

Empowering Future Science Teachers: Boosting Self-Efficacy Through an Intervention Programme Based on Digital Material Design

OKTAY KIZKAPAN*¹ AND EMIN TAMER YENEN²

Grounded in experiential learning, the Technological Pedagogical Content Knowledge framework and social cognitive theory, the present study examines the effects of an intervention programme based on digital material design on the self-efficacy of pre-service science teachers in developing digital teaching materials in the context of teacher education in Türkiye. A one-group pretest–posttest experimental design was employed, involving 31 pre-service science teachers who were participating in a 16-week intervention. Data were collected using the Self-Efficacy Scale of Teachers’ Digital Teaching Material Development before and after the intervention, and the collected data were analysed through descriptive and inferential statistical methods. The findings revealed a statistically significant increase in the pre-service science teachers’ overall and general self-efficacy related to digital material development, with the most notable gains observed in the “development” dimension. In contrast, no significant changes were found in the “design” and “negative view” dimensions, indicating that the intervention had differentiated effects across self-efficacy dimensions. These results suggest that while interventions based on digital material design can effectively enhance pre-service teachers’ confidence in improving and using digital materials, additional or more targeted instructional support may be necessary to strengthen design-related competencies and attitudinal change. The study contributes to the limited empirical literature on digital teaching self-efficacy by providing a structured, semester-long intervention model; however, its generalisability is constrained by the single-group design, small sample size and country-specific context. Future research employing comparative designs and larger samples is recommended to further examine the mechanisms through which interventions based on digital material design influence distinct dimensions of digital teaching

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self-efficacy in diverse educational settings.

Keywords: digital material design, pre-service science teachers, self-efficacy

Opolnomočenje bodočih učiteljev naravoslovja: spodbujanje samoučinkovitosti s programom posredovanja, ki temelji na oblikovanju digitalnih gradiv

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Na podlagi izkustvenega učenja, okvira tehnološko-pedagoško-vsebinskega znanja (TPVZ) in socialno-kognitivne teorije ta študija preučuje učinke intervencijskega programa, ki temelji na oblikovanju digitalnih gradiv, samoučinkovitost bodočih učiteljev naravoslovja pri razvoju digitalnih učnih gradiv v okviru izobraževanja učiteljev v Turčiji. Uporabili smo eksperimentalni načrt s predtestom in potestom, in sicer z eno skupino 31 bodočih učiteljev naravoslovja, ki so se udeležili 16-tedenskega intervencijskega programa. Podatki so bili zbrani z uporabo lestvice samoučinkovitosti pri razvoju digitalnih učnih gradiv za učitelje pred programom in po njem, zbrane podatke pa smo analizirali z deskriptivnimi in inferenčnimi statističnimi metodami. Izsledki so pokazali statistično pomembno povečanje skupne in splošne samoučinkovitosti bodočih učiteljev naravoslovja v povezavi z razvojem digitalnih gradiv, pri čemer je bil najopaznejši napredek zaznan v dimenziji »razvoj«. Nasprotno pa v dimenzijah »oblikovanje« in »negativno mnenje« niso bile ugotovljene nobene pomembne spremembe, kar kaže na to, da je imel program različne učinke na različne dimenzije samoučinkovitosti. Ti izsledki kažejo, da lahko intervencijski programi, ki temeljijo na oblikovanju digitalnih gradiv, sicer učinkovito okrepijo samozavest bodočih učiteljev pri izboljševanju in uporabi digitalnih gradiv, vendar je za okrepitev kompetenc, povezanih z oblikovanjem, in spremembo stališč mogoče potrebna dodatna ali bolj usmerjena pedagoška podpora. Študija prispeva k omejeni empirični literaturi o samoučinkovitosti pri digitalnem poučevanju, in sicer s tem, da ponuja strukturiran model intervencije, ki traja en semester, vendar pa njeno splošno veljavnost omejujejo: zasnova z eno skupino, majhna velikost vzorca in kontekst, specifičen za državo, v kateri je študija potekala. Priporočamo nadaljnje raziskave s primerjalnimi zasnovami in z večjimi vzorci, da bi podrobneje preučili mehanizme, prek katerih intervencije, ki temeljijo na oblikovanju digitalnih gradiv, vplivajo na različne dimenzije samoučinkovitosti pri digitalnem poučevanju v različnih izobraževalnih okoljih.

Ključne besede: oblikovanje digitalnih gradiv, bodoči učitelji naravoslovja, samoučinkovitost

Introduction

Technology pervades the lives of individuals of all age groups, particularly children and young people, who engage with it extensively (Bennett et al., 2008). Information technology is one domain of technology that continually evolves, introducing new elements to facilitate daily life. Smartphones, computers, tablets and the internet are easily accessible to nearly everyone and are widely used by adults in professional settings, while children and young people benefit from them in educational pursuits, and individuals of all ages leverage these technologies for social interaction (Harini et al., 2023). Educators are empowered by technology to create conducive teaching environments and develop digital educational materials. In this regard, the integration of digital materials in education supports pedagogical approaches such as problem-based and case-based learning, contributing to the development of students' critical thinking and problem-solving skills (Elgheit & Nashat, 2025), and fostering more flexible and self-directed learning environments, thereby promoting life-long learning competencies (Ivanova Ruiz-Rojas, 2020).

The literature highlights the need for teachers to create their own digital materials in order to actively involve students in the learning process and to respond to students' needs (Carrete-Marín & Domingo-Peñafiel, 2022). In the digital era, the adoption of digital teaching materials – such as lesson presentations, instructional videos, interactive worksheets and online learning resources designed to support classroom instruction – has enhanced teachers' proficiency in using digital technologies for teaching, thereby improving their overall digital competence (Beardsley et al., 2021). For the effective integration of digital resources, the digital teaching self-efficacy of pre-service science teachers (PSSTs) should be systematically supported. From a self-efficacy perspective, providing structured opportunities for mastery experiences and guided practice in digital material development can enhance PSSTs' confidence in their ability to design and implement technology-supported instruction, thereby shaping their beliefs about their own instructional capabilities rather than merely increasing technical exposure (Tanrikulu, 2021).

Gaining experiences in different environments and with different tools during pre-service teacher education provides pre-service teachers with the knowledge and skills necessary to teach in real learning environments in the future (Uppin et al., 2023). Recognising pre-service teachers as future educational designers, they must be encouraged to consciously strategise the use of technology to enhance student learning (McLeod, 2018). Apart from understanding and employing educational tools, teachers should possess the instructional

design knowledge required to create effective learning materials and guide students in their preparation (Khalil & Elkhider, 2016).

The abundance of technological resources in education environments does not necessarily equate to teachers easily harnessing these tools with interest and willingness. A study by Dağ (2016) revealed that although schools possessed adequate technological equipment, such as computers, reliable internet access and basic audiovisual tools (e.g., projectors and presentation software), teachers lacked the necessary technological competence to effectively utilise this equipment to address the needs of the modern age. This indicates that both in-service and pre-service teachers encounter challenges in integrating technology into their learning environments. Identifying the level of computer and instructional technology competencies among teacher candidates before they enter the profession is crucial in order to ensure the efficient integration of technology within educational settings (Donmez-Usta et al., 2020). Research conducted in Türkiye on technology usage indicates that teachers primarily employ technological devices such as computers, smart boards, projectors and tablets, while video-sharing websites and presentations are also commonly used in learning environments (Quinn et al., 2008). Donmez-Usta and Turan-Güntepe (2017) assert that teachers in Türkiye generally believe that creating presentations or utilising videos is sufficient to integrate technology into the learning process. Moreover, teacher candidates' experiences and perceptions regarding technology affect their intentions and readiness to use technology in real-world contexts (Park & Son, 2022). Consequently, it becomes essential to examine PSSTs' digital material self-efficacy.

Self-Efficacy

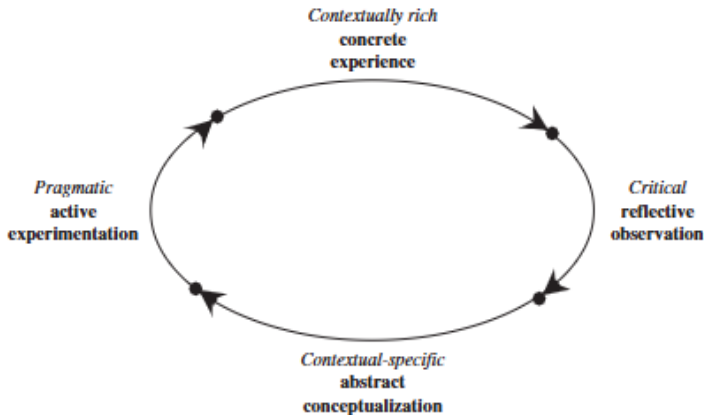
According to Bandura (1977), self-efficacy is the belief an individual holds about their capability to carry out a specific task or behaviour effectively. Bandura (1997) emphasises the significance of self-efficacy beliefs in shaping how individuals feel, behave and stay motivated in various situations. Individuals with high self-efficacy tend to be more resilient when encountering difficulties and setbacks, demonstrating increased confidence and determination (Pajares, 2002). Consequently, people who possess strong self-efficacy are more likely to engage in tasks despite having limited knowledge of the topic, unlike those with lower self-efficacy (Nordén et al., 2017).

The idea of self-efficacy is employed by individuals seeking to acquire new skills or elevate their proficiency levels in education, training or other activities (Zimmerman, 2000). Bandura (1997) asserts that self-efficacy beliefs originate from the individual's interpretation of past experiences, their

emotional responses and the reactions of others. He outlines four main factors that shape self-efficacy: mastery experiences, observational learning, verbal encouragement and emotional conditions.

Mastery experiences involve the individual's direct encounters with successful or unsuccessful actions (Senemoğlu, 2013, p. 234). By evaluating the outcomes of such actions in the past, the individual forms beliefs about their efficacy to perform similar tasks. Successful experiences boost self-efficacy, while repeated failures diminish it (Pajares, 2002). Consequently, the individual's own experiences are considered the most influential factor in the development of self-efficacy beliefs (Thompson, 2016, p. 51). Thus, PSSTs' experiences in material design are likely to enhance their self-efficacy. Observational learning, on the other hand, involves the individual making inferences about their efficacy by observing or modelling others rather than through direct experiences (Lee, 2009). Verbal encouragement, although not as impactful as mastery and observational experiences, comprises feedback on the learner's performance received from family, peers and teachers. Additionally, emotional conditions affect the individual's perceptions of self-efficacy, as emotions reflect their reactions to various situations and their beliefs about them (Lee, 2009). The effect of these sources on self-efficacy may be influenced by factors such as gender and culture (Usher & Pajares, 2006). For example, while the research conducted by Stevens et al. (2006) reported that mastery experiences, observational learning and verbal encouragement were the main elements of self-efficacy in a Western culture, the results of a recent study conducted in the Asia Pacific region (Ma et al., 2025) showed that mastery experience and verbal encouragement were more effective than observational learning and emotional conditions. On the other hand, a study conducted in the Turkish context (Özyürek, 2005) revealed that mastery experience, verbal encouragement and emotional conditions predicted self-efficacy, while observational learning was not considered a source of self-efficacy. Hence, the findings regarding the self-efficacy of PSSTs in Türkiye, a country with elements of Eastern and Western cultures, will be informative for researchers and practitioners from both Western and Eastern countries.

There is a strong correlation between self-efficacy and contemporary technological frameworks, such as Kolb's 3E framework and the Technological Pedagogical Content Knowledge (TPACK) framework (Kolb et al., 2014). Kolb's 3E framework, a popular framework for experiential learning, includes four phases: direct experience, reflective observation, theoretical conceptualisation and practical experimentation. An infographic showing the Kolb's experiential learning model is presented in Figure 1.

Figure 1*The experiential learning cycle (Morris, 2020)*

Kolb's experiential learning model conceptualises learning as a cyclical process involving concrete experience, reflective observation, abstract conceptualisation and active experimentation. Empirical research indicates that this experiential cycle is closely associated with the development of self-efficacy, as the individual's confidence in their capabilities increases through repeated engagement in experience-based and reflective learning activities. For example, Nijakowska (2022) reported a statistically significant increase in teachers' self-efficacy following a face-to-face experiential training programme, with mean self-efficacy scores rising from pretest to posttest and a large effect size ($r = -.59$), suggesting that direct experiential engagement plays a substantial role in strengthening self-efficacy beliefs. Similarly, Ezberci Çevik and Bektaş (2023) found significant pre–post improvements in college students' self-efficacy after participation in outdoor experiential learning activities, demonstrating that concrete experience combined with reflection can lead to measurable gains in self-efficacy. In the context of teacher education, Baltaoğlu and Güven (2019) identified significant relationships between pre-service teachers' self-efficacy perceptions and their experiential learning preferences, indicating that self-efficacy varies systematically with engagement in experiential learning processes. Supporting these findings, Taneja et al. (2023) showed that all four dimensions of Kolb's experiential learning model significantly predicted students' self-efficacy, highlighting the fact that self-efficacy development is not a result of exposure alone but emerges through structured experiential and reflective learning cycles. In conclusion, the 3E framework and self-efficacy are closely intertwined

concepts that can complement each other to facilitate learning and personal growth. By providing opportunities for concrete experiences, reflection and active experimentation, the 3E framework can aid individuals in developing self-efficacy and the confidence to tackle new challenges.

Digital Material Design

Digital materials encompass a range of media and resources that are presented through electronic means, including web-based tools, projectors and computers (Howell & O'Donnell, 2017). While some of these materials are readily available, others are custom-designed by teachers. The development and effective utilisation of these materials are taught to pre-service teachers at the education faculty of a state university in Türkiye as part of their education in instructional technologies and material development skills within the curriculum of the Instructional Technologies and Material Design Course (Bediroğlu, 2021).

The current era revolves around the internet and computers, with digital applications becoming increasingly integrated into daily life and transforming the communication styles of the masses. Digital learning materials offer educational opportunities that surpass those provided by traditional face-to-face teaching methods (Zwart et al., 2020). Therefore, teachers need to possess skills related to information and communication technologies, including media and digital literacy, in order to provide enriching experiences for their students. Teachers should also take into account the needs and interests of their students, while keeping abreast of the evolving understanding of play and entertainment among the new generation. In recent years, children and young people have shown a preference for digital games over traditional games (Yaralı, 2024). Given that the younger generation today is adept in the digital realm, it is important for teachers to understand that digital games can be incorporated into teaching environments, and to recognise the positive impact of such materials on cultivating skills such as problem-solving, rapid and precise decision-making, and strategic thinking (Hazar et al., 2017).

Significance and Purpose of the Study

In the era of digital education, it has become evident, particularly through experiences during the pandemic, that educational activities transcend the limitations of time and space, becoming integrated with technology. Teaching in the digital environment demands extensive preparation from educators. Considering the rapid technological advancements worldwide, the presence of technology in education creates a need for teachers to enhance their skills

in this domain and adapt to evolving educational practices. Consequently, the use and development of digital teaching materials by teachers play a pivotal role in the process of technology integration. Numerous studies have explored the self-efficacy of teachers and pre-service teachers in using digital materials in both Western and Asian contexts (Beardsley et al., 2021; Bediroğlu, 2021; Donmez-Usta et al., 2020; Kim & Lee, 2022; Nordén et al., 2017; Zwart et al., 2020). However, there has not yet been a thorough assessment of self-efficacy specifically concerning digital teaching among PSSTs, which has the potential to provide valuable insights. The present study aims to identify the need for teacher training programmes focusing on digital competencies, especially the utilisation of digital material design. It specifically seeks to investigate the impact of an instructional technologies course based on the development and use of digital materials on the digital material self-efficacy of PSSTs. Based on this aim, the research questions (RQ) are formulated as follows:

- RQ₁: What is the impact of an intervention programme based on digital material design on PSSTs' general digital material self-efficacy?
- RQ₂: What is the impact of an intervention programme based on digital material design on the "development" dimension of PSSTs' digital material self-efficacy?
- RQ₃: What is the impact of an intervention programme based on digital material design on the "design" dimension of PSSTs' digital material self-efficacy?
- RQ₄: What is the impact of an intervention programme based on digital material design on the "negative views" dimension of PSSTs' material self-efficacy?

Method

Participants

The population of the research consisted of PSSTs studying at the education faculty of a state university in Türkiye. The sample comprised 31 PSSTs who were studying science education at the sophomore level and were preparing to teach at the middle school level (grades 5–8). Participants were selected using convenience sampling, which involves studying individuals who are readily accessible to the researchers (Fraenkel & Wallen, 2009). The study was conducted at the university where the researchers are employed, which limited access to a broader or more diverse participant pool. Of the participants, 24 were female and 7 were male, indicating a notable gender imbalance. Although

this distribution reflects the general gender composition of science education programmes in Türkiye, it may have influenced the findings, and it limits the extent to which the results can be generalised across genders. Additionally, the relatively small sample size restricts the statistical power of the analyses and further constrains the generalisability of the results, despite the reported reliability and validity of the measurement instrument.

Data Collection Tool

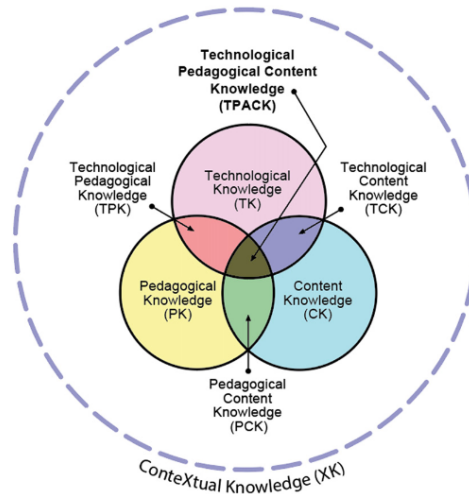
The research data were collected using the Self-Efficacy Scale of Teachers' Digital Teaching Material Development developed by Korkmaz et al., (2019), which is a five-point Likert type scale consisting of 38 items under three factors. The first factor is "Development" and consists of 14 items (sample item: "I can create graphics, shapes and objects that are appropriate to the goals and learning outcomes using Web 2.0 software"); the second factor is "Design" and consists of 18 items (sample item: "I can design the material according to the student's needs"); and the third factor is "Negative View" and consists of 6 items (sample item: "I struggle to design digital teaching materials according to visual design principles"). The Negative View sub-dimension refers to pre-service teachers' perceived difficulties, time-related concerns and self-doubt regarding the development and instructional use of digital teaching materials. Previous researchers reported the Cronbach Alpha reliability coefficient of the scale as 0.961. In the present study, the reliability coefficient of the scale was calculated as 0.94 for Development, 0.92 for Design, 0.82 for Negative View, and 0.95 for the whole scale. Confirmatory factor analysis of the Self-Efficacy Scale of Teachers' Digital Teaching Material Development yielded acceptable goodness of fit indices (Chi-Square/ df = 1.40; RMSEA = 0.081; CFI = 0.90; IFI = 0.90).

Data Collection Process

The research data were collected within the scope of the Instructional Technologies course, in which the TPACK framework is adopted. The TPACK framework is often used in the design of digital materials for educational purposes. A revised version of the TPACK model is presented in Figure 2.

Figure 2

Revised version of the TPACK model (Mishra, 2019)



TPACK can help designers to create effective digital learning materials that integrate technology, pedagogy and content knowledge. The TPACK framework helps designers to identify the digital tools and resources that can support learning and teaching; to determine how to use these tools effectively in teaching; to understand how to design digital materials that are aligned with the learning goals and subject matter; and to use pedagogical strategies that can enhance learning through the use of technology (Archambault & Barnett, 2010). In line with this definition, in the first seven weeks of the Instructional Technologies course, the instructor explained the subjects and concepts related to instructional technologies to the PSSTs. In these weeks, the course covered teaching principles, ASSURE and ADDIE instructional design models (instructional design models that guide teachers in systematically planning, implementing and evaluating instruction, with ASSURE emphasising learner analysis and technology integration at the lesson level, and ADDIE providing a broader framework for course or programme design); teacher competencies to use instructional technology; visual design elements; visual design principles; teaching material preparation principles; Web 2.0 tools to create a presentation, concept map, mind map, concept cartoon, puzzle, worksheet or video; and instructional material evaluation forms. The PSSTs were divided into groups of 4–5 people and each group determined a subject from the middle school (grades 5–8) science curriculum and the objectives of this subject. They then

prepared digital materials determined by the instructor for each objective, with each group producing worksheets, puzzles, mind maps, concept maps, concept cartoons and videos on a weekly basis. These materials were selected because they reflect commonly used digital teaching materials in science education and align with curriculum requirements at the middle school level. In the 15th week of the course, for example, the PSSTs prepared a video for the objective “*Explain the functions of the structures of organs belonging to the digestive system using models*”, whereas they chose to prepare a concept cartoon for the objective “*Realise that food must undergo physical and chemical digestion to pass into the blood*” in the 14th week. Thus, the PSSTs made a pedagogical decision by determining the objectives for appropriate digital material. In addition, they were asked to write a lesson scenario showing how they would use the material they had prepared in an imaginary classroom setting. With these scenarios, the instructor aimed to increase the PSSTs’ awareness of using appropriate teaching methods and techniques for the subject. Thus, technology, pedagogy and science content knowledge was integrated in accordance with the TPACK framework. The PSSTs were given one week for each objective, during which time they prepared the selected material and devised a lesson scenario showing how they would use the material in an imaginary classroom environment. The materials and scenarios were examined by the instructor and the other participating PSSTs and feedback was provided. The instructor reviewed the materials through formative assessment, the purpose of which was to support the PSSTs’ learning and improvement rather than to generate grades or quantitative scores. Feedback was provided by the instructor based on alignment with instructional objectives, appropriateness of the selected Web 2.0 tools and pedagogical coherence. The PSSTs then gave their products their final form according to the feedback they had received. For example, in the 15th week, all of the groups came to class with a video of at least three minutes duration about the science topic they had chosen. All of the groups watched and evaluated the videos and feedback was given by the instructor and the PSSTs in the other groups. Later, all of the groups revised their videos according to the feedback they had received and gave their material its final form. This cycle lasted for seven weeks in total, with each group preparing a total of seven items of digital material, one per week. The intervention lasted a total of 16 weeks. Intervention fidelity was maintained by ensuring that the course was delivered by the same instructor throughout the 16-week intervention, following a predefined weekly plan aligned with the instructional objectives. No external observers or interrater reliability procedures were employed, as the intervention focused on formative learning processes rather than summative evaluation; however,

consistency was supported through standardised instructional materials, recurring task structures and uniform feedback criteria applied to all of the participants. Information about the scope of the course is presented in Table 1.

Table 1

Intervention and data collection process

Period	Weeks	Focus
Pre-intervention	Week 1	Course introduction and administration of the pretest
Intervention	Weeks 2-7	Instruction on basic teaching principles, instructional design models (ASSURE, ADDIE), teacher competencies in instructional technology, visual design principles, Web 2.0 tools and instructional material evaluation
Mid-intervention assessment	Week 8	Mid-term examination
Intervention (practice & feedback)	Weeks 9-15	Development, presentation and formative feedback on instructional materials (presentations, worksheets, puzzles, mind maps, concept maps, concept cartoons and videos)
Post-intervention	Week 16	Administration of the posttest

Data Analysis

The research data were analysed using descriptive and inferential statistics, facilitated by the SPSS-22 software package. Skewness and kurtosis values were calculated to check the normality assumption. For inferential statistics, a paired samples t-test was used to test whether the intervention based on digital material design had enhanced the PSSTs' digital material self-efficacy.

Research Design

The research adopted a one-group pretest-posttest experimental design of the quantitative research method, whereby a single group is measured both before and after being exposed to a treatment of some kind (Fraenkel & Wallen, 2009). The absence of a control group constitutes a significant methodological limitation. However, the use of a control group was not feasible due to institutional constraints, including the limited availability of PSSTs, as well as ethical considerations related to withholding instructional experiences from a comparison group. Accordingly, the findings should be interpreted with caution, as causal inferences regarding the effectiveness of the intervention based on digital material design cannot be made with certainty.

Results

In order to answer the research questions (RQ1–RQ4), skewness and kurtosis values were first calculated to test whether the pre-digital material self-efficacy (Pre_DMSE) and post-digital material self-efficacy (Post_DMSE) scores were normally distributed for the total DMSE scores and for the scores of each dimension. In the normality analysis, the kurtosis and skewness values for the pretest and posttest scores were within the acceptable range for each dimension as well as for the overall scale. The results obtained are presented in Table 2.

Table 2

Descriptive statistics for pretest and posttest DMSE

		Pre_Total	Post_Total	Pre_Develop	Post_Develop	Pre_Design	Post_Design	Pre_Negative	Post_Negative
<i>N</i>	Valid	31	31	31	31		31		31
	Missing	0	0	0	0		0		0
Mean		121.10	133.48	43.55	51.55	61.26	64.97	16.29	16.97
Median		120.00	130.00	44.00	49.00	62.00	63.00	16.00	17.00
Mode		109	121	42 ^a	45	54	54	12 ^a	18
Skewness		-.543	.876	-1.168	.721	-1.031	.945	.639	-.306
Kurtosis		1.277	-.086	2.032	-.532	1.800	.030	1.059	.565

a. Multiple modes exist. The smallest value is shown

Table 2 indicates that the skewness and kurtosis values are between -2 and +2 for almost all of the scores. There is only a little violation in the pretest scores of the Develop sub-dimension, but it is thought to be tolerable. Therefore, all of the scores are accepted to be distributed normally, thus meeting the normality assumption for the parametric tests. Hence, the paired sample t-test as a parametric test is used to compare the pretest and posttest scores for each sub-dimension for the overall DMSE scores of the PSSTs. Within the scope of inferential statistics, a paired samples t-test was conducted to test whether the intervention based on digital material design enhanced the PSSTs' overall digital material self-efficacy (RQ1) as well as its sub-dimensions, namely Development (RQ2), Design (RQ3) and Negative Views (RQ4). The results addressing RQ1–RQ4 are presented in Table 3.

Table 3

Comparison of pretest and posttest results for the sub-dimensions and overall DMSE

	Paired Differences			<i>t</i>	<i>df</i>	Sig.	Cohen <i>d</i>
	Mean	<i>S.D.</i>	<i>S.E.</i>				
Pre_Post_Develop	-8.00	14.95	2.69	-2.98	30	.006	0.54
Pre_Post_Design	-3.71	14.09	2.53	-1.47	30	.153	0.26
Pre_Post_Negative	-.68	6.35	1.14	-.59	30	.557	0.11
Pre_Post_Total	-12.39	26.61	4.78	-2.59	30	.015	0.47

S.D.: Standart Deviation, *S.E.*: Standard Error, *Sig.*: Significance

As presented in Table 3, the paired samples t-test results addressing **RQ2** reveal a notable difference between the pretest and posttest scores in the Development sub-dimension of the DMSE, in favour of the posttest. The effect size indicates a moderate practical impact ($d = 0.54$), suggesting that the intervention based on digital material design had a meaningful influence on the PSSTs' self-efficacy related to digital material development.

With respect to **RQ1**, the analysis of the total DMSE score also demonstrates a statistically significant improvement from pretest to posttest, accompanied by a moderate effect size ($d = 0.47$). This finding indicates that the intervention significantly enhanced the PSSTs' overall digital material self-efficacy.

In contrast, the results addressing **RQ3** and **RQ4** indicate that no statistically significant differences were found between pretest and posttest scores in the Design and Negative View dimensions of the DMSE. Accordingly, the intervention did not lead to a significant improvement in the PSSTs' digital material self-efficacy related to design, nor did it significantly alter their views towards digital material design.

Discussion

The present study was conducted to investigate the impact of an intervention based on digital material design on the digital material self-efficacy of PSSTs. The findings indicate that the intervention programme, which involved active preparation of digital materials by pre-service teachers, had a partial effect on their digital material self-efficacy. While the programme significantly increased the participating PSSTs' self-efficacy in digital material development and their overall self-efficacy regarding digital materials, it did not have a significant effect on their self-efficacy in digital material design and their views

on digital materials. Several factors may account for this outcome, warranting a detailed examination of the intervention's effectiveness and areas where improvement may be needed.

The intervention's notable positive impact on the PSSTs' material development self-efficacy can be attributed to Kolb's 3E learning framework. According to this framework, students acquire new knowledge and skills through experiences, gain meaning through reflection on these experiences, and test the resulting concepts and ideas (Kolb, 1984). Following these characteristics of Kolb's model, the PSSTs received theoretical information on material development during the initial phase of the intervention. Subsequently, they actively engaged in developing digital materials using this information and received feedback from the instructor, which they utilised to refine their materials. This process incorporated the experience, exploration and explanation stages of Kolb's model, leading to the development of the PSSTs' material development self-efficacy. This result aligns with Bandura's self-efficacy theory, according to which positive experiences with a phenomenon increase self-efficacy towards that phenomenon (Bandura, 1977; Pajares, 2002). Consequently, experiences gained through active participation in digital material development positively impacted the PSSTs' self-efficacy. Similar findings are supported in the literature; for instance, studies have shown that student-centred practices contribute to enhanced self-efficacy beliefs (Onbaşılı, 2020), and intervention programmes can lead to increased self-efficacy and reduced resistance to digital material development among teachers (Kardemir, 2018).

The intervention programme had a positive effect on the PSSTs' general self-efficacy regarding digital materials. The observed increase in overall self-efficacy scores was primarily driven by significant gains in the Development sub-dimension, while no statistically significant differences were found in the Design and Negative View sub-dimensions. Nevertheless, stability in these dimensions also contributed to the enhancement of general digital material self-efficacy. Previous research shows that self-efficacy significantly increases when learners actively design, create or adapt digital materials. Participants involved in hands-on, problem-based and design-oriented digital tasks reported higher gains in perceived competence and confidence compared to those who primarily consumed digital content (Lucas et al., 2021). Similarly, the PSSTs participating in the present study actively developed digital materials and implemented them through teaching scenarios. This resulted in an improvement in their digital materials self-efficacy, both in general and in the developmental dimension.

Previous studies have reported increases in pre-service and in-service teachers' self-efficacy following interventions focused mainly on the use or

technical design of digital materials (e.g., Horzum, 2013; Sánchez-García et al., 2020; Tanrikulu, 2021). However, these studies generally did not explicitly address digital teaching self-efficacy as a pedagogically grounded construct, nor did they systematically integrate instructional design, formative feedback and reflective practice into the intervention process. In contrast, the present study specifically aimed to fill this gap by employing a structured, semester-long intervention that combined instructional design models, digital material development and iterative feedback, thereby contributing to a more comprehensive understanding of how digital teaching self-efficacy can be developed beyond technical proficiency alone. This is a valuable outcome especially when considering the fact that teachers need to have a high level of self-efficacy belief in order to be successful in their profession (Kızılkapan et al., 2024). Hence, teachers' positive experiences with digital tools have the potential to impact colleagues, students and other individuals, and are therefore strongly endorsed by policy makers (Kim & Lee, 2022).

However, the present intervention programme did not yield a statistically significant improvement in the PSSTs' self-efficacy in designing digital materials. Rather than reflecting a simple lack of effectiveness, this outcome may stem from multiple interacting factors related to implementation, measurement and contextual conditions.

From an implementation perspective, the instructional emphasis appears to have been placed primarily on the pedagogical and didactic affordances of digital materials rather than on the iterative design process itself. While this focus aligns with the goal of improving instructional quality, it may have inadvertently limited opportunities for the PSSTs to engage in creative decision-making, experimentation and reflection, which are key components of design self-efficacy (Higbee et al., 2025). Moreover, the absence of external observers or fidelity checks restricts the ability to determine whether the intervention was enacted consistently across sessions, or whether unintentional instructor effects shaped the participants' learning experiences. The lack of observed impact may reflect limitations in how the intervention was operationalised rather than in its theoretical foundation.

An alternative explanation relates to the measurement of design self-efficacy. It is possible that the instrument used was insufficiently sensitive to capture subtle or emerging changes in the PSSTs' confidence, particularly given their limited prior experience with digital material design. Design self-efficacy is a complex and domain-specific construct that may require prolonged practice and repeated feedback to manifest measurable change (Chien et al., 2022). Thus, the intervention duration or assessment timing may not have been

adequate for such changes to be reflected quantitatively.

Additionally, the PSSTs' novice status in digital material design likely functioned as a confounding factor. The participants may have relied heavily on the instructor's exemplars as models, which, while supportive, may have constrained autonomous design thinking. This reliance can lead to surface-level replication rather than the development of internalised design competence and confidence. In this sense, high-quality modelling may paradoxically suppress self-efficacy growth if not accompanied by explicit scaffolding for independent experimentation and risk-taking.

Contextual and cultural factors also warrant deeper consideration. In examination-oriented and performance-driven educational cultures, such as those common in many teacher education contexts, students often prioritise course completion and grade attainment over creative exploration. This orientation may discourage risk-taking and innovation, particularly in tasks perceived as technically demanding or evaluatively consequential. As a result, the PSSTs in the present study may have adopted conservative design strategies aimed at meeting minimum course requirements rather than exploring novel uses of Web 2.0 tools. This tendency aligns with prior research indicating that assessment-focused motivation can negatively affect creativity and design confidence (Donmez-Usta et al., 2020).

Furthermore, individual psychological factors – including stress, anxiety and fear of failure – may have moderated the intervention's impact. Designing digital materials requires not only technical knowledge but also emotional readiness to cope with uncertainty and potential failure. As noted by Lee (2009), individuals' mental states can substantially influence their perceptions and responses to instructional interventions. Without structured emotional and motivational support, such affective barriers may have limited the PSSTs' willingness to engage deeply with the design process.

Taken together, these findings suggest that the non-significant change in negative views and design dimensions should not be interpreted as evidence that the intervention was ineffective. Rather, it highlights the need for future interventions in order to more explicitly foreground design-oriented learning outcomes, incorporate fidelity monitoring, use sensitive and multidimensional assessment tools, and address cultural and affective factors that shape pre-service teachers' engagement with digital material design. Integrating reflective design cycles, peer critique and low-stakes creative tasks may be particularly important for fostering both confidence and creativity in digital material development.

Conclusion

The results of the present research highlight the need for future instructional technologies courses to explicitly differentiate between material development and design competencies. While guided modelling and structured tasks appear effective for strengthening development-related self-efficacy, design self-efficacy may require instructional strategies that emphasise iterative design cycles, learner autonomy, peer feedback and opportunities for low-stakes experimentation. Without such elements, pre-service teachers may prioritise functional completion over creative exploration.

Several limitations should be considered when interpreting the findings. The use of a single-group experimental design limits causal inference, while the scope of the materials and digital tools was restricted to a predefined set aligned with course requirements. In addition, the findings reflect the context of a single teacher education programme in Türkiye and should not be generalised beyond similar contexts without exercising caution.

Based on these limitations, future research should employ controlled or mixed-method designs to better isolate intervention effects and explore how specific instructional features (e.g., design-focused scaffolding, feedback mechanisms or assessment practices) influence design self-efficacy. Expanding the range of digital tools and incorporating qualitative data may also provide deeper insight into pre-service teachers' design processes and beliefs. From a practical perspective, teacher educators are encouraged to balance technical guidance with structured opportunities for creativity and risk-taking, thereby supporting more holistic development of digital material competencies.

In summary, the present study contributes to the growing body of research on technology integration in teacher education by demonstrating that interventions can enhance certain dimensions of digital material self-efficacy, while also underscoring the need for more design-centred approaches in order to foster comprehensive professional competence.

Ethical Statement

This study was conducted in accordance with institutional and national ethical guidelines. The research study was approved by the Nevşehir Hacı Bektaş Veli University Ethical Research Committee (Approval No: 2025.07.254). Participation was voluntary, and informed consent was obtained from all of the participants prior to data collection. The participants were assured of confidentiality and anonymity, informed of their right to withdraw at any time without

penalty and assured that no identifying information was collected. The study posed no physical or psychological risk to the participants.

Data Availability Statement

The data supporting the findings of this study are available in the Zenodo repository and can be accessed at <https://doi.org/10.5281/zenodo.18923065>.

Disclosure Statement

The first author was responsible for the study's conceptualisation and design, and also conducted the intervention, while the second author contributed to the study design and manuscript writing. Both of the authors read and approved the final manuscript. This research did not receive any specific funding. The authors declare that they have no conflicts of interest related to this study.

During the preparation of this article, the authors used ChatGPT and Web of Science Research Assistant on 15 January 2025 and 19 May 2025 to support language editing and literature exploration. The prompts used with these tools included the following requests: "Improve the academic clarity and grammar of this paragraph", "Revise this text for coherence and formal tone" and "Identify relevant literature and summarize key themes related to digital material design/self-efficacy". All of the outputs generated by these tools were carefully reviewed, verified and substantially revised by the authors. The authors take full responsibility for the accuracy, integrity and final content of the manuscript.

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