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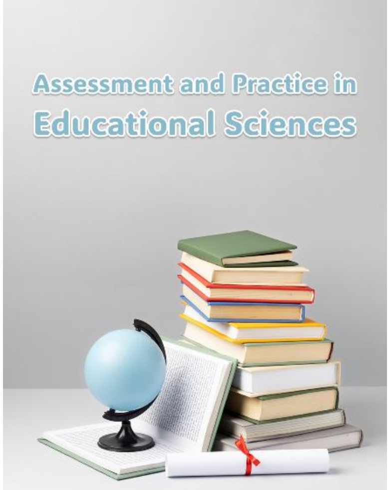

Analysis of Differences in Electronic Mathematics Teaching Competencies Among In-Service Student Teachers at Farhangian University: A Descriptive Interpretation of Findings Based on the Technology Acceptance Model

ABSTRACT

This study aimed to examine differences in electronic mathematics teaching competencies among in-service student teachers at Farhangian University. In terms of methodology, the study was descriptive–analytical, and in terms of design, it employed a cross-sectional quantitative approach. The statistical population consisted of in-service teachers studying in the Mathematics Education program at Farhangian University, from whom 296 participants were selected through convenience sampling. Data were collected using a researcher-developed questionnaire designed to assess electronic teaching competencies, encompassing five components: clarity of content delivery, utilization of electronic instructional aids, organization and sequencing of content, instructional interaction, and technological skills. The data were analyzed using descriptive statistics, the independent samples t-test, analysis of variance (ANOVA), and multivariate analysis of variance (MANOVA). The findings indicated statistically significant differences between trained and untrained teachers across all examined components, with the trained group reporting higher scores on all indicators. Given the cross-sectional nature of the research design and the absence of experimental manipulation, these findings are interpreted as "group differences" and as evidence of the "association between training and higher levels of reported competencies." The findings were interpreted in light of the Technology Acceptance Model, and it is recommended that future studies directly investigate TAM constructs as well as dimensions of self-regulation using standardized attitudinal instruments.

Keywords: electronic teaching, mathematics education, teacher education, technological competency, Technology Acceptance Model

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Introduction

The rapid expansion of digital technologies in education has fundamentally transformed teaching and learning processes across schools and higher education systems worldwide. In the twenty-first century, educational systems are increasingly expected to integrate digital learning environments, electronic instructional resources, intelligent educational systems, and online communication platforms into instructional practice in order to respond to the evolving demands of learners and societies (1). The acceleration of technological integration became particularly visible following the global disruptions associated with the COVID-19 pandemic, which compelled educational institutions to adopt online and hybrid instructional models at an unprecedented scale (2). This transformation has not merely altered the delivery mode of education; rather, it has reshaped the competencies expected of teachers, especially in relation to technological literacy, digital pedagogy, instructional interaction, and the effective management of online learning environments. Contemporary educational discourse increasingly emphasizes that teachers are no longer expected to function solely as transmitters of knowledge, but also as facilitators of technologically enriched learning experiences capable of integrating multimedia tools, interactive digital resources, and learner-centered strategies into classroom practice (3). Within this context, the concept of electronic teaching competency has emerged as one of the most significant dimensions of teacher professional development and educational quality.

Electronic teaching competency refers to the collection of technological, pedagogical, communicative, and organizational skills required for the effective implementation of digital instruction. These competencies encompass a wide range of abilities, including the preparation and use of electronic instructional content, management of virtual interactions, integration of multimedia resources, organization of digital learning materials, and adaptation of instructional strategies to technology-mediated environments (4). Research has shown that teachers' digital competencies directly influence instructional effectiveness, learner engagement, and the quality of educational experiences in online settings (5). In mathematics education, the importance of electronic teaching competencies becomes even more pronounced because mathematics is inherently conceptual, abstract, and cognitively demanding. Effective mathematics instruction frequently requires visual representations, simulations, dynamic modeling, and interactive demonstrations that can be substantially enhanced through electronic media and digital technologies (6). Multimedia learning theory suggests that learners achieve deeper understanding when verbal and visual information are meaningfully integrated within instructional environments, particularly when instructional materials are carefully designed to reduce cognitive overload and promote active learning processes (6). Consequently, mathematics teachers who possess stronger electronic teaching competencies may be better equipped to create engaging and conceptually accessible learning environments for students.

The effectiveness of digital teaching practices is closely associated with teachers' acceptance and use of educational technologies. One of the most influential theoretical frameworks for understanding technology adoption in educational contexts is the Technology Acceptance Model. According to TAM, individuals' intention to use technology is primarily influenced by perceived usefulness and perceived ease of use (7). Numerous studies have demonstrated that teachers' technological acceptance significantly predicts their willingness to integrate digital technologies into instructional practice (8). Teachers who perceive digital tools as useful, manageable, and supportive of learning outcomes are more likely to adopt innovative instructional technologies and sustain their use in educational settings. Meta-analytic evidence has further confirmed that TAM constructs provide a robust explanatory framework for understanding teachers' adoption of digital technologies in education (7). More recent studies have extended TAM by incorporating variables such as digital literacy, self-regulated learning, affinity for technology, and adaptive instructional technologies, thereby providing a more comprehensive understanding of technology integration in modern educational systems (9, 10). The relevance of TAM to teacher education is therefore substantial, particularly in contexts where teachers are expected to simultaneously develop technological proficiency and pedagogical effectiveness.

In addition to technology acceptance, self-regulation has emerged as a critical factor influencing success in online and technology-mediated learning environments. Self-regulated learning refers to the active process through which individuals monitor, control, and direct their cognitive, motivational, and behavioral processes toward the achievement of learning goals (11). Online educational environments require learners and teachers alike to exercise higher levels of autonomy, planning, time management, and technological adaptability. Studies have shown that self-regulated learning strategies are strongly associated with academic achievement and successful engagement in online higher education environments (12). Recent research has also suggested that self-regulated learning may interact with technology acceptance variables, thereby influencing individuals' willingness and ability to engage effectively with electronic learning systems (9). In the context of teacher education, self-regulation may influence how future teachers adapt to digital instructional demands, develop technological competencies, and sustain engagement with online teaching practices. This issue is particularly relevant for in-service student teachers who are simultaneously balancing academic responsibilities and professional teaching duties.

Teacher education institutions therefore play a crucial role in preparing future educators for digitally mediated instructional environments. Recent scholarship has emphasized that teacher preparation programs must move beyond traditional pedagogical approaches and explicitly incorporate digital competence development into their curricula (13). Teacher educators are increasingly expected to cultivate preservice teachers' abilities to design digital instructional materials, facilitate online interaction, and critically evaluate educational technologies (14). The importance of such preparation has become even more evident in light of the growing integration of adaptive learning technologies, personalized feedback systems, and interactive artificial intelligence tools in educational contexts (15). Studies indicate that digital literacy significantly moderates the effectiveness of technology-enhanced learning systems, suggesting that the successful implementation of educational technologies depends not only on access to digital tools but also on teachers' competencies and attitudes toward technology use (15). Similarly, investigations into online learning effectiveness have demonstrated that students' academic performance in digital learning environments is closely associated with instructional quality, technological support, and meaningful interaction within online platforms (16). Consequently, the preparation of digitally competent teachers has become a strategic priority for educational systems worldwide.

Another important theoretical perspective relevant to electronic teaching is social constructivism, which emphasizes the role of interaction, collaboration, and shared meaning-making in the learning process. In online learning environments, meaningful interaction between teachers and students constitutes a central determinant of instructional effectiveness (17). Electronic teaching environments that encourage communication, collaborative learning, and active participation are more likely to foster student engagement and deeper learning outcomes. Mathematics education, in particular, benefits from interactive teaching practices that enable learners to discuss concepts, solve problems collaboratively, and receive immediate feedback through digital platforms. Teachers who possess strong competencies in managing electronic interactions and integrating collaborative digital tools may therefore contribute to more effective mathematics instruction in online and blended learning settings. At the same time, however, the successful implementation of such approaches depends heavily on teachers' confidence, technological skills, and acceptance of digital learning systems.

Despite the increasing importance of digital teaching competencies, previous studies have identified substantial variability in teachers' readiness for electronic instruction. Research conducted in different educational contexts has shown that many teachers continue to experience challenges related to technological proficiency, instructional adaptation, and the effective use of digital resources (4, 5). Differences in training opportunities, institutional support, prior technological experience, and attitudes toward educational technologies may contribute to disparities in electronic teaching competencies among teachers. These challenges may be especially significant among in-service student teachers who are simultaneously engaged in professional teaching practice and university-level academic training. Although prior research has examined technology acceptance, digital competence, and online learning effectiveness in various educational contexts, fewer studies have specifically investigated differences in electronic mathematics teaching competencies among in-service student teachers based on training experiences related to electronic content production and technology integration. Moreover, the majority of existing studies have focused either on preservice teachers or on general educational contexts, while comparatively limited attention has been devoted to mathematics education within teacher preparation programs.

Methodologically, educational research investigating technological competencies and instructional effectiveness frequently employs descriptive and comparative designs because such approaches facilitate the analysis of existing educational conditions and group differences without experimental intervention (18). Comparative investigations of trained and untrained teacher groups can provide valuable insights into the association between professional development experiences and perceived instructional competencies. In this regard, examining electronic teaching competencies among student teachers may contribute to a deeper understanding of how teacher education programs can better prepare future educators for technology-rich learning environments. Furthermore, understanding the relationship between training experiences and electronic teaching competencies may assist policymakers, curriculum designers, and teacher educators in developing more effective professional development initiatives and digital competency frameworks within teacher education institutions.

Given the growing importance of electronic teaching competencies in mathematics education, the increasing integration of digital technologies into educational systems, and the central role of technology acceptance in shaping instructional practices, the present study aimed to analyze differences in electronic mathematics teaching competencies among in-service student teachers at Farhangian University based on training experiences related to the production and use of electronic educational content.

Methods and Materials

The present study was applied in terms of purpose and descriptive–analytical in terms of methodological orientation, and it was conducted using a quantitative approach. From the perspective of research design, the study employed a cross-sectional design, as the data were collected at a single point in time without any experimental manipulation of variables (Creswell & Creswell, 2018). The selection of a descriptive–analytical design was appropriate given the primary objective of the study, which was to examine differences and associations among variables related to electronic teaching and technology-based instructional competencies. Previous studies in the field of educational technology acceptance and electronic learning effectiveness have similarly adopted descriptive and cross-sectional approaches because such designs enable the examination of existing conditions and intergroup differences without intervention (Barz et al., 2024).

The statistical population consisted of in-service student teachers enrolled in the Mathematics Education program at Farhangian University who simultaneously had teaching experience in schools. This population was considered particularly important because the attitudes, competencies, and technological experiences of these student teachers may directly influence the quality of mathematics instruction in educational settings. Mathematics, as a conceptually abstract subject, requires effective integration of digital media and electronic instructional resources; therefore, examining the competencies and perceptions of mathematics student teachers regarding electronic teaching was regarded as highly significant.

The study sample included 296 mathematics student teachers selected through convenience sampling. Eligibility criteria included having educational experience related to electronic teaching or belonging to one of the two comparison groups, namely "trained" and "untrained," with regard to the preparation and use of electronic instructional content. Although probability sampling techniques are generally preferred in terms of external validity and generalizability, convenience sampling is widely accepted in educational research, particularly in university contexts where access to participants may be limited. Furthermore, the sample size was considered statistically adequate for the inferential analyses employed in the study, including the independent samples t-test, analysis of variance (ANOVA), and multivariate analysis of variance (MANOVA).

Data Collection Tools

Data were collected using a researcher-developed questionnaire designed to assess electronic teaching competencies. Although the study did not directly employ a standardized Technology Acceptance Model instrument, several dimensions of the questionnaire conceptually overlapped with TAM constructs, particularly perceived usefulness and perceived ease of use. The questionnaire was developed based on a systematic review of the literature on electronic learning, technology acceptance, and instructional competencies associated with digital educational media.

The instrument consisted of 22 items organized into five principal components. The first component assessed the clear and effective delivery of instructional content through electronic resources and included five items. The second component measured the use of electronic instructional aids and consisted of six items. The third component evaluated the organization, sequencing, and structuring of educational content using electronic media and included three items. The fourth component focused on instructional interaction with students through electronic media and consisted of four items. The fifth component assessed the technological skills and proficiency of student teachers in preparing and utilizing electronic media and also included four items. Responses to all items were scored using a five-point Likert scale ranging from “strongly disagree” to “strongly agree.” The use of Likert-type scales is common in educational research due to their ease of administration and suitability for quantitative statistical analyses.

The content validity of the questionnaire was evaluated through expert judgment. Three specialists in educational sciences and educational technology reviewed all questionnaire items and assessed their degree of relevance to the intended constructs using a five-level relevance scale ranging from “irrelevant” to “completely relevant.” The results indicated that the majority of items were rated within the categories of “highly relevant” and “completely relevant,” supporting the adequacy of the instrument’s content validity. The use of expert evaluation for establishing content validity is recognized as an accepted procedure in the development of researcher-made instruments.

The reliability of the questionnaire was examined in two stages. Prior to the main implementation, internal consistency reliability was assessed using Cronbach’s alpha coefficients. The reliability coefficients for the five components ranged from 0.63 to 0.68, while the overall reliability coefficient for the entire questionnaire was 0.66. Although several coefficients were slightly below the conventional threshold of 0.70, these values were considered acceptable given the exploratory nature of the study and the researcher-developed structure of the instrument. Previous methodological literature has indicated that reliability coefficients above 0.60 may be acceptable in exploratory social science research, particularly during the early stages of instrument development.

In the main administration of the study, reliability was reassessed using the Guttman split-half method separately for the trained and untrained groups. The findings demonstrated satisfactory levels of reliability in both groups. The overall questionnaire reliability coefficient was reported as 0.97 for the trained group and 0.88 for the untrained group. These results indicated strong internal consistency and supported the dependability of the instrument in the primary research setting. However, the exceptionally high reliability coefficient observed in the trained group may also suggest overlap among some questionnaire items, and therefore the findings should be interpreted cautiously with regard to conceptual diversity.

The implementation procedure began after obtaining the necessary institutional permissions. The questionnaires were distributed among the student teachers, and the objectives of the study were clearly explained to all participants. Participation in the study was entirely voluntary, and participants were assured that their information would remain confidential and that the results would be reported solely in the form of scientific analyses. Ethical considerations associated with educational research were fully observed throughout the study.

Data analysis was conducted using the IBM SPSS Statistics software package. In accordance with the objectives of the study, both descriptive and inferential statistical methods were employed. Descriptive statistics included the calculation of means, standard deviations, skewness, and kurtosis indices in order to summarize the characteristics of the data and examine distributional properties.

For inferential analysis, the independent samples t-test was used to compare mean differences between the trained and untrained groups. In addition, one-way analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) were conducted to examine differences across multiple competency dimensions simultaneously. The selection of these statistical techniques was based on the nature of the variables, the measurement level of the data, and the comparative objectives of the research.

Prior to conducting the inferential analyses, the statistical assumptions underlying the analyses were examined. These assumptions included normality of data distribution, homogeneity of variances, and independence of observations. Ensuring compliance with these assumptions was considered necessary for maintaining the validity and interpretability of the statistical findings.

Findings and Results

The study sample consisted of 296 student teachers enrolled in the Mathematics Education program at Farhangian University. Among the participants, 65.2% were male and 34.8% were female. The highest proportion of participants belonged to the age range of 20 to 25 years. In terms of educational background, most participants reported between one and five years of academic experience. Furthermore, the majority of the sample were undergraduate students pursuing bachelor's degrees in mathematics education.

Table 1. Descriptive Statistics of the Research Variables

Variables	Mean	Standard Deviation	Skewness	Kurtosis
Clear and Explicit Content Delivery	17.04	2.90	0.09	-0.29
Use of Electronic Instructional Aids	22.93	5.50	-0.04	-0.75
Organization, Sequencing, and Structuring of Content	11.16	3.00	-0.04	-0.49
Interaction with Students	14.76	4.10	0.01	-0.64
Teachers' Technological Skill and Proficiency	13.40	3.20	-0.16	-0.03
Preparation and Use of Electronic Content	79.29	17.10	-0.05	-0.78

The descriptive findings indicated that the highest mean score belonged to the variable "Preparation and Use of Electronic Content" ($M = 79.29$, $SD = 17.10$), whereas the lowest mean score was observed for "Organization, Sequencing, and Structuring of Content" ($M = 11.16$, $SD = 3.00$). In addition, the skewness and kurtosis indices for all variables were within the acceptable range of ± 1, suggesting an approximately normal distribution of the data. These results supported the appropriateness of applying parametric statistical analyses in the subsequent stages of data analysis.

Prior to conducting the multivariate analysis, the statistical assumptions underlying the analyses were examined. The results of the Kolmogorov–Smirnov test demonstrated that all dependent variables were normally distributed, as all significance levels exceeded 0.05. Furthermore, the Box's M test was non-significant ($p = 0.120$), indicating that the assumption of homogeneity of variance–covariance matrices was satisfied. The results of Levene's test also confirmed the equality of variances across groups for all dependent variables ($p > 0.05$). Collectively, these findings indicated that the assumptions required for conducting MANOVA and ANOVA were adequately met.

Table 2. Results of One-Way Analysis of Variance (ANOVA)

Variables	Sum of Squares	df	Mean Square	F	p	Partial Eta Squared
Clear and Explicit Content Delivery	1925.76	1	1925.76	1050.74	<0.001	0.78
Use of Electronic Instructional Aids	8284.99	1	8284.99	3856.15	<0.001	0.93
Organization, Sequencing, and Structuring of Content	2304.99	1	2304.99	2149.75	<0.001	0.88

Interaction with Students	4405.96	1	4405.96	2498.14	<0.001	0.89
Teachers’ Technological Skill and Proficiency	1148.27	1	1148.27	900.52	<0.001	0.75

The results of the one-way ANOVA analyses revealed statistically significant differences between the trained and untrained groups across all components of electronic teaching competencies ($p < 0.001$). The findings demonstrated that the trained group consistently achieved higher scores on all examined variables. The largest effect sizes were observed for “Use of Electronic Instructional Aids” ($\eta^2 = 0.93$), “Interaction with Students” ($\eta^2 = 0.89$), and “Organization, Sequencing, and Structuring of Content” ($\eta^2 = 0.88$), indicating that group membership accounted for a substantial proportion of variance in these competencies. Nevertheless, these large effect sizes should be interpreted cautiously because the non-random sampling procedure, the absence of random assignment, and the lack of pretest controls may have contributed to an overestimation of the observed group differences. In addition, the use of self-report measures may have increased the likelihood of ceiling effects within some variables.

Table 3. Independent Samples t-Test for Gender Differences in the Preparation and Use of Electronic Content

Group	Gender	Mean	Levene’s F	Levene’s p	t	df	p
Trained	Male	94.35	0.124	0.270	3.74	146	<0.001
Trained	Female	97.40	—	—	—	—	—
Untrained	Male	62.88	0.119	0.730	0.26	146	0.795
Untrained	Female	62.69	—	—	—	—	—

The results of the independent samples t-test indicated that within the trained group, a statistically significant gender difference existed in the preparation and use of electronic content ($t = 3.74$, $p < 0.001$), with female participants reporting slightly higher mean scores than male participants. In contrast, no statistically significant gender difference was observed within the untrained group ($t = 0.26$, $p = 0.795$). Given the cross-sectional nature of the study, these findings should be interpreted solely as group differences rather than causal relationships. Future studies are therefore recommended to control for contextual and demographic variables in order to provide a more comprehensive explanation of these observed differences.

Discussion and Conclusion

The present study aimed to analyze differences in electronic mathematics teaching competencies among in-service student teachers at Farhangian University based on their participation in training related to the preparation and use of electronic educational content. The findings demonstrated statistically significant differences between trained and untrained student teachers across all examined dimensions of electronic teaching competency, including clear content delivery, use of electronic instructional aids, organization and sequencing of content, interaction with students, and technological skills and proficiency. In all dimensions, the trained group reported higher competency levels than the untrained group. These findings suggest that exposure to training experiences related to digital content production and electronic instruction is associated with stronger perceptions of instructional competence in technology-mediated educational environments. The findings are theoretically consistent with the Technology Acceptance Model, which proposes that individuals who perceive technology as useful and manageable are more likely to integrate it into their professional practices (7). Teachers who receive structured exposure to digital technologies may develop stronger perceptions of usefulness and ease of use, thereby increasing their confidence and willingness to employ electronic instructional strategies. The present findings are also aligned with studies indicating that teachers’ digital competence positively influences technology acceptance and educational technology integration (8). In this regard, training experiences may contribute not only to technical proficiency but also to positive attitudes toward technology-supported instruction.

One of the major findings of the study was the substantial difference between trained and untrained groups in the use of electronic instructional aids and in the organization and sequencing of digital instructional content. These findings highlight the importance of pedagogical training in enabling teachers to effectively manage multimedia instructional environments. According to multimedia learning theory, instructional effectiveness increases when verbal and visual information are integrated in cognitively meaningful ways (6). Mathematics education particularly benefits from visual demonstrations, simulations, dynamic representations, and interactive media that facilitate conceptual understanding of abstract mathematical ideas. Teachers who possess stronger competencies in organizing electronic content may therefore be more capable of reducing cognitive overload and promoting deeper understanding among learners. The results of the present study support prior research emphasizing the significance of instructional design models and their relationship with effective electronic learning environments (3). Effective use of digital instructional aids requires not only technological familiarity but also pedagogical understanding of how instructional materials should be structured to maximize student engagement and comprehension. Consequently, training programs that emphasize both technological and pedagogical dimensions of digital teaching may substantially improve instructional quality in mathematics education.

The findings related to instructional interaction with students are also noteworthy. The trained group demonstrated significantly higher competency levels in electronic interaction with learners, suggesting that training experiences may improve teachers' ability to establish communication and maintain engagement in digital learning environments. This finding can be interpreted within the framework of social constructivist learning theory, which emphasizes the importance of interaction, collaboration, and active participation in the learning process (17). In online and blended learning environments, interaction serves as a critical mechanism for sustaining learner motivation, promoting collaborative problem-solving, and facilitating meaningful learning experiences. Mathematics instruction, in particular, requires opportunities for discussion, questioning, immediate feedback, and guided problem-solving. Teachers with stronger competencies in digital interaction may therefore be better positioned to create supportive and participatory learning environments for students. The findings are consistent with previous studies demonstrating that online learning effectiveness is strongly associated with instructional interaction and the quality of learner engagement (16). Furthermore, recent evidence suggests that adaptive learning technologies and interactive digital tools can enhance student engagement when teachers possess adequate digital literacy and technological competency (15). The present findings therefore reinforce the argument that teacher preparation programs should prioritize the development of interactive digital teaching skills rather than focusing solely on technical tool usage.

Another important finding of the study was the high mean score observed for the preparation and use of electronic content among trained student teachers. This finding may reflect the increasing normalization of digital technologies in contemporary educational environments and the growing expectation that teachers be capable of producing electronic instructional materials. Recent literature has highlighted that the accelerated digital transformation of education has fundamentally altered the competencies expected of educators (2). Teachers are increasingly required to integrate learning management systems, multimedia resources, intelligent educational tools, and online communication platforms into instructional practice. The present findings support the argument that training experiences may play a substantial role in helping teachers adapt to these changing professional demands. Moreover, the results are aligned with research emphasizing the importance of developing digital competence frameworks within teacher education programs (4). Teacher education institutions are now expected to prepare future educators not only for traditional classroom instruction but also for flexible and technology-mediated educational environments. In this regard, the findings of the present study provide empirical support for recent calls to transform teacher education curricula in response to contemporary digital challenges (13).

The study findings may also be interpreted through the perspective of self-regulated learning theory. Self-regulation refers to individuals' capacity to monitor, organize, and direct their own learning processes toward desired goals (11). Digital learning environments often require higher levels of self-management, adaptability, and autonomous engagement than traditional instructional settings. Student teachers who participated in training programs related to electronic content preparation may have developed stronger self-regulatory strategies that facilitated their adaptation to digital instructional contexts. Previous studies have demonstrated that self-regulated learning strategies are strongly associated with academic achievement and effective participation in online learning environments (12). More recent investigations have further suggested that self-regulated learning may strengthen technology acceptance and digital engagement among students and teachers (9). The present findings therefore suggest that electronic teaching competency may not solely reflect technical proficiency, but may also involve broader cognitive and motivational processes associated with self-regulation and professional adaptability.

The significant differences observed between trained and untrained groups additionally support recent findings emphasizing the central role of digital competence in educational quality and instructional effectiveness. Research has consistently shown that teachers with stronger digital competencies are more likely to integrate technology meaningfully into their pedagogical practices and to create engaging learning environments for students (5). Similarly, investigations into digital learning trends have indicated that successful technology integration depends heavily on teachers' preparedness and technological confidence (1). The present findings extend this literature by specifically focusing on mathematics student teachers who simultaneously function as in-service educators. Because these individuals operate within both academic and professional contexts, their competencies may directly influence the implementation of technology-supported teaching practices in schools. Furthermore, the findings are consistent with studies highlighting the importance of teacher educators in shaping preservice teachers' digital competencies (14). Educational institutions that provide systematic opportunities for digital training may therefore contribute substantially to the preparation of technologically competent teachers capable of responding to contemporary educational demands.

An additional finding of the study concerned gender differences in the preparation and use of electronic content within the trained group. Female participants in the trained group reported slightly higher levels of electronic content preparation and use compared to male participants, whereas no significant gender differences were observed in the untrained group. Although the cross-sectional nature of the study prevents causal interpretation, this finding may indicate that training experiences interact differently with demographic and motivational factors among participants. Previous research on digital competence and technology acceptance has produced mixed findings regarding gender differences, with some studies suggesting that technological training may reduce gender-related disparities in technology use and confidence (8). The present findings may therefore suggest that structured technological training contributes to greater engagement with electronic instructional practices among both genders while simultaneously amplifying individual motivational differences. Nevertheless, because the study did not directly examine psychological or contextual factors related to gender, these findings should be interpreted cautiously and viewed as exploratory rather than definitive.

Despite the statistically significant findings and large reported effect sizes, the results should be interpreted with methodological caution. The exceptionally large effect sizes observed across several variables may partially reflect characteristics of the study design, including the use of convenience sampling, the absence of random assignment, and reliance on self-report data. Without pretest measures or experimental controls, it is difficult to determine the extent to which the observed differences are exclusively attributable to training experiences. Selection bias may also have influenced the results because participants who voluntarily engaged in electronic content training may already have possessed stronger technological interest, motivation, or digital literacy. Furthermore, self-report questionnaires are susceptible to social desirability bias and potential ceiling effects, particularly when participants evaluate their own technological competencies. Nevertheless, even with these limitations, the consistency of the findings across multiple competency dimensions suggests that training experiences are meaningfully associated with higher levels of perceived electronic teaching competency among mathematics student teachers.

The findings of the present study contribute to the growing literature on digital competence, technology acceptance, and teacher preparation by demonstrating the importance of training experiences in shaping electronic teaching competencies among in-service mathematics student teachers. As educational systems continue to integrate digital technologies into instructional practice, teacher education institutions will increasingly be required to design comprehensive training programs that simultaneously address technological proficiency, pedagogical effectiveness, instructional interaction, and self-regulated learning capacities. The findings further suggest that electronic teaching competency should be conceptualized as a multidimensional construct encompassing not only technical skills but also attitudes, instructional strategies, and interactive pedagogical practices. Consequently, educational policymakers and curriculum developers should consider the integration of systematic digital competency training into teacher education programs as a strategic priority for improving instructional quality and preparing teachers for future educational environments.

One limitation of the present study was the use of a cross-sectional and non-experimental design, which restricts the ability to infer causal relationships between training experiences and electronic teaching competencies. The use of convenience sampling also limits the generalizability of the findings to broader populations of teachers and student teachers. In addition, the reliance on self-report measures may have increased the likelihood of response bias and inflated evaluations of competency levels. The absence of pretest data and control variables such as prior technological experience, institutional support, socioeconomic status, and access to digital infrastructure further limits the interpretability of the findings. Finally, the study focused specifically on mathematics student teachers at a single university context, which may reduce the applicability of the results to other disciplines or educational systems.

Future research is recommended to employ longitudinal and experimental designs in order to more accurately examine the causal impact of digital training programs on teachers' electronic teaching competencies. Researchers may also investigate the mediating and moderating roles of self-regulated learning, technological self-efficacy, digital literacy, and motivational factors within the relationship between training experiences and instructional competency. Comparative studies across different academic disciplines, educational levels, and institutional contexts may provide a broader understanding of digital competency development among teachers. In addition, future studies should incorporate standardized instruments based on the Technology Acceptance Model and related theoretical frameworks in order to directly examine the psychological mechanisms underlying teachers' technology integration behaviors. Qualitative approaches such as interviews and classroom observations may also complement quantitative findings by providing deeper insight into teachers' lived experiences within electronic teaching environments.

Educational institutions and policymakers should prioritize the integration of comprehensive digital competency training into teacher education curricula and professional development programs. Such programs should move beyond basic technical instruction and focus on pedagogical applications of technology, instructional interaction strategies, multimedia content design, and adaptive online teaching practices. Universities and schools should also provide continuous technological support, access to digital resources, and opportunities for collaborative professional learning among teachers. Encouraging reflective and self-regulated learning practices among student teachers may further strengthen their readiness for technology-mediated educational environments. In addition, educational systems should establish clear competency standards for electronic teaching and regularly evaluate teachers' preparedness for digital instruction in order to ensure the quality and sustainability of technology-enhanced learning environments.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adhered in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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