

Curriculum Literacy in the Digital Age: Enhancing Pre-Service Teachers' Competence through Digital Literacy

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Curriculum literacy is a core professional competence that enables pre-service teachers to interpret curricula accurately and translate curricular objectives into effective instructional practices. In digitally mediated learning environments, this competence may also support the purposeful use of digital technologies. This study examined the mediating role of digital literacy in the relationship between pre-service teachers' curriculum literacy and their competence in designing instruction in digital environments. Using a relational survey design, data were collected from 314 fourth-year pre-service teachers enrolled at two state universities in Türkiye. The Curriculum Literacy Scale, Digital Literacy Scale, and Competence Scale for Designing Instruction in Digital Environments were used as data collection instruments. Structural equation modelling was conducted using the robust maximum likelihood estimator, and indirect effects were tested through bootstrapping with 2,000 samples. The findings showed that curriculum literacy significantly predicted competence in designing instruction in digital environments and digital literacy. Digital literacy also significantly mediated the relationship between curriculum literacy and digital instructional design competence ($\beta = .261$, 95% CI [.188, .355]). Gender and GPA did not significantly predict digital instructional design competence. Overall, the findings indicate that curriculum literacy contributes to pre-service teachers' competence in designing digitally supported instruction both directly and indirectly through digital literacy. Teacher education programmes should therefore integrate curriculum literacy and digital literacy in a coordinated manner to strengthen pre-service teachers' capacity to design curriculum-aligned digital learning environments.

Introduction

In today's rapidly changing and digitalizing world, it is of critical importance that education systems prepare individuals in line with the requirements of the era. In this context, the competencies that teachers must possess in the 21st century have become a significant research topic in the field of educational sciences. The central role that teachers play in enhancing the quality of education and in preparing individuals to meet the expectations of

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contemporary society is widely acknowledged in the literature (Darling-Hammond, 2017). Moving beyond traditional educational paradigms, the training of teachers who possess the knowledge, skills, and competencies required by the digital age is considered a key factor in the transformation of education systems (Haleem et al., 2022; Timotheou et al., 2023).

The rapid advancements in information and communication technologies (ICT) have led to radical changes in educational processes, necessitating a redefinition of teachers' professional competencies (McCarthy et al., 2023; Mishra & Koehler, 2006). In this regard, the Technological Pedagogical Content Knowledge (TPACK) model provides a comprehensive framework that enables teachers to interactively utilize content knowledge, pedagogical knowledge, and technological knowledge (Mishra & Koehler, 2006). The TPACK model guides teachers in effectively integrating technology into their instructional processes and plays a critical role in the design of teacher education programs (Nguyen et al., 2022; Voogt & McKenney, 2016). Recent studies have shown that teacher education practices based on the TPACK model positively impact teacher candidates' self-efficacy perceptions regarding technology and their instructional design skills (Çam & Koç, 2024).

One of the fundamental competencies teachers need to possess in the digital age is digital literacy. Digital literacy is defined as the ability of individuals to acquire, analyze, interpret, and generate new information using digital technologies (Martin, 2006). Digital literacy enables teachers to effectively utilize digital tools and educational materials within a pedagogical context, thereby directly contributing to student learning processes (Çetin & Türkan, 2022). Research has demonstrated that the integration of digital instructional materials into educational processes enhances students' academic achievement, critical thinking skills, attitudes toward learning, and motivation (Hürsen & Baş, 2019; Partovi & Razavi, 2019; Syawaludin, Gunarhadi, & Rintayati, 2019; Şahin, 2021; Tamimi, 2024; Walter, 2024).

Studies on the digital literacy levels of teacher candidates indicate that variables such as gender, type of educational program, socio-economic status, and prior technology experience play a decisive role in digital skill development (Aslan, 2021; Tor, Demir Başaran & Arık, 2022). Therefore, it is emphasized that teacher education programs should include structured content aimed at enhancing digital pedagogical competencies while considering individual differences (Basilotta-Gómez-Pablos et al., 2022; Süzer & Koç, 2024).

In terms of instructional design skills in digital learning environments, teachers must possess not only digital literacy but also curriculum literacy competencies (Erdem & Eğmir, 2018). Curriculum literacy is defined as the ability of teachers to comprehend the curriculum, effectively organize content, and develop instructional strategies aligned with curriculum objectives in contemporary educational settings. Accordingly, aligning digital environments with curriculum objectives will make learning processes more effective (Wash, 2014). The Learning Design Model supports the development of learning environments aligned with curriculum objectives by providing a framework that assists teachers in consciously and systematically designing technology-supported instructional environments (Dalziel, 2015; Darling-Hammond et al., 2019).

Examining the processes by which teachers adopt digital tools, the Technology Acceptance Model (TAM) provides an important theoretical framework that explains how factors such as perceived ease of use and perceived usefulness influence teachers' attitudes toward and tendency to adopt technology (Davis, 1989). Research has shown that teachers' self-efficacy

perceptions, professional support mechanisms, and institutional infrastructure are key determinants in the process of adopting digital technologies (Paetsch, Franz & Wolter, 2023; Teo, 2011).

Furthermore, the Digital Competence Framework (DigCompEdu) identifies the competencies teachers need to successfully integrate digital tools into their teaching processes and categorizes these competencies to allow teachers to assess their development (Redecker, 2017). The DigCompEdu framework helps teachers evaluate their digital pedagogical skills within a six-level development model, ranging from "Newcomer" to "Pioneer" (Bayrak-Karlı et al, 2023; Süzer & Koç, 2024).

The COVID-19 pandemic, in particular, has underscored the critical role of teachers' digital literacy and curriculum literacy competencies in educational processes (Aslan et al., 2025; García-Peñalvo et al., 2020). During the pandemic, teachers encountered various challenges in adapting curriculum objectives to digital environments and effectively utilizing digital tools in remote education (Sing Yun, 2023; Wohlfart & Wagner, 2024). In this context, current research emphasizes the need for structured training programs aimed at enhancing teachers' digital pedagogical competencies (Arstorp, Olofsson & Lindberg, 2024).

In conclusion, this study aims to examine the mediating role of digital literacy in the relationship between teacher candidates' curriculum literacy and their competence in instructional design in digital environments. By contributing to the development of a theoretical model based on TPACK, TAM, the Learning Design Model, and the DigCompEdu framework, this study seeks to provide significant insights for teacher education.

Conceptual Framework

Curriculum Literacy

Curriculum literacy is one of the fundamental skills for teachers and pre-service teachers in the twenty-first century. It encompasses teachers' ability to know the curriculum and its content, accurately understand the curriculum content, formulate a curriculum plan and implement it according to its principles (Arslan & Gürlen, 2019). Aslan (2019) offers a broader perspective on curriculum literacy, defining it as the ability to understand the structure of a curriculum, analyze the relationships among its core components (objectives, content, instruction, and assessment), and evaluate their coherence in relation to contemporary needs and cultural context. Curriculum literacy refers to the knowledge, skills and understanding required for teachers or pre-service teachers to effectively orchestrate and carry out processes such as planning, implementation, evaluation and redesign of the educational process (Arslan & Gürlen, 2019; Aslan, 2019). This concept entails teachers not only organizing course content based on learning objectives but also designing instruction while considering students' various learning styles, differences, cultural characteristics and needs. It also includes grasping the curriculum's purpose, objectives, content, methods and evaluation strategies among the variables affecting the teaching process and acting accordingly (Ornstein & Hunkins, 2017; Bolat & Baş, 2023).

Teachers must understand the designing principles curriculum or be curriculum literate to effectively implement it (Ornstein & Hunkins, 2017). Curriculum literacy ensures that the objectives of the curriculum are met and the quality of education increases (Aslan, 2019). A good curriculum fosters students' cognitive, emotional and social development by providing



them with engaging, meaningful and immersive learning experiences (Aslan, 2019; Ornstein & Hunkins, 2017; Bolat & Baş, 2023). Therefore, teachers must possess curriculum literacy to achieve learning objectives in the classroom and maximize students' learning processes. Without a solid understanding and implementation of the curriculum, teachers may struggle to achieve success in their teaching processes (Bolat & Baş, 2023). Thus, curriculum literacy serves as a significant competency for teachers (Bolat, 2017; Bolat, & Baş, 2023). In this regard, teachers must have curriculum literacy skills during their pre-service training. By doing so, pre-service teachers can effectively implement training programs when they start working. Moreover, those who start their careers by gaining curriculum literacy skills can help students understand the objectives of the curriculum, thus nurturing individuals with 21st-century skills. Pre-service teachers with curriculum literacy skills may also contribute to making informed decisions in their teaching practices to promote effective and permanent learning. In this respect, providing pre-service teachers with curriculum literacy skills should be an important part of teacher training programs. This will help them manage the teaching process more effectively and efficiently. Curriculum literacy has the potential to not only boost the ability to manage the instructional process effectively and efficiently but also enrich students' learning experiences and support their cognitive, emotional, and social development. Therefore, teacher training programs should employ diverse strategies and methods to equip pre-service teachers with this skill.

Digital Literacy

One of the roles expected from individuals in the 21st century is to have digital literacy skills. The concept of digital literacy became widely popular following Paul Gilster's book "Digital Literacy", with its emphasis on information access and information management (Bawden, 2001). Digital literacy refers to the digital skills and knowledge required to operate and use computers and the internet, communicate and engage with others through these media, create content in various digital forms, and function in an information and knowledge-based society (Lee, 2014, p. 30). It involves an array of elements such as creativity, critical thinking and evaluation, functional skills, collaboration, the ability to access and choose information, effective communication, e-safety, and cultural and social awareness (Payton & Hague, 2010). Thanks to digital literacy, cognitive-emotional-social skills are combined with technical processes, necessitating a continuous pursuit of the latest educational innovations (Karabacak & Sezgin, 2019, p. 328). Teachers have a significant responsibility for achieving this. They must be digitally literate to impart this skill to individuals. Teachers should receive training in digital literacy during their pre-service training. When pre-service teachers acquire this skill during the pre-service training period, they gain knowledge about the integration of digital teaching materials with the curriculum objectives. Hence, they are better prepared to design an effective teaching environment when they start working.

Enhancing pre-service teachers' digital literacy skills is one of the significant issues for elevating the quality of the teaching profession. It is a necessary skill for teachers to access information, transform it into a format suitable for student comprehension, and use information and communication technology tools to facilitate this process. Teacher training programs should offer pre-service teachers skills on how to integrate and apply digital technologies into curricula. Pre-service teachers acquiring these skills can design teaching effectively in digital environments when they commence their careers.

Designing Instruction in Digital Environments

Today's education systems are evolving to use digital teaching materials in teaching processes. New technological systems and tools are spreading rapidly in direct proportion to the advancements in educational technology and are used for the benefit of educational activities (Joo, Bong & Choi, 2002). In contemporary educational settings, there is a growing emphasis on conducting classroom instructional activities in digital environments rather than printed resources. Studies indicate that instructional activities designed in digital environments provide students with engaging and effective learning opportunities (Bhattacharya & Mohalik, 2020; Coutinho, 2008; Smaldino, Lawther & Mims, 2015).

Digital environments offer students active learning environments that foster collaboration, sharing and production skills (Clements & Boyle, 2018). Designing instruction in digital environments is critical for pre-service teachers to transfer information to students more effectively. This requires pre-service teachers to understand the pedagogical potential of digital technologies and effectively integrate these technologies into their teaching processes. In this way, they can ensure that students comprehend information thoroughly and utilise it effectively.

The use of digital environments in education is of critical importance for teachers of the twenty-first century. Digital technologies facilitate access to information, help students take charge of their learning, and offer teachers opportunities to personalise and diversify learning experiences. Implementing the curriculum in digital environments may enhance teachers' ability to convey teaching objectives to students more effectively. Besides, implementing the curriculum in digital environments holds the potential to provide students with richer and more diverse learning experiences. To illustrate, teachers can engage students in solving real-world problems and create and share knowledge using digital tools. This may support students' long-term learning and their cognitive, emotional, as well as social development. In this regard, digital literacy is likely to have a mediating role in ensuring that pre-service teachers are competent in imparting the curriculum objectives in digital teaching settings.

Current Study

The integration of digital technologies into educational settings has significantly transformed instructional design and delivery processes, necessitating that educators possess both pedagogical expertise and digital literacy competencies. In contemporary educational landscapes, digital learning environments serve as critical platforms for curriculum implementation, underscoring the imperative for teachers to demonstrate a high level of curriculum literacy. Curriculum literacy equips educators with the ability to design instructional strategies that align with curriculum objectives while effectively leveraging digital tools. However, the extent to which pre-service teachers' curriculum literacy influences their competence in designing instruction within digital environments remains an underexplored area in the literature. Addressing this research gap is essential for optimising teacher preparation programs to ensure that prospective educators are proficient in utilising digital technologies within pedagogical frameworks.

Curriculum literacy encompasses the ability to define learning objectives, select appropriate instructional materials, structure pedagogical sequences, and evaluate educational outcomes (Aslan, 2019; Bolat, 2017; Keskin & Korkmaz, 2021). Simultaneously, digital literacy has emerged as an indispensable competency for educators, enabling them to effectively integrate technological tools into their instructional methodologies (Audrin & Audrin, 2022; Corbeil &

Corbeil, 2023). While previous research has underscored the significance of curriculum literacy in fostering instructional efficacy (Aslan, 2018; Marsh, 2009; Stabback, 2016), its direct and indirect effects on pre-service teachers' digital instructional design competencies remain insufficiently examined. A comprehensive investigation into these relationships would yield valuable insights for the enhancement of teacher education programs by integrating curriculum literacy and digital literacy as complementary pedagogical components.

Despite the increasing emphasis on digitalisation in education, a significant proportion of teacher education programs have yet to incorporate curriculum literacy training alongside digital literacy development fully. Extant research predominantly examines either curriculum literacy (Bolat & Baş, 2023; Erdem & Eǧmir, 2018) or digital literacy (Lee, 2014; León et al, 2023; Payton & Hague, 2010) as independent constructs, rather than investigating their interplay in the context of digital instructional design. Furthermore, although prior studies have highlighted the role of digital literacy in effective teaching practices (Shively & Palilonis, 2018; Özbay & Özdemir, 2014), empirical evidence concerning how pre-service teachers' curriculum literacy directly influences their digital literacy—and, in turn, their capacity to design instruction in digital environments—remains limited. This study aims to bridge this gap by investigating the mediating role of digital literacy in the relationship between curriculum literacy and instructional design competence within digital environments.

The theoretical framework of this study is informed by curriculum theory (Ornstein & Hunkins, 2017; Stenhouse, 1975) and digital literacy frameworks (Claro et al., 2018; Engeness, 2021). Stenhouse (1975) posits that a well-structured curriculum is a fundamental determinant of high-quality teaching environments. Similarly, Marsh (2009) and Stabback (2016) contend that teachers' curriculum literacy significantly influences their ability to design pedagogically effective learning experiences. In parallel, digital literacy frameworks emphasise the necessity of incorporating technological competencies into modern instructional practices (Bhattacharya & Mohalik, 2020; Smaldino, Lawther & Mims, 2015). By synthesising these theoretical perspectives, this study explores the intersection of curriculum literacy and digital literacy in shaping instructional design efficacy.

To address these research gaps, the present study formulates and examines the following hypotheses:

- **Hypothesis 1:** Pre-service teachers' curriculum literacy directly affects their competence in designing instruction in digital environments.
- **Hypothesis 2:** Pre-service teachers' curriculum literacy directly affects their digital literacy.
- **Hypothesis 3:** Pre-service teachers' curriculum literacy indirectly influences their competence in designing instruction in digital environments through their digital literacy.

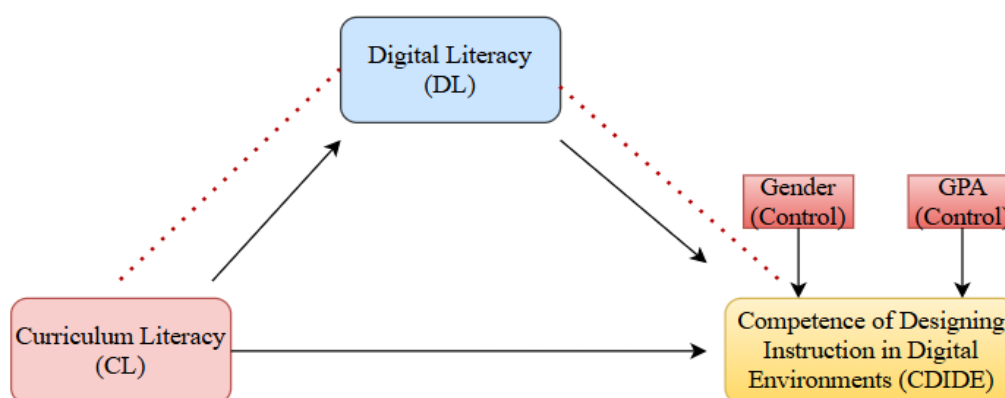


Figure 1. Proposed model

Figure 1 illustrates the hypothesised structural model of the study. In the model, curriculum literacy (CL) is proposed to have a direct effect on pre-service teachers' competence in designing instruction in digital environments (CDIDE), reflecting the assumption that the ability to interpret curriculum objectives, organise content, and align instructional and assessment processes supports effective digital instructional design. Curriculum literacy is also expected to directly predict digital literacy (DL), suggesting that pre-service teachers with stronger curriculum literacy may use digital tools more purposefully and pedagogically. In addition, digital literacy is positioned as a mediator in the relationship between curriculum literacy and CDIDE, indicating that curriculum literacy may contribute to digital instructional design competence indirectly by enhancing digital literacy. Gender and GPA are included as control variables to account for potential individual and academic differences in CDIDE.

Method

Research Design

This study adopted a relational survey design, one of the quantitative research approaches. Relational survey models are widely used in educational research to explore the relationships between variables and to predict their effects on one another (Creswell, 2012; Fraenkel, Wallen & Hyun, 2012). The primary aim of relational research is to investigate the direction and strength of relationships between variables or to make predictions about these variables (Mills & Gay, 2019). In this study, Structural Equation Modelling (SEM) was employed as the main analytical technique. SEM is particularly advantageous for understanding complex multivariate relationships, as it enables researchers to assess both direct and indirect effects (Kline, 2016). The choice of SEM aligns with the study's objective of examining the mediating role of digital literacy in the relationship between pre-service teachers' curriculum literacy and their competence in designing instruction in digital environments.

Participants

The participants of this study consisted of 314 pre-service teachers in their fourth year of study at two state universities. Convenience sampling was employed as the sampling method, as it allowed researchers to include participants who were easily accessible and

available within the universities where the study was conducted (Neuman, 2007). Fourth-year pre-service teachers were specifically chosen because they possess advanced knowledge of curriculum-related content and have completed most of the teaching courses relevant to their fields. This makes them suitable participants for a study investigating curriculum literacy, digital literacy, and instructional design competence.

The sample size of 314 participants was deemed sufficient for conducting SEM, based on the recommendations of Bentler and Chou (1987), who suggest a minimum sample size of 150 for SEM applications, and Hu and Bentler (1999), who recommend at least 250 participants for robust results. Among the participants, 233 (74%) were female, and 81 (26%) were male. In terms of academic focus, the sample was distributed as follows: 66 (21%) participants specialized in Turkish education, 63 (20%) in social studies education, 59 (19%) in mathematics education, 47 (15%) in science education, 35 (11%) in English language teaching, 25 (8%) in Arabic education, and 19 (6%) in classroom teaching. Furthermore, 194 (62%) participants had an academic GPA between 3.01 and 4.00, while 120 (38%) participants had a GPA between 2.01 and 3.00.

Data Collection Tools

Three validated and reliable scales were utilised to collect data in this study. Each scale was carefully chosen based on its relevance to the constructs being investigated.

Curriculum Literacy Scale: This scale, developed by Bolat (2017), measures pre-service teachers' curriculum literacy levels. It consists of 29 items divided into two subdimensions: "Reading" (15 items) and "Writing" (14 items). Sample items include statements like "I can identify the consistency of the objectives with each other" (Reading) and "I can write objectives tailored to the student's level" (Writing). The scale's reliability was demonstrated through Cronbach's alpha values of .88 for the Reading dimension, .90 for the Writing dimension, and .94 for the overall scale. Exploratory factor analysis revealed that the scale explained 43.05% of the total variance, with item loadings ranging from .405 to .839. Confirmatory factor analysis showed acceptable fit indices, indicating the scale's validity.

Digital Literacy Scale: Originally developed by Ng (2012) and adapted into Turkish by Üstündağ, Güneş, and Bahçivan (2017), this scale assesses pre-service teachers' digital literacy. It is a single-factor, 10-item scale with statements like "I can learn new technologies easily." The exploratory factor analysis for the Turkish version revealed that the scale explained 40% of the total variance, with factor loadings ranging from .46 to .74. The reliability of the scale was confirmed with a Cronbach's alpha value of .86.

Competence Scale for Designing Instruction in Digital Environments: This study utilised the "Competence of Designing Instruction in Digital Environments" subdimension of the "Pre-service Teachers' Digital Competence Perception Scale" developed by Karakuş, Sünbül, and Kılıç (2022). This 8-item scale measures pre-service teachers' abilities to design effective instruction in digital environments. Sample items include "I can apply measurement tools in digital environments." The scale's exploratory factor analysis indicated that it explained 41.37% of the total variance, with factor loadings ranging from .53 to .78. Reliability was confirmed with a Cronbach's alpha value of .90. Confirmatory factor analysis indicated acceptable fit indices.

Control Variables

The study included gender and academic achievement as control variables to account for their potential influence on the dependent variable. Gender was coded as Female = 0 and Male = 1, while academic achievement was coded as 2.00-2.99 = 0 and 3.00-4.00 = 1. These variables were included to provide a more nuanced analysis of the relationships between curriculum literacy, digital literacy, and instructional design competence.

Data Analysis

Data analysis was conducted using SPSS 30 and Mplus 8.1 software. The analysis process included descriptive statistics, correlation analysis, and SEM. Before analysis, the dataset was checked for missing values, outliers, and normality. No missing data or outliers were identified. The assumption of univariate normality was assessed by examining skewness and kurtosis values, which fell within the acceptable range of ± 3.0 (Kline, 2016).

Since Mardia's test indicated that the data did not meet the assumption of multivariate normality (Mardia skewness = 812.008, kurtosis = 3166.278, $p < .01$), the Robust Maximum Likelihood (MLR) estimator was used for parameter estimation. MLR is recommended for datasets that deviate from normality (Brown, 2015).

Correlation analysis was performed to examine the relationships between variables. Pearson correlation coefficients were interpreted based on Pallant's (2015) guidelines: values between .10 and .29 indicate low correlation, .30 and .49 indicate moderate correlation, and .50 and above indicate high correlation.

The SEM model fit was evaluated using multiple fit indices, including χ^2/df , RMSEA, SRMR, CFI, and TLI. A χ^2/df value of ≤ 5 , RMSEA and SRMR values of $\leq .05$, and CFI and TLI values of $\geq .90$ were considered indicative of a good fit (Hu & Bentler, 1999; Kline, 2016; Tabachnick & Fidell, 2013; Thakkar, 2020). Bootstrapping with 2000 samples was employed to calculate confidence intervals for direct, indirect, and total effects (Fritz & MacKinnon, 2007).

Findings

The study was conducted in three stages. Initially, descriptive statistics and reliability analysis results were analysed, followed by the correlation analysis results. Finally, the study estimated the direct and indirect relationships between pre-service teachers' curriculum literacy, their competencies in designing instruction in digital environments, and their digital literacy using SEM. Table 1 displays descriptive statistics and reliability values of the variables.

Table 1. Findings regarding descriptive statistics and reliability analyses of the variables

Variables	n	$\bar{X}$	sd	Skewness	Kurtosis	AVE	α	CR
Competence of Designing Instruction in Digital Environments	314	4.06	.68	-.736	.573	.64	.92	.93
Curriculum Literacy	314	4.08	.59	-.664	1.852	.51	.97	.96
Reading	314	4.12	.60	-.851	2.433	.50	.96	.93
Writing	314	4.02	.63	-.481	.909	.54	.95	.93
Digital Literacy	314	3.73	.61	-.300	.548	.77	.87	.90

Table 1 suggests that pre-service teachers' competencies of designing instruction in digital environments ($\bar{X} = 4.06$, $sd = .68$), the reading factor of curriculum literacy ($\bar{X} = 4.12$, $sd =$

.60), the writing factor ($\bar{X} = 4.02$, $sd = .61$), overall ($\bar{X} = 4.08$, $sd = .59$) and digital literacy ($\bar{X} = 3.73$, $sd = .61$) were noted to be high. The standard deviation values of the variables indicated a homogeneous distribution among the participants. Kurtosis values ranged between 2.433 and .548 and the skewness values ranged from -.300 and -.851, signifying normal distribution (Kline, 2016).

Cronbach's Alpha coefficient was examined to assess the reliability of the data, and all variables exhibited coefficients above .70, which indicates the reliability of the data (Pallant, 2015). This study also analysed the composite reliability coefficient (CR) and average variance extracted (AVE). Fornell and Larcker (1981) imply that the CR value should be .70 and above, while the AVE value should be .50 and above. Notably, both CR and AVE values surpassed these thresholds. Table 2 summarises the correlation coefficients between pre-service teachers' curriculum literacy, their competencies in designing instruction in digital environments, and their digital literacy levels.

Table 2. Findings on correlation analysis

Variables	CDIDE	R	W	DL
Competence of Designing Instruction in Digital Environments (CDIDE)	-			
Reading (R)	.53**	-		
Writing (W)	.52**	.87**	-	
Digital Literacy (DL)	.67**	.53**	.52**	-

** $p < .01$

As in Table 2, a highly positive and significant relationship was identified between the competencies of designing instruction in digital environments and both the reading factor ($r = .53$; $p < .01$) and the writing factor ($r = .52$; $p < .01$) of curriculum literacy. Besides, a strong positive and significant correlation was noted between the reading factor of curriculum literacy and both the writing factor ($r = .87$; $p < .01$) and digital literacy levels ($r = .53$; $p < .01$). Additionally, Table 2 highlights a highly positive and significant correlation between digital literacy and the writing factor of curriculum literacy ($r = .52$; $p < .01$).

In the last stage of the study, the mediating role of digital literacy in the relationship between pre-service teachers' curriculum literacy and their competencies in designing instruction in digital environments was explored through the use of SEM. Structural relationships between variables are illustrated in Figure 2.

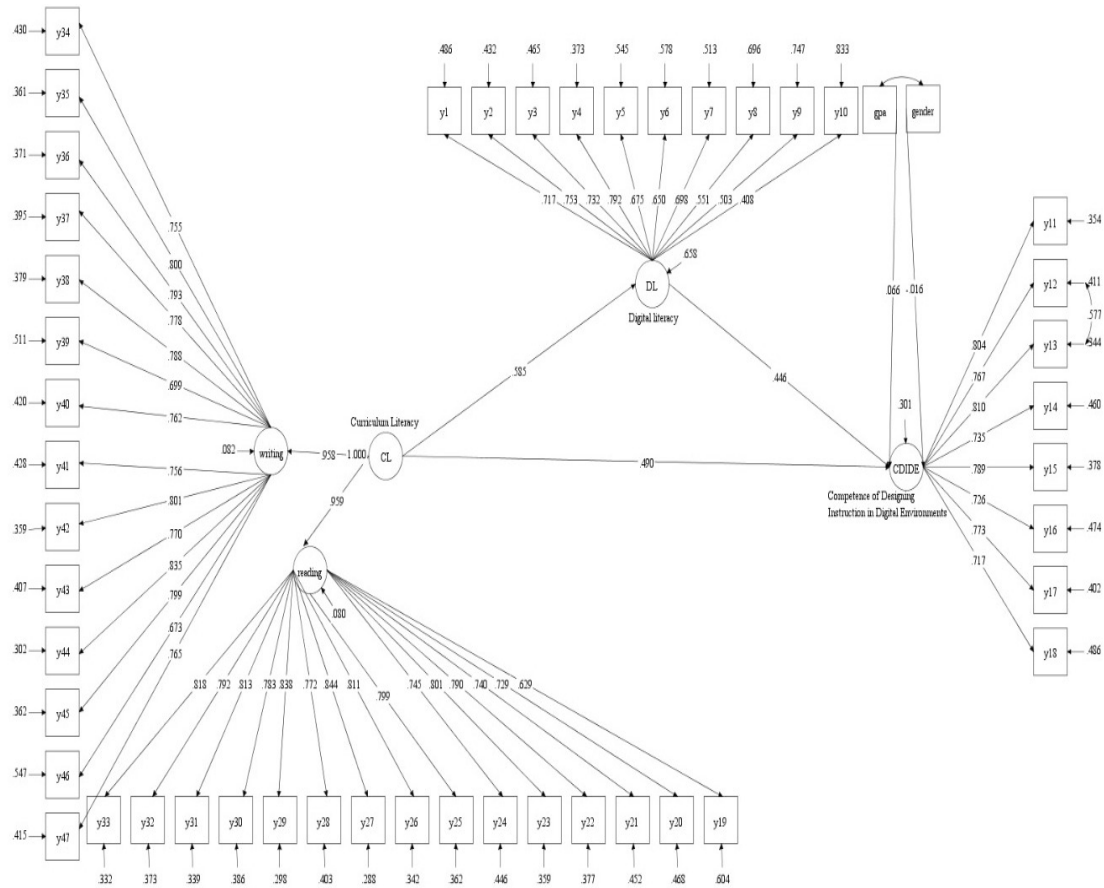


Figure 2. Structural relationships between variables

The fit indices of the structural model were examined, and the fit indices ($\chi^2/df = 1.24$ [$<.05$], RMSEA = 0.04 [$<.05$], SRMR = 0.05 [$<.10$], CFI = 0.91 [$>.90$], TLI = 0.91 [$>.90$] and IFI=0.91 [$>.90$]) were found to be within acceptable levels. These findings suggest that the structural equation model indirectly explains the digital literacy levels of pre-service teachers' curriculum literacy and their competencies in designing instruction in digital environments.

Analyses were conducted using the bootstrap technique with 2000 samples to determine the significance of the mediating role of digital literacy in the effect of pre-service teachers' curriculum literacy on their competence in designing instruction in digital environments. Table 3 presents findings revealing the direct, indirect and total effects of pre-service teachers' curriculum literacy and their competence in designing instruction in digital environments on their digital literacy.

Table 3. Bootstrap results regarding SEM mediation relationships

Construct	Product of the coefficient		z	95% Bootstrap CI		R ²	p
	Point Estimate	SE		Lower	Upper		
Standardised total effect							
CL → CDIDE	.750	.042	17.698	.674	.813		.000
Standardised direct effects							
CL → CDIDE	.490	.067	7.263	.373	.593	.342	.000
CL → DL	.585	.064	9.167	.473	.684		.000
GENDER → CDIDE	-.016	.038	-.420	-.080	.042		.675
GPA → CDIDE	.066	.040	1.657	.001	.131		.098
Specific indirect effects							
CL → DL → CDIDE	.261	.049	5.277	.188	.355	.699	.000

CL: curriculum literacy; DL: digital literacy; CDIDE: competence of designing instruction in digital environments; Based on 2000 bootstrapped samples; CI = confidence interval.

As is seen in Table 3, the results of bootstrapping analysis revealed a substantial and statistically significant direct effect of pre-service teachers' curriculum literacy on their competence in designing instruction in digital environments ($\beta = .750$, $p < .05$). Moreover, a moderately significant effect of curriculum literacy on digital literacy level was observed ($\beta = .585$, $p < .05$). Table 3 demonstrates that 34% of the variance regarding the pre-service teachers' digital literacy levels is explained by the curriculum literacy. These findings show that pre-service teachers' curriculum literacy directly influences both their ability to design instruction in digital environments and their digital literacy. Consequently, Hypothesis 1 and Hypothesis 2 were confirmed based on these results.

The mediating effect of digital literacy ($\beta = .261$, $p < .05$) on pre-service teachers' curriculum literacy competencies in designing instruction in digital environments was found to be positively significant at a low level within the 95% confidence interval (.188, .355). Curriculum literacy accounted for 69% of the variance regarding pre-service teachers' competencies in designing instruction in digital environments through their digital literacy. Pre-service teachers' digital literacy levels play a significant and influential mediating role between their curriculum literacy and their competence in designing instruction in digital environments. This result shows that Hypothesis 3 was also confirmed.

Discussion

The first hypothesis of our study centred on exploring the direct effect of pre-service teachers' curriculum literacy on their competence in designing instruction in digital environments. The results indicated a highly significant impact of pre-service teachers' curriculum literacy on their competence in designing instruction in digital environments, suggesting that an increase in curriculum literacy leads to enhanced abilities in designing effective digital instruction. Stenhouse (1975) states that the curriculum is decisive in designing a qualified teaching environment. Aslan (2018) underscores the importance of teachers' accurate understanding of the curriculum for efficient organisation of the teaching environment. Nsibandé and Modiba (2012) pinpoint that teachers can prepare teaching plans tailored to the conditions if they have curriculum literacy skills. Likewise, Marsh (2009) emphasises that if teachers understand the curriculum, they can design environments where they can help students acquire the curriculum objectives. Stabback (2016) stresses the significance of designing effective environments to ensure the successful implementation of the curriculum. All these theoretical explanations indicate that teachers can design the teaching environment effectively if they become curriculum literate. Therefore, pre-service teachers with curriculum literacy skills are likely to be able to design digital environments

effectively when they commence their careers. This result reports the influence of pre-service teachers' curriculum literacy on their competence in designing digital instruction. Curriculum literacy encompasses pre-service teachers' skills to define learning objectives, select appropriate teaching materials, evaluate the learning process, and develop strategies to address the diverse learning needs of students. In short, curriculum literacy includes a broad set of competencies, including understanding, implementing, evaluating, and critically analysing the curriculum (Ariav, 1991; Aslan, 2018; Aslan, 2019; Bolat, 2017; Keskin & Korkmaz, 2021). These skills play a decisive role in the process of designing instruction in digital environments, enabling pre-service teachers to create instructional materials by taking into account students' individual differences and cultural diversity. This may contribute to pre-service teachers organising an effective learning-teaching process by using digital environments when they start their careers. Thus, students' academic achievement may increase. This result is also considered to be critical for teacher training programs. Integrating curriculum literacy training into teacher preparation programs holds the potential to enhance pre-service teachers' competencies in designing instruction in digital environments. In this regard, this result reveals that teacher training programs should focus on developing curriculum literacy skills. Providing that teacher training programs centre on curriculum literacy skills, pre-service teachers' competencies in these programs to effectively design instruction in digital environments may be improved. This may help pre-service teachers organise an effective teaching process using digital environments and provide students with 21st-century skills when they start working.

The second hypothesis was grounded on the direct effect of pre-service teachers' curriculum literacy on their digital literacy. The findings suggested that pre-service teachers' curriculum literacy directly affected their digital literacy at a moderate and significant level. This highlights the pivotal role of curriculum literacy in shaping the digital competencies of educators. Shively and Palilonis (2018) conclude that digital literacy strategies are instrumental in preparing effective curricula. Özbay and Özdemir (2014) emphasise that teachers must be digitally literate and integrate digital teaching materials into the curriculum for effective implementation of Turkish curricula. These references affirm the relationship between curriculum literacy and digital literacy, which is considered a significant result of our study. A pre-service teacher equipped with high curriculum literacy knows curriculum objectives, content, teaching-learning process and evaluation (Akyıldız, 2020; Aslan, 2019). Moreover, pre-service teachers with high curriculum literacy have the skills to formulate objectives, create goal-oriented content, organise and implement the learning-teaching process, and select and prepare evaluation tools (Bolat, 2017; Keskin, 2020). Hence, it is of critical concern for pre-service teachers to possess curriculum literacy skills so that they can effectively implement curricula when they start their careers. Nowadays, the incorporation of digital teaching materials into the teaching environment has become a crucial consideration for effective curriculum implementation. Digital technologies must be integrated into teaching processes to achieve curriculum objectives. In this regard, the impact of pre-service teachers' curriculum literacy on their digital literacy gives clues about their teaching practices by integrating digital technologies into their curricula when they start working. The results of such instructional practices may lead to enhanced academic achievement among students, as well as improvements in their motivation and attitudes towards the subject. This result also provides considerable feedback to teacher training programs. Provided that teacher training programs are organised by taking into account curriculum literacy, pre-service teachers can improve their proficiency in employing digital teaching materials effectively within the curriculum. In this context, structuring teacher training programs by focusing on curriculum literacy may contribute to the development of the professional skills and competencies

requisite for 21st-century educators.

The third hypothesis posits the indirect effect of pre-service teachers' curriculum literacy on their competence in designing instruction in digital environments through their digital literacy. The findings suggested a high and statistically significant mediation impact of pre-service teachers' digital literacy levels on their curriculum literacy and competence in designing instruction in digital environments. This result shows that pre-service teachers' curriculum literacy significantly influences their competence in designing instruction in digital environments, albeit indirectly, through their digital literacy levels. The explanations above have elucidated the impact of the curriculum on digital literacy and the design of teaching environments. Kocoglu et al. (2023) confirm that pre-service teachers can prepare digital teaching materials and employ them in teaching environments within the scope of digital literacy skills. This reference points out that curriculum literacy has a mediating role in designing instruction within digital environments. This result is fundamental for both our study and the future of the education system. Pre-service teachers with high curriculum literacy levels can select and apply digital teaching materials that will facilitate students' learning and ensure permanent learning while designing teaching in digital environments. As a result, students' academic achievement can increase, and individuals with 21st-century skills can be raised, thereby contributing to the realisation of countries' educational objectives. In addition, this result provides important feedback to faculty members within teacher training programs. They may contribute to the training of 21st-century teachers by integrating activities designed to enhance pre-service teachers' curriculum literacy skills and familiarise them with digital teaching materials in their courses. Those trained in this way can effectively design teaching in digital environments, particularly crucial during periods of emergency distance education, such as the COVID-19 pandemic.

Curriculum literacy is recognised as a critical competency for teachers to effectively plan, implement, and evaluate educational processes. The findings of this study reveal a strong relationship between curriculum literacy and competency in designing digital instruction. This aligns with the predictions of the Technological Pedagogical Content Knowledge (TPACK) model (Mishra & Koehler, 2006), which emphasises the need for teachers to integrate three knowledge components—pedagogical, content, and technological knowledge—to create effective digital instructional designs. Pre-service teachers with high curriculum literacy do not merely integrate digital tools at a superficial level but rather use them consciously in alignment with curriculum objectives and pedagogical principles.

Furthermore, the Learning Design Model (Dalziel, 2015) demonstrates that structured instructional design processes can enhance the effectiveness of digital learning environments. In line with this model, a deep understanding of the curriculum enables pre-service teachers to design digital learning processes that align with both students' needs and the curriculum. It is emphasised that pre-service teachers should perceive digital tools not merely as supplementary elements but as fundamental components that shape the learning process.

The findings also indicate a direct impact of curriculum literacy on digital literacy. The DigCompEdu framework (Redecker, 2017) provides a structured roadmap for developing teachers' digital pedagogical competencies. The results of this study demonstrate that pre-service teachers with high curriculum literacy can utilise digital tools more effectively and that this competency directly contributes to digital pedagogical processes. This underscores the importance of not only using technological tools in the digitalisation of education but also fostering pedagogical awareness regarding how and why these tools should be employed.

Additionally, the findings suggest that digital literacy plays a mediating role in the relationship between curriculum literacy and digital teaching design competency. This result highlights that teachers' awareness of how and in what contexts to use digital tools becomes pedagogically meaningful and effective when integrated with their curriculum knowledge. When examined within the framework of the Technology Acceptance Model (TAM) (Davis, 1989), it is observed that pre-service teachers with strong curriculum literacy perceive digital tools as more "useful" and "accessible," which, in turn, encourages them to develop their digital literacy skills actively.

Conclusion

This study provides empirical evidence that pre-service teachers' curriculum literacy significantly enhances their ability to design instruction in digital environments, both directly and indirectly through its influence on digital literacy. The findings indicate that pre-service teachers with a strong foundation in curriculum literacy demonstrate greater competence in digital instructional design. This supports the notion that effective teaching in digital contexts necessitates the integration of curriculum knowledge with digital pedagogical skills.

The study directly addresses its research questions by demonstrating that both curriculum and digital literacy positively and significantly affect digital instructional design competency. Moreover, the mediating role of digital literacy suggests that curriculum literacy deepens teachers' comprehension of instructional frameworks and facilitates the pedagogically meaningful integration of digital tools. These results highlight the necessity of teacher education programs that systematically interconnect curriculum literacy and digital literacy to foster comprehensive instructional competencies.

The results of this study suggest that strengthening both curriculum literacy and digital literacy among pre-service teachers is essential for preparing them to design and implement pedagogically sound digital learning environments. Enhancing these competencies will not only facilitate teachers' adaptation to the demands of the digital era but also contribute to their overall instructional effectiveness. Future research may explore the longitudinal impact of curriculum literacy on teachers' digital pedagogical practices in real-world classroom settings. Additionally, subsequent studies could examine the role of institutional support and teacher education policies in fostering these competencies at a systemic level.

By emphasising the interconnection between curriculum literacy, digital literacy, and instructional design competencies, this study offers a conceptual framework for advancing teacher preparation in the digital age. The findings contribute to the refinement of teacher education programs, inform educational policymakers, and provide actionable insights for equipping educators with the necessary skills to create curriculum-aligned, technology-enhanced learning experiences.

Recommendations

From a theoretical standpoint, the study broadens the literature by integrating frameworks such as TPACK, the Learning Design Model, and DigCompEdu to explain how curriculum literacy interacts with digital teaching competencies. It offers a holistic perspective, highlighting curriculum literacy as a core foundation for developing digital pedagogical expertise and emphasising that effective digital competence requires aligning technology with curricular goals and pedagogical principles.



From a practical perspective, the study stresses the importance of embedding curriculum literacy training more comprehensively into teacher education programs. It suggests restructuring curricula so that pre-service teachers view digital tools as integral to teaching and learning. Integrating TPACK can support the balanced development of pedagogical, content, and technological knowledge, while DigCompEdu-based training can provide structured guidance for improving digital competencies in line with curricular objectives.

From a policy perspective, the findings point to the need for aligning teacher education policies with digital transformation. This includes revising certification standards to ensure comprehensive training in both curriculum and digital literacy and promoting professional development initiatives that enable educators to design curriculum-driven digital learning environments. Based on the research results, it is recommended that teacher training programs structure the curriculum to strengthen literacy and digital literacy skills. In this way, pre-service teachers can be equipped with the skills to use digital teaching materials effectively in teaching processes, and their competencies in preparing effective instructional designs in digital environments can be improved.

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