom practices is still underutilized. Mayer (2003) emphasized the value of multimedia tools to help students understand and remember mathematical concepts, while Tamim et al. (2011) showed that technology-supported learning environments yield better learning outcomes compared to traditional methods. Research suggests that teachers often do not use technology effectively in classroom settings, limiting their application to superficial uses such as games or exercises (Mercader & Gairín, 2020; Isa et al, 2025). Bayhan et al. (2002) found that 81.8% of teachers did not use computers for instructional purposes, attributing this to a lack of confidence and insufficient professional development. Similarly, studies from the United Kingdom revealed that teachers face barriers to technology integration, including limited technical support, insufficient equipment, and lack of awareness about the pedagogical benefits of technology (Jones, 2004).

Teachers are decisive to the successful integration of technology in education, as their attitudes, beliefs, and skills directly influence how technological tools are utilized in classrooms. By fostering innovation, facilitating student engagement, and adapting technology to meet diverse learning needs, teachers shape how technology enhances educational outcomes. Their willingness to embrace and effectively apply technology ensures its potential to transform teaching and learning processes is fully realized. Zhao and Hoge (2004) stressed the importance of teachers' conceptual understanding of technology's role in teaching and learning to cope with ongoing innovations. Moreover, teachers' attitudes and beliefs are crucial determinants of how effectively technology could integrate into classroom practices. In this context, understanding the factors influencing teachers' beliefs in technology is imperative. Teo (2009) found perceived usefulness, ease of use, and self-efficacy as critical factors affecting teachers' adoption of technology. Specifically, Öksüz et al., (2009) found that mathematics teachers with positive beliefs of technology are more inclined to use it effectively, particularly in visualizing abstract concepts and enhancing problem-solving skills. The influence of mathematics on technological advancements is clear, but technology also plays a significant role in improving mathematics learning and shaping students' attitudes toward the subject. Moreover, how teachers integrate technology into their teaching impacts students' perceptions of these tools (Erdener & Kandemir, 2019). Teachers use a more passive, traditional approach, where students have limited engagement with technology, while others actively use technology to present information and foster participation in their classrooms.

When teachers incorporate technology into their instructional practices, they create an environment where students have greater agency over their own learning, with the teacher acting as a facilitator rather than simply a transmitter of information. This approach aligns closely with student-centered learning frameworks, as it encourages active engagement and participation from students (Erdener & Kandemir, 2019).

Although the clear potential benefits of integrating technology into mathematics education, teachers continue to face substantial challenges that can hinder effective implementation. These obstacles can broadly categorize into external and internal factors. External challenges often include limited access to adequate digital devices, unreliable internet connectivity, insufficient technical support, and a lack of comprehensive professional training (McGarr, 2024). Such systemic constraints can prevent teachers from fully leveraging technological tools, even when they motivated to do so. Internal challenges are equally significant and may involve low self-confidence regarding technological proficiency, resistance to changing established teaching practices, and deeply ingrained pedagogical beliefs that may not align with technology-enhanced learning approaches.

These challenges highlight that successful integration of technology into mathematics teaching is not a matter of simply providing digital tools. Rather, it requires careful planning, sustained professional development, and reflective practice to ensure that technology used in ways that meaningfully enhance learning. Teachers must navigate both the practical and cognitive dimensions of technology adoption, aligning new tools with curriculum goals, pedagogical strategies, and the diverse needs of their students. Research suggests that when these factors addressed thoughtfully, technology can facilitate more interactive, personalized, and conceptually rich learning experiences. Conversely, neglecting these considerations may result in superficial or ineffective use of technology, where digital tools are present but fail to contribute meaningfully to student learning outcomes.

Central to overcoming these barriers is the concept of teacher self-efficacy. As Abu Bakar et al. (2018) have demonstrated, teachers who possess a strong belief in their capacity to effectively use technology are more likely to adopt and experiment with digital resources in their classrooms. However, research by Clark-Wilson et al. (2020) highlights that pre-service mathematics teachers do not receive sufficient guidance on how to meaningfully incorporate technology into their practice. Liu et al. (2024) argued that teacher education programs must address these deficiencies to enable effective integration, while Gumiero and Pazuch (2024) underscore the necessity of developing professional knowledge for designing and implementing technology-enhanced mathematics instruction.

The literature consistently emphasizes that mathematics teachers' acceptance and integration of technology is crucial for improving both instructional quality and student learning outcomes. Teachers who are confident in their technological competence are more likely to employ digital tools in ways that promote engagement and conceptual understanding (Abu Bakar et al., 2018; Bakar et al., 2018). This self-efficacy not only encourages innovation but also supports teachers in overcoming the inevitable challenges that arise when adopting innovative technologies.

Moreover, Erdener and Kandemir (2019) point out that the strategies mathematics teachers use to integrate technology can significantly influence students' attitudes towards these tools. Student-centered, technology-rich environments foster greater engagement and allow students to manage their learning more independently, with appropriate guidance from the teacher. Nonetheless, many educators still tend to use technology primarily for surface-level tasks, such as presenting content or supporting routine exercises, rather than fully exploiting its potential to foster deeper conceptual understanding or enhance students' problem-solving skills (Clark-Wilson et al., 2020; Erdener and Kandemir, 2019).

Targeted professional development has emerged as a key strategy for addressing these issues. Teachers who participate in specialized training are better equipped to integrate digital tools meaningfully into mathematics instruction (Liu et al., 2024). Furthermore, Gumiero and Pazuch (2024) advocate systematic improvements in teacher education programs, emphasizing the importance of professional knowledge in fostering effective and sustainable technology adoption in mathematics classrooms.

The Technology Acceptance Model, or TAM, first introduced by Davis in 1989, has long been recognized as a foundational framework for understanding why individuals choose to adopt and engage with new technologies. At its core, TAM emphasizes two key constructs. The first, perceived usefulness, reflects the degree to which users believe that a particular technology will meaningfully enhance their performance or productivity. The second, perceived ease of use, pertains to the extent to which a technology is perceived as intuitive, straightforward, and free from unnecessary complexity or effort. Over the past three decades, numerous studies have confirmed the predictive power of these constructs. When users perceive a technology as both useful and easy to use, they are significantly more likely to integrate it into their professional or daily practices. This insight has made TAM a cornerstone not only in general technology adoption research but also in education, where understanding teachers' attitudes toward digital tools can inform strategies to promote effective technology integration.

TAM's popularity is not just theoretical; it has widely applied across various sectors, from education and healthcare to business. Its straightforward approach allows researchers and practitioners alike to assess the psychological factors driving technology adoption. For instance, research consistently demonstrates that pre-service teachers who perceive technology as both beneficial and manageable develop more positive attitudes toward integrating it in their future classrooms (Erdener & Kandemir, 2019; Erdoğan, 2025; Teo, 2009; Venkatesh & Davis, 2000).

Nevertheless, TAM has its shortcomings, particularly in educational contexts. While it effectively predicts initial adoption, it does not adequately address the deeper factors that contribute to sustained, meaningful integration of technology into teaching practices. Long-term use often depends on more complex influences, such as teachers' self-efficacy, pedagogical beliefs, and the level of institutional support available. Elements like ongoing professional development, resource accessibility, and the alignment of innovative technology with instructional goals all play a pivotal role in determining whether technology becomes a routine part of teaching, rather than a temporary experiment. For example, Teo (2009) emphasizes that, although TAM's constructs foster positive initial attitudes, deeper factors such as self-efficacy and underlying pedagogical beliefs are critical for lasting integration. Furthermore, TAM's broad approach frequently overlooks subject-specific challenges—for instance, mathematics teachers may require tools that specifically address the visualization of abstract concepts (Erdener & Kandemir, 2019).

Current research on technology acceptance highlights the intricate interplay between individual beliefs, technical resources, and broader contextual factors in influencing teachers' use of technology. Self-efficacy and attitudes toward technology are significant predictors of willingness to adopt new tools. The actual availability and functionality of technological resources, meanwhile, dictate how these tools incorporated into instruction. Environmental factors, including institutional support, school culture, and opportunities for professional growth further shape the integration process. Together, these variables underscore the importance of a comprehensive approach to promoting sustained technology use in education. Studies by Paraskeva et al. (2008) show that teachers' computer self-efficacy impacts their ability to integrate technology effectively. Thong et al. (2002) note that technological complexity can deter adoption, while Ngai et al. (2007) identify technical support, time, and equipment access as critical facilitators. Ultimately, understanding teachers' attitudes and the interplay of these diverse factors is essential, particularly when developing professional development programs for both pre-service and in-service educators.

Teachers' Self-Efficacy in Using Technology

The successful integration of technology in educational settings relies not solely on teachers' technical skills, but significantly on their self-efficacy beliefs. It is not enough for teachers to possess a positive attitude toward digital tools; they must also perceive themselves as capable of utilizing these resources effectively in their teaching practices. Bandura's (1977) social cognitive theory conceptualizes self-efficacy as an individual's belief in their ability to execute specific actions successfully. This belief, as Bandura (1994) later explained, exerts a strong influence on one's thinking, emotional responses, and behaviors. In the context of education, research has consistently demonstrated that teachers' self-efficacy regarding technology integration is a critical factor shaping how often and how effectively they employ digital tools in instruction (Sang et al., 2010; Tondeur et al., 2017).

Self-efficacy is shaped by four main sources: mastery experiences (direct success in relevant tasks), vicarious experiences (learning by observing others), verbal persuasion (encouragement from peers or mentors), and physiological or emotional states (such as stress or anxiety levels). Understanding these dimensions underscores the necessity of fostering self-efficacy among teachers to achieve meaningful and sustainable technology integration.

Within the sphere of educational technology, self-efficacy refers to teachers' confidence in their capacity to use digital tools to enhance instruction. Zhang (2023) expands on this by describing self-efficacy in technology integration as teachers' belief in their ability to utilize technology actively and interactively in the teaching and learning process. This perspective highlights not only technical proficiency, but also the adaptability required to integrate technology into various pedagogical strategies, thereby enriching the learning environment.

Teachers' self-efficacy beliefs have a profound impact on their pedagogical decisions, instructional approaches, and willingness to pursue innovation (Pajares, 1997a, 1997b). Furthermore, self-efficacy is connected to the wider school climate. Tobin et al. (1994) characterized self-efficacy as a marker of teaching success, affecting teachers' thought processes, motivation, classroom behavior, and emotional responses. It also shapes the selection of classroom activities, persistence in overcoming obstacles, and the time dedicated to resolving challenges (Pintrich & Schunk, 2002). Tschannen-Moran and Woolfolk Hoy (2001) argue that teaching effectiveness should be examined both as an overall quality and through specific practices, such as classroom management. Teacher effectiveness, as defined by researchers, includes the ability to foster student engagement, manage classrooms, motivate learners, and facilitate academic achievement within the broader context of the school environment (Adolfo & Ducot, 2025).

Ertmer (1999) identified two categories of barriers to technology integration: primary (external) and secondary (internal). Primary barriers encompass physical obstacles, such as insufficient hardware, technical problems, and lack of support. Secondary barriers, in contrast, involve teachers' beliefs, attitudes, and self-efficacy related to technology use. Ertmer's (1999) research emphasizes that internal barriers frequently exert a greater influence than external ones in determining actual technology adoption. Recognizing and addressing these internal dynamics is therefore essential for promoting sustained and effective technology integration in educational practice.

Teacher Self-Efficacy and Technology Integration

Ertmer and Ottenbreit-Leftwich (2010) identified four essential factors for teachers to effectively integrate technology into their teaching: knowledge, self-efficacy, pedagogical beliefs, and school culture. Teachers who possess high self-efficacy are more inclined to experiment with innovative technologies and address challenges as they arise. Notably, a teacher's knowledge and beliefs closely interconnected in shaping their sense of self-efficacy (Chand et al., 2020). In other words, what teachers know and what they believe about their abilities directly influence how confident they feel in managing their teaching practices and integrating new strategies or tools.

Research by Joo et al. (2018) highlighted that higher TPACK (Technological Pedagogical Content Knowledge) levels are associated with stronger teacher self-efficacy. Birisci and Kul (2019) found that there is a strong positive correlation between pre-service teachers' self-efficacy in technology integration and their technology-pedagogical content knowledge (TPACK), and that TPACK is a significant predictor of self-efficacy Thomson et al. (2016) further confirmed a relationship between pedagogical content knowledge (PCK) and self-efficacy, emphasizing the influence of teachers' internal belief systems on their ability to integrate technology.

Importantly, teachers' self-efficacy in technology use is a multidimensional concept shaped by confidence, pedagogical expertise, and contextual factors—not just technical skills. Ertmer (1999) categorized the barriers to technology integration as either external (such as limited hardware, software issues, or lack of technical support) or internal (such as attitudes and beliefs). Effective teacher education must address both types of barriers, with a particular focus on strengthening teachers' beliefs in their own abilities to use technology. Such efforts can support more meaningful and effective classroom technology integration.

Purpose of the Study

The effective integration of technology in contemporary educational settings depends not only on the availability of digital tools but also, and perhaps more importantly, on teachers' proficiency in using these tools and their attitudes toward adopting innovative technologies. In this context, the present study investigates the relationship between mathematics teachers' technology acceptance and their self-efficacy beliefs regarding the integration of technological tools into their instructional practices. Examining this relationship offers valuable insight into how teachers' openness to technology shapes their confidence, motivation, and perceived capability to incorporate digital resources effectively. By exploring these dynamics, the study aims to contribute to the development of informed strategies that promote more purposeful and confident technology use among mathematics teachers.

More broadly, this research highlights the need for well-designed professional development programs that not only equip teachers with technical skills but also foster positive attitudes toward adoption of technology. Such programs are essential for supporting teachers in adapting to increasingly technology-rich learning environments and ensuring that digital tools used to enhance, rather than simply supplement, mathematics instruction.

Based on this theoretical grounding, the study's hypothesis follows:

H1: Mathematics teachers' levels of technology acceptance influence their self-efficacy perceptions regarding technology integration.

Methodology

This research adopted a relational study model, a quantitative approach designed to explore both the direction and strength of relationships among multiple variables (Karasar, 2012; Creswell, 2012). Quantitative research provides a systematic way to evaluate objective theories by analyzing relationships among variables or identifying differences across groups. In this approach, constructs translated into measurable indicators, analyzed with statistical techniques, and interpreted in ways that can be generalized to broader populations (Creswell & Creswell, 2023). In this study, the key constructs were measured using established scales, and the collected data were analyzed using quantitative methods.

To explore how mathematics teachers' levels of technology acceptance influenced their self-efficacy beliefs regarding technology integration, Structural Equation Modeling (SEM) was employed. SEM is a powerful analytical method that brings together both latent and observed variables, making it possible to evaluate complex theoretical models (Heck & Thomas, 2020). By incorporating both the measurement model and the structural model, SEM allows researchers to visualize and examine direct and indirect links among variables within a unified framework (Schumacker & Lomax, 2004). This makes SEM particularly valuable when the goal is to understand intricate patterns of interaction and the underlying processes shaping teachers' beliefs and behaviors.

Interpreting the results of Structural Equation Modeling depends on evaluating several model-fit indices. According to Kline (2016), indices such as χ^2/df, p-values, RMSEA, CFI, and TLI offer a sufficient basis for evaluating whether a model fits the data well. Commonly accepted thresholds include a χ^2/df value below 5, SRMR and RMSEA values below 0.08, and CFI and TLI values above 0.90. Together, these indicators help determine how well the proposed model represents the observed data. When supported by both statistical evidence and theoretical grounding, these results strengthen the reliability and interpretive clarity of the study's conclusions.

Sample Characteristics

The study's sample consisted of 381 teachers working across different school levels. A convenience sampling strategy was used, in which participants were selected based on their accessibility, willingness, and availability (Dornyei, 2007). Table 1 presents a detailed overview of the participants' demographic characteristics. Although convenience sampling is not the most rigorous form of sampling, it remains a practical and commonly used approach in studies where time, resources, or access to participants are limited.

Table 1.

Descriptive Statistics of Participants' Demographic Variables

Variable	Frequency	%
Gender		
Female	262	68,77%
Male	119	31,23%
Type of school he/she works at		
Anatolian High School	101	26,51%
Vocational High School	81	21,26%
Science High School	17	4,46%
Other	182	47,77%
Postgraduate studies		
Master's Degree	158	41,47%
Doctorate	30	7,87%
None	193	50,66%
Years of professional seniority		
1-5 years	76	19,95%
6-10 years	52	13,65%
11-15 years	67	17,59%
16-20 years	52	13,65%
21 years and above	134	35,17%
Taking a technology course		
Yes	260	68,24%
No	121	31,76%
Using Web 2.0 tools in classes		
Yes	242	63,52%
No	139	36,48%
Participating in an in-service training program on technology		
Yes	255	66,93%
No	126	33,07%

The study recruited participants who were easily accessible and willing to take part, following the approach described by Saumure and Given (2008). Data collection conducted online using Google Forms, which distributed to teachers digitally. Participation was entirely voluntary and teachers independently completed the forms at their own convenience. Ethical considerations were addressed thoroughly: the research team obtained approval from the institutional ethics committee before starting data collection, and all necessary official permissions secured to ensure compliance with relevant guidelines. All participants participated in the study on a voluntary basis.

Tools of Data Collection

For data collection, two established tools were employed: the Technology Acceptance Scale (T-TAM) and the Self-Efficacy Perception Scale for Technology Integration. These instruments were specifically selected to assess participants' levels of technology acceptance, as well as their confidence in integrating technology into their teaching practices.

Technology Acceptance Scale (T-TAM)

In this research, the Technology Acceptance Scale (T-TAM), originally developed by Ursavaş et al., (2014) was used to assess teachers' levels of technology acceptance. Rooted in the Technology Acceptance Model (TAM), the T-TAM provides an in-depth evaluation by examining eleven dimensions: perceived usefulness, perceived ease of use, behavioral intention, self-efficacy, subjective norm, anxiety, facilitating conditions, technological complexity, perceived enjoyment, convenience, and attitude toward use. Together, these dimensions offer a nuanced framework to capture the multifaceted nature of technological acceptance in educational environments.

The scale employs a 5-point Likert-type format, allowing participants to indicate their degree of agreement or disagreement with each statement. Its validity and reliability have confirmed in prior studies, supporting its appropriateness for educational research. By encompassing a wide range of cognitive, emotional, and contextual factors, the T-TAM reflects the complexity inherent in technology adoption and facilitates a comprehensive understanding of the variables influencing teachers' integration of technology.

The items comprising the 'Technological Complexity' and 'Anxiety' sub-dimensions of the T-TAM scale—such as 'It takes too long to learn how to use IT', 'I need to spend a lot of time learning how to use new technologies', 'Using IT is a troublesome process for me', 'I get nervous when using IT', 'Using IT is too complicated for me', and 'I feel challenged when using IT in my classes'—are all negatively phrased. In the original scale developed by Ursavaş et al. (2014), these items were conceptualized as distinct factors and were shown to exhibit negative associations with Perceived Ease of Use. In the present study, the items were similarly analyzed as separate constructs, consistent with the original scale structure, and were not reverse-coded. As a result, the negative factor loadings observed (e.g., T8 = −0.33, T10 = −0.46) should not be interpreted as measurement errors (Table 6), but rather as a theoretically coherent reflection of the expected negative relationship between Technological Complexity, Anxiety, and Perceived Ease of Use (Venkatesh & Bala, 2008).

Self-Efficacy for Technology Integration

To assess how confident mathematics teachers feel about weaving technology into their classrooms, this study utilized the Self-Efficacy Perception Scale for Technology Integration. The original scale developed by Wang et al. (2004) and was later adapted for use in the Turkish educational context by Ünal and Teker in 2018, ensuring its relevance and applicability to local teaching practices. This adaptation went beyond simple translation—it involved rigorous checks for validity and reliability.

The Turkish version of the scale revealed two core dimensions. First, "Computer Technology Proficiency and Strategies," which gauges teachers' confidence in both their technical skills and their ability to meaningfully integrate technology into their instruction. Second, "External Factors Affecting Computer Use," which reflects how things like available resources and institutional support can shape a teacher's ability to use technology effectively.

This adapted scale offers substantive insight into teachers' beliefs and capacities regarding technology integration in education. With a Cronbach Alpha coefficient of .94, its reliability is notably strong—making it a robust instrument for examining self-efficacy in tech-savvy teaching environments.

Reliability Coefficients of the Scales

The values for Cronbach's alpha and McDonald's ω values, which assess the internal consistency of the scales, are presented in Table 2.

Table 2.
Reliability Coefficients of the Scales

	Coefficient α	Coefficient ω
T-TAM	0.669	0.028
S-ET	0.833	0.909
Total	0.735	0.706

Table 2 presents values for both Cronbach's Alpha and McDonald's ω, covering the T-TAM and S-ET categories along with their combined mean. The S-ET sub-dimension demonstrates strong internal consistency, as reflected by Cronbach's Alpha at .833 and McDonald's ω at .909. In contrast, the T-TAM sub-dimension falls short of the generally accepted threshold; Cronbach's Alpha is .669 and McDonald's ω is particularly low at .028, both indicating limited reliability. On the total scale, Alpha (.735) and ω (.706) suggest that, overall, the scale achieves a sufficient—though not exceptional—level of internal consistency.

Data Analysis

In this research, Structural Equation Modeling (SEM) was utilized to explore the interplay among the study's variables. SEM offers a robust framework for dissecting both the direct and indirect effects within the system, making it particularly effective for analyzing the relationship between mathematics teachers' technology acceptance and their self-efficacy concerning technology integration. By accommodating the simultaneous testing of measurement models and structural paths, SEM allows for a nuanced understanding of these dynamics (Kline, 2016). To assess the quality of the model, several fit indices examined, including chi-square/df, p-value, RMSEA, CFI, and TLI—standards outlined by Kline (2016). The thresholds used for model fit were as follows: chi-square/df values below 5, SRMR and RMSEA values below 0.08, and CFI and TLI values exceeding 0.90 (Byrne, 2016; Kline, 2016).

Additionally, the study evaluated multicollinearity and linear relationships among variables using the Variance Inflation Factor (VIF) and Pearson correlation coefficients. To enhance the reliability of the findings, a Bootstrap method with 5,000 iterations and a 95% confidence interval implemented during the analysis phase.

Cronbach's Alpha and McDonald's Omega coefficients calculated to assess the internal consistency of the data collection instruments. Confirmatory factor analysis (CFA) was then conducted to evaluate construct validity, and relevant goodness-of-fit indices reported. All statistical analyses were conducted using JASP software.

The research aimed to develop a model examining the structural relationships between pre-service teachers' technology acceptance and their self-efficacy regarding technology integration. Technology acceptance was operationalized through the variables of perceived usefulness, perceived ease of use, and behavioral intention, following the Technology Acceptance Model (TAM) as described by Ursavaş et al. (2014). Self-efficacy measured using two sub-dimensions—technology competence and external factors—via the "Self-Efficacy Perception Scale for Technology Integration" created by Wang et al. (2004) and later adapted to Turkish by Ünal and Teker (2018).

Both direct and indirect effects of technology acceptance dimensions on self-efficacy were assessed using structural equation modeling (SEM). To check whether the data met normality assumptions, skewness and kurtosis values for total scale scores were examined. Table 3 presents the skewness and kurtosis values for the latent variables included in the SEM analysis.

Table 3.

Multivariate Test of Normality (Mardia's coefficients).

	Coefficient	z	χ^2	*df*	*p*
Skewness	35.500		816.497	455	< .001
Kurtosis	221.912	8.004			< .001

Table 3 presents the outcomes of Mardia's tests, which evaluate whether the dataset meets the assumption of multivariate normality. The calculated skewness coefficient stands at 35.5, and the related chi-square test produced a value of 816.5 with 455 degrees of freedom (p < .001). This clearly indicates a substantial deviation from normality regarding skewness. As for kurtosis, the coefficient reached 221.9, with a z-score of 8.0 (p < .001), again pointing to a significant departure from normal distribution. In summary, both skewness and kurtosis measures suggest that the data notably violates the assumption of multivariate normality.

Table 4.

Pearson's Correlations

Variable		T-TAM	S-ET
T-TAM	Pearson's r	—	
	p-value	—	
	Lower 95% CI	—	
	Upper 95% CI	—	
	Effect size (Fisher's z)	—	
	SE Effect size	—	
S-ET	Pearson's r	0.541	—
	p-value	< .001	—
	Lower 95% CI	0.411	—
	Upper 95% CI	0.649	—
	Effect size (Fisher's z)	0.605	—
	SE Effect size	0.086	—

Table 4 displays the results of the Pearson correlation analysis examining the relationship between Technology Acceptance (T-TAM) and Self-Efficacy for Technology Integration (S-ET). The calculated Pearson correlation coefficient ® is 0.541, indicating a moderate positive relationship between the two variables; in other words, higher T-TAM scores are associated with higher S-ET scores.

This correlation is statistically significant (p < .001), suggesting that the association observed is highly unlikely to be due to chance. The 95% confidence interval for the correlation ranges from 0.411 to 0.649, further supporting the presence of a moderate relationship. Additionally, the effect size, determined using Fisher's z transformation, is 0.605, with a standard error of 0.086. The low standard error reinforces the reliability of these findings. Overall, these results suggest that there is a meaningful and statistically robust connection between technology acceptance and self-efficacy for technology integration.

Results

This section outlines the primary findings derived from the quantitative data analysis, which align with the central aim of the study. The results cover the path analyses examining relationships among key variables—specifically, Technology Acceptance and Self-Efficacy for Technology Integration—within the SEM framework. Additionally, explanatory ratios for each variable are reported, alongside measurement details and fit indices for the structural model as a whole. The SEM analysis was conducted with a sample of 213 PSTs. For a comprehensive overview of the model's fit indices, refer to Table 5.

Table 5 details the fit indices for Model 1 within the framework of structural equation modeling (SEM). The chi-square statistic (χ^2) for the model reported at 294.074 with 64 degrees of freedom ($p < .001$). While a significant p value traditionally signals a lack of model fit, it is important to note that the χ^2 test is extremely sensitive to large sample sizes and may flag significance even when the model appropriate (Bentler, 1990). To provide additional context, the χ^2/df ratio presented at 2.93. This falls below the accepted cutoff of three, though it does not meet the more conservative threshold of two for optimal fit (Kline, 2016).

The RMSEA value stands at .161 (confidence interval: [.143, .180]), which notably exceeds the commonly accepted threshold of .08 or below (MacCallum et al., 1996). A high RMSEA value indicates that the model does not fit the data well and that its ability to explain the observed relationships is limited. In contrast, the SRMR is quite low at .0101, comfortably under the .08 benchmark, indicating that the model's residuals are within acceptable limits (Hu & Bentler, 1999).

Table 6 provides the factor loadings for the latent variables (Technology Acceptance and Self-Efficacy for Technology Integration) on their respective indicators, offering an assessment of the measurement model's validity.

Table 5.

Fit Indices of the Structural Equation Model

Model	χ^2	df	p	χ^2/df	CFI	TLI	RMSEA [90% CI]	SRMR	AIC	BIC
Model 1	294.074	64	<.001	2.93	.775	.726	.161 [.143, .180]	.0101	2756.789	2835.825

Table 6.

Factor Loadings of the Measurement Model

Latent	Indicator	Std. estimate	Std. error	z-value	p
T-TAM	T1	0.676	0.050	13.496	< .001
	T2	0.769	0.039	19.719	< .001
	T3	0.762	0.040	19.114	< .001
	T4	0.791	0.036	21.861	< .001
	T5	0.402	0.075	5.367	<.001
	T6	0.818	0.033	25.112	< .001
	T7	0.837	0.030	27.759	< .001
	T8	-0.332	0.079	-4.194	< .001
	T9	0.522	0.066	7.965	< .001
	T10	-0.460	0.071	-6.494	< .001
	T11	0.297	0.081	3.654	< .001
	Y	0.762	0.046	16.705	< .001
S-ET	O1	0.939	0.029	31.897	< .001
	O2	0.859	0.034	25.426	< .001

Table 6 presents the factor loadings, standard errors, z-values, and p-values for the indicators linked to the latent variables Technology Acceptance (T-TAM) and Self-Efficacy for Technology Integration (S-ET), as part of the measurement model validation process. These factors reflect how well each observed variable represents its respective latent construction, offering evidence for the overall construct validity of the model.

With respect to T-TAM, the factor loadings show considerable variability. Indicators T1, T2, T3, T4, T6, T7, and Y all report loadings above 0.67, with T7 (0.837) and T6 (0.818) standing out for their particularly strong contributions. These values surpass the commonly accepted threshold of 0.50 (Hair et al., 2019), supporting the adequacy of these items in measuring the construction. In contrast, T5 (0.402) and T11 (0.297) have low loadings, and T8 (-0.332) and T10 (-0.460) exhibit negative loadings, which raises questions about their suitability as indicators. Despite these concerns, all T-TAM indicators display highly significant z-values ($p < .001$), suggesting the loadings are unlikely to be attributable to chance.

Turning to S-ET, both O1 and O2 demonstrate exceptionally high factor loadings (0.939 and 0.859, respectively), indicating a robust representation of the construct. Their associated z-values (31.897 for O1 and 25.426 for O2) are also highly significant ($p < .001$), providing robust evidence of reliability and convergent validity within this dimension.

In summary, most T-TAM indicators adequately reflect the underlying construct, although certain items (notably T5, T8, T10, and T11) may warrant further examination. The S-ET indicators, meanwhile, show strong and statistically significant relationships with their latent variable, reinforcing the validity of this aspect of the model.

Structural Equation Modelling

The proposed Structural Equation Model was assessed using a variety of fit indices to evaluate how well it represented the observed data (Table 7):

Table 7.

Multiple Fit Indices

χ^2 (64)	294.074
χ^2/df	2.930
p	< .001
RMSEA	.161
SRMR	.101
CFI	.775
GFI	.711
TLI	.726

The model's overall fit isn't flawless; however, certain indices do fall within accepted parameters. Specifically, the χ^2/df ratio stands at 2.930, which is considered acceptable according to established guidelines (Kline, 2016). Additionally, all path coefficients reached statistical significance ($p < .001$), indicating empirical support for the hypothesized structural relationships within the model. The corresponding path diagram illustrating these relationships is provided in Figure 1.

Figure 1.

Path diagram of the SEM with standardized estimates

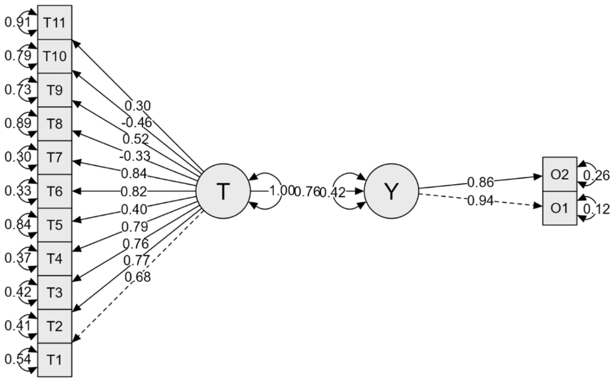

Figure 1 presents the Structural Equation Model (SEM) along with the standardized path coefficients, illustrating the relationships between the latent variables T-TAM (Technology Acceptance Model) and S-ET (Self-Efficacy for Technology). In this model, T-TAM is measured using 11 indicators (T1–T11) that capture mathematics teachers' acceptance of technology, while S-ET is represented by two indicators (O1 and O2) reflecting their self-efficacy in integrating technology into their teaching.

Examining the factor loadings for T-TAM, most indicators—specifically T1, T2, T3, T4, T6, T7, T9, and Y—demonstrate satisfactory values above 0.50, ranging from 0.522 to 0.837. This suggests these items are well-aligned with the T-TAM construct. In contrast, T5 (0.402) and T11 (0.297) show lower loadings, indicating weaker associations. More noteworthy, T8 (-0.332) and T10 (-0.460) exhibit negative factor loadings, which may result from reverse-coding or unexpected theoretical relationships, as noted by Hair et al. (2019).

For the S-ET variable, the indicators O1 (0.94) and O2 (0.86) display extremely high loading factors, indicating a strong measured reliability and capturing the intended dimension effectively within the model. Overall, Figure 1 provides a clear visualization of both the robust and weaker associations present in the measurement model.

The standardized path coefficient between the T-TAM and S-ET latent variables is 0.42, indicating a moderate, positive relationship. In other words, greater technology acceptance (T-TAM) is associated with higher self-efficacy regarding technology use (S-ET). The covariance between the error terms of T-TAM and S-ET is reported as 0.760, which suggests that the unexplained variance in these constructs is interrelated.

Discussion

This study provides valuable insight into the interplay between mathematics teachers' acceptance of technology and their self-efficacy in integrating technological tools into their instruction. The findings demonstrate a moderate, positive association—indicated by a standardized path coefficient of 0.42—between teachers' openness to adopting technology and their confidence in effectively weaving it into classroom practice. Greater acceptance of technology among mathematics teachers corresponds with heightened self-efficacy regarding technology integration.

This pattern aligns with prior research, such as the work of Abu Bakar et al. (2018), who underscore the importance of self-efficacy and positive attitudes for successful technology integration. Similarly, Teo (2009) and Sang et al. (2010) found that the constructs within the Technology Acceptance Model, including perceived usefulness, contribute meaningfully to teachers' self-efficacy in using technology. Erdener and Kandemir (2019) also highlight the direct influence of teachers' attitudes on their technology-related beliefs and practices.

Further, the observed covariance (0.760) between the error terms of the technology acceptance and self-efficacy variables suggests that unexplained variance in these constructs is interrelated. This points to the possible influence of additional contextual or external factors. As noted by Ngai et al. (2007), environmental conditions such as technical support and accessibility can significantly impact technology integration outcomes. Within the Turkish educational context, challenges such as limited technological infrastructure and insufficient professional development support may contribute to suboptimal results in technology acceptance and efficacy measures—a finding echoed by Erdoğan, (2025), who stress the critical role of contextual influences.

In brief, mathematics teachers face challenges, including curriculum demands and limited resources—that may bear on both their attitudes toward technology and their perceived ability to use it effectively in their classrooms. These findings highlight the importance of both attitudinal and structural support for successful technology integration in mathematics education.

The findings of this study both align with previous research in literature and highlight certain limitations that deserve attention. The moderate positive correlation (r = 0.541) observed between T-TAM and S-ET is consistent with conclusions drawn by Teo (2009) and Venkatesh and Davis (2000), who emphasized that the core components of the Technology Acceptance Model (TAM)—namely, perceived usefulness and perceived ease of use—positively influence teachers' attitudes toward technology integration and their self-efficacy. In the specific context of mathematics instruction, Erdener and Kandemir (2019) and Paraskeva et al., (2008) noted that positive attitudes toward technology can support pedagogical practices such as visualizing abstract concepts and developing problem-solving skills.

The path coefficient of 0.42 identified in this study further confirms the impact of technology acceptance on self-efficacy among teachers, although the moderate strength of this relationship indicates the influence of additional variables, such as pedagogical beliefs or institutional support. Ibrahim et al. (2025) pointed out that TAM does not adequately account for contextual factors, such as a lack of technical support, which can hinder technology integrational —a limitation that may correspond with the less-than-ideal model fit observed here.

Of note are the low and negative factor loadings for items T8 and T10 on the T-TAM scale (−0.332 and −0.460, respectively), which raise concerns regarding the validity of these items. However, the observed negative factor loadings and the modest model fit indices (RMSEA = .161, CFI = .775) reflect a theoretically coherent pattern that is frequently reported in the TAM literature. Technological Complexity and Anxiety conceptualized as negatively valenced determinants of Perceived Ease of Use in extended TAM models (Venkatesh & Davis, 2000; Venkatesh & Bala, 2008). In the Turkish adaptation of T-TAM by Ursavaş et al., (2014), these constructs likewise retained as separate factors, and negative associations with Perceived Ease of Use documented.

In the present study, because these items were not reverse-coded, the measurement model represents these negative relations in a manner consistent with the theoretical nature of the constructs. This pattern does not indicate a scale deficiency or a cultural mismatch; rather, it provides a valid empirical reflection of the continued prevalence of teachers' perceptions of technological anxiety and complexity in the Turkish context. A substantial body of research similarly reports that teachers often experience important levels of anxiety and stress regarding the use of educational technologies, frequently perceiving the process as overwhelming or complex (Fernández-Batanero et al., 2021; Khlaif et al., 2022). In particular, the rapid shift to online teaching during the COVID-19 period has shown to generate significant anxiety and stress among teachers, due to insufficient training, increased workload, and limited institutional support (Klapproth et al., 2020; Zheng et al., 2022)

Additionally, the T-TAM scale demonstrated low reliability coefficients (α = .669, ω = .028), which may be attributable to insufficient support for preservice teachers in technology integration, as discussed by Clark-Wilson et al. (2020). The internal consistency of the scale may also have compromised by the heterogeneity of the sample, which included teachers from various school types (e.g., Anatolian, Vocational, and Science High Schools) and with differing levels of professional experience. For instance, disparities in access to technology or experience with technology use could have influenced self-efficacy beliefs and, consequently, the scale's reliability. Teachers with less experience may report lower self-efficacy, whereas those with ongoing training or greater familiarity with digital tools may report higher confidence.

These observations suggest that future research should consider revising the T-TAM scale to better account for context-specific factors relevant to Turkish educators. In contrast, the S-ET scale exhibited strong factor loadings and high reliability, indicating that self-efficacy beliefs measured consistently and reinforcing their importance in facilitating technology integration among mathematics teachers (Abu Bakar et al., 2018).

The model's less-than-ideal fit is not exactly surprising, considering the well-documented issues in the literature—violations of normality and measurement inconsistencies have noted repeatedly (Byrne, 2016). Liu et al. (2024) argue that when teacher education programs do not provide clear direction for technology integration, these kinds of inconsistencies tend to crop up. Similarly, Gumiero and Pazuch (2024) highlight that successful technology used in mathematics classrooms closely tied to pedagogical support and domain-specific expertise. In this study, the observed problems with normality and measurement may well reflect the absence of those supports.

To summarize, this research confirms a notable relationship between mathematics teachers' acceptance of technology and their self-efficacy beliefs. Still, certain limitations such as low or negative factor loadings and the model's overall suboptimal fit stand out. These issues underscore the ongoing importance of context: technical support, adequate training, and culturally attuned measurement tools, as emphasized by Erdoğan (2025) and Clark-Wilson et al. (2020).

The findings point to a clear need for teacher education programs to prioritize hands-on technology training and focused pedagogical guidance, aiming to better equip preservice mathematics teachers for tech integration. On the institutional side, schools can help by investing in robust technical infrastructure, offering regular in-service training, and fostering a school culture that values technology. Future research should consider adapting the T-TAM scale for the Turkish context either by revising existing items or creating new ones. Given the data's deviation from normality and the model's weak fit, employing more flexible statistical methods such as Partial Least Squares SEM or Bayesian SEM could generate more reliable results. Including variables like school culture, technical support, and curriculum design as independent factors might provide a deeper understanding of the interplay between technology acceptance and teacher self-efficacy.

Limitations

This study provides valuable insights into the relationship between mathematics teachers' technology acceptance, as measured by the T-TAM scale, and their self-efficacy regarding technology integration, assessed through the S-ET scale. However, several limitations should be acknowledged. Notably, certain items on the T-TAM scale, particularly T8 and T10, displayed low or even negative factor loadings, and the reliability coefficients were below ideal levels (α = .669, ω = .028).

These negative factor loadings stem from the strong inverse relationship between the constructs of Technological Complexity and Anxiety and the Perceived Ease of Use dimension. While future studies could consider reverse-coding these items to integrate them into the Perceived Ease of Use factor and potentially improve model fit, in this study we chose to retain the original theoretical structure of the T-TAM (Ursavaş et al., 2014), which aligns with the negative antecedents described in extended TAM models (Venkatesh & Bala, 2008).

Additional limitations relate to data collection and sample characteristics. Data were collected exclusively online, which may have limited both the diversity and representativeness of the participants. Furthermore, model fit indices were suboptimal, and the data did not fully meet the normality assumption, both of which restrict the generalizability of the findings.

For future research, it is recommended to use measurement instruments that are culturally adapted and validated for the target population, to recruit a broader and more balanced sample, and to consider alternative structural modeling techniques, such as Partial Least Squares Structural Equation Modeling (PLS-SEM). Researchers may also explore whether treating Technological Complexity and Anxiety as separate factors or reverse-coding specific items within the Perceived Ease of Use dimension yields a more parsimonious and statistically robust model.

Declarations

Ethical Approval: Ethical Approval: This study was approved by the University institutional review board.

Consent to Participate: Informed consent was obtained from all individual participants included in the study.

Research involving human participants.

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Author Contribution: The authors contributed equally to the article.

Conflicts of Interest: The authors declare no conflicts of interest.

Availability of data and materials: Data is available on request.

AI Disclosure: In this study, AI-based tools were utilized as part of the sentence restructuring process to enhance the linguistic accuracy and academic style of the text.

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