

Research Paper

Cultivating Digital Pedagogies in the 21st Century: A Quantitative Examination of Pre-Service Teachers' Capabilities and Readiness

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ABSTRACT

In the 21st century, the concept of digital literacy (DL) has become an essential skill set that empowers educators to harness the full potential of technology in the classroom as a crucial element for teaching 21st-century skills (T21C). This study aims to explore pre-service teachers' level of DL and their capabilities of T21C, and whether their DL level influences their capabilities of T21C. A quantitative research design was employed using SPSS 21.0 and AMOS 21.0 to conduct descriptive statistics, reliability and validity analyses, Pearson correlation, and path analysis within a structural equation modeling framework to examine the relationships among variables at a 95% confidence level. The study was conducted on 383 pre-service teachers studying at different faculties of education in Türkiye. The results revealed that the majority of pre-service teachers exhibited a moderate level of DL, but with a smaller proportion falling into the categories of low or high DL. Pre-service teachers' overall capabilities of T21C were detected as moderate. In contrast, the majority of pre-service teachers had a moderate level of capabilities in utility of technology (UOT), collaboration (CO), and innovation and problem-solving (IP). Still, a smaller proportion was categorized as low or high. The findings also identified a significantly substantial and positive correlation between pre-service teachers' DL and their capabilities of T21C, which indicates that as their DL levels rose, there was a corresponding tendency towards their enhanced proficiency in T21C, including the constructs of UOT, CO, and IP.



INTRODUCTION

The landscape of education has been profoundly transforming in the 21st century, which imperiously requires educational administrators and practitioners to re-evaluate the skills and competencies developed by educational institutions aiming to prepare students for an increasingly complex and technology-driven world. Because of the unprecedentedly rapid technological advancements, Singh et al. (2022) underlined the significance of adapting to changes and learning new skills in this century by upgrading the new knowledge. In this context, the development of 21st-century skills, including cognitive, intrapersonal, and interpersonal competencies, becomes essential for not only individual development but also societal advancement (Zhou, 2023). Therefore, these skills are indispensable in this century characterized by the complexity of knowledge and technology.

21st-century skills refer to a set of competencies that students need to possess to succeed in the modern world. According to the Partnership for 21st Century Skills (P21, 2019), there are three different categories of skills: (1) learning and innovation skills including "creativity and innovation, critical thinking and problem-solving, communication, and collaboration" (4Cs); (2) information, media and technology skills such as "information literacy, media literacy, and ICT (information, communications, and technology) literacy"; (3) life and career skills comprising of "flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, leadership and responsibility". 21st-century skills are significant because they prepare students for the workforce, lifelong learning, and the global economy. These skills help students develop the capability of processing and using information effectively, making learning relevant to the current digital society and developing job-oriented skills (Carlgren, 2013). These skills go beyond traditional academic knowledge and emphasize practical proficiencies that enable individuals to address real-world challenges, innovate, and communicate across cultures and digital platforms (DiBenedetto, 2019; Kennedy & Sundberg, 2020; Saavedra & Opfer, 2012).

As the cornerstone of the 21st-century skill transformation, digital literacy (DL) has emerged as an essential attribute that enables teachers to make effective use of technology in the classroom. DL supports the ability to critically navigate, evaluate, and utilize digital tools and information effectively, which is indispensable for modern educators (Umar & Dangwaran, 2023). Antoniuk and Zasiadivko (2023) defended that DL is crucial for teachers in creating a digital environment in the classroom and equipping students with modern skills. Basically, it is among the fundamental skills that affect many areas of learning. Vaskov et al. (2021) listed the competencies DL includes as "information literacy, skills for interaction in an electronic environment, the ability to

generate digital content [along with] ensuring the safety of the physical and psychological health of users, [and] the ability to identify and eliminate technical problems when working with digital devices” (p. 1). Thus, the development of DL in educational institutions is significant for adapting to the requirements of the digital economy and preparing students for the technological revolution.

Teacher education programs play a central role in shaping the educators of tomorrow and equipping them with the tools necessary to foster 21st-century skills among their students. Teacher education functions as the center where educators are shaped and equipped with the knowledge, abilities, and attitudes they require to motivate and instruct the next generation (Darling-Hammond, 2017). In the 21st century, this mission is intrinsically tied to DL along with digital pedagogies. In addition to being skilled in conventional pedagogical methods, pre-service teachers must also be capable digital navigators and integrators (Kozma, 2003). DL, which is beyond the ability to handle computers, includes competencies in information literacy, digital interaction, creation of digital content, protection of user safety, and troubleshooting technical problems (Coker, 2020). Moreover, DL supports technology integration practices into teaching. Ertmer et al. (2012) qualified technology integration as the biggest impact on student success according to the results of their study on teacher beliefs. Consequently, DL has a critical role in teacher education since it enables teachers to successfully use technology as a teaching tool, which promotes both student engagement and effective learning (Vaskov et al., 2021). Pre-service teachers must learn how to incorporate digital tools and resources into their teaching practices by adopting appropriate pedagogical approaches because it is necessary to create dynamic and interactive learning environments for students of digital natives and to encourage deeper understanding and engagement in their classes (Koehler et al., 2013).

21st-century competencies are considered fundamental including “searching and evaluating information, solving problems, exchanging information or developing ideas” in a digital environment (Hilliker & Loranc, 2022, p. 2). Thus, the instructional environment of the 21st century has demonstrated the complex and improvisational character of the teaching profession (Meneses et al., 2023). In this regard, it is critical to investigate how pre-service teachers’ level of DL affects their capacity to teach 21st-century skills, which can guide the necessary improvements in teacher education. Therefore, this study aimed to examine pre-service teachers’ DL, their capacity to teach 21st-century skills, and whether their level of DL influences their ability to teach these skills. The results contribute to why and how teacher education programs can integrate DL into their curricula effectively, which will sustain the ongoing development of teacher education in the 21st century. In this way, teacher education institutions can tailor their programs to better prepare future educators.

Digital Literacy in Teacher Education for 21st-Century Skills

Educational frameworks, in general, intend to develop and improve the skills that individuals need to succeed in life and promote quality in the 21st century (Gonzalez-Perez & Ramirez-Montoya, 2022; P21, 2019). Teacher education programs aiming to train teachers who are the cornerstone of individuals’ education cannot be excluded from the scope of this century’s requirements. In this respect, DL is a key to unlocking a transformative educational landscape by empowering educators to effectively integrate technology into their teaching methodologies and practices, and equip students with the essential 21st-century skills so that they can succeed in a global society.

To create an effective teacher education program improving DL as part of the 21st-century skills, several studies were conducted in the existing literature focusing on different aspects of DL in teacher education and professional development units. Barbutiu and Kack (2016), in their study on the integration of ICTs in teacher education, revealed the persistent challenges in the integration of DL into higher education identified by pre-service teachers such as establishing a learning organization, maintaining an updated concept of DL, and overcoming obstacles in dispersed teacher education programs; accordingly, the complexities of coordinating across departments and the demanding conditions faced by teacher educators were determined as the hindrance against the integration of DL and the incorporation of ICTs into pedagogical practices. Similarly, Campbell and Kapp (2020), in their case study on pre-service teachers’ digital practices and perceptions, identified pre-service teachers’ understanding of how digital elements function in their classrooms in connection with their individual DL practices, which suggests the full integration of DL into the pedagogical aspects of teacher education programs. Akayoglu et al. (2020) studied the concept of DL and the use of digital tools among pre-service teachers at the departments of English language teaching and highlighted the pedagogical aspect of digital tools by suggesting the integration of technology-related courses with pedagogy and digital material design within the scope of teacher education programs. Consistently, Palacios-Hidalgo and Huertas-Abril (2022), in their quasi-experimental research with English language teachers, emphasized the significance of DL in distance education and suggested that higher education institutions, especially having distance programs, should strengthen their training programs on digital skills.

Briefly, DL is a crucial element for teaching 21st-century skills (T21C). Critical thinking is essential for DL along with a comprehension of how technology aligns with a teacher’s pedagogical responsibilities (Arstop, 2021). In this respect, teacher education programs should be reconsidered to incorporate comprehensive training modules enhancing both pre-service and in-service teachers’ DL and its reflection into their teaching practices of 21st-century skills. Teachers should keep up with the rapid technological changes concerning their DL pedagogically within the context of classroom teaching to foster a more effective educational environment.

METHODS

Research Model

Employed as a quantitative research design, this study aimed to explore pre-service teachers' level of DL and their capabilities of T21C in terms of utility of technology (UOT), collaboration (CO), and innovation and problem-solving (IP), and whether their level of DL influences their capabilities of T21C. Accordingly, the following research questions (RQs), along with the formulated hypotheses, were investigated as listed below and illustrated in Figure 1:

RQ1: How proficient are pre-service teachers in DL?

RQ2: To what extent are pre-service teachers capable of T21C?

RQ2.1: How capable are pre-service teachers in UOT?

RQ2.2: How capable are pre-service teachers in CO?

RQ2.3: How capable are pre-service teachers in IP?

RQ3: Is there a relationship between pre-service teachers' level of DL and their capabilities of T21C?

H₁: Pre-service teachers' DL positively influences their capabilities of UOT in T21C.

H₂: Pre-service teachers' DL positively influences their capabilities of CO in T21C.

H₃: Pre-service teachers' DL positively influences their capabilities of IP in T21C.

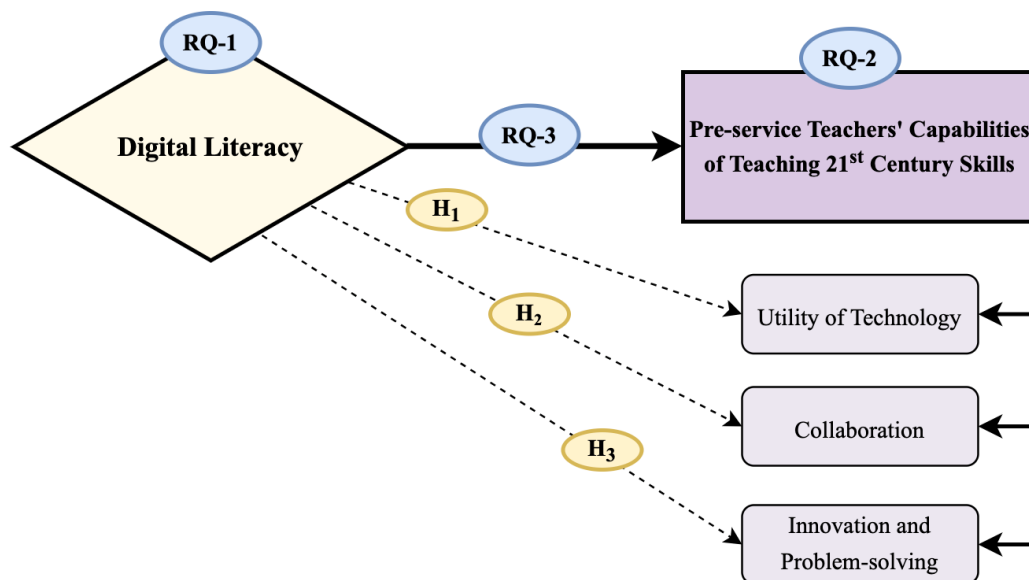


Figure 1. Research design

RQ1 and RQ2 were examined through descriptive analyses to find out the pre-service teachers' DL levels and T21C capabilities, comprising three constructs of UOT, CO, and IP. Regarding RQ3, the possible effect of pre-service teachers' DL on T21C was investigated with the formulated H₁, H₂, and H₃.

Participants

The population of this study consisted of pre-service teachers studying at different faculties of education in Türkiye. The research sample was determined as 383 participants based on convenience sampling, one of the non-probability sampling methods. The participants were accessed through digital platforms, including different groups dedicated to prospective teachers enrolled in different education faculties. The online link to the questionnaire was disseminated within these communities to ensure accessibility and a broad range among the target population. To provide a clearer picture of the sample composition, the participants were categorized based on the seven geographical regions of Türkiye. Accordingly, the distribution of the participants across the regions was as follows: Marmara Region (n=71; 18.5%), Central Anatolia Region (n=66; 17.2%), Aegean Region (n=64; 16.7%), Southeastern Anatolia Region (n=57; 14.8%), Black Sea Region (n=49; 12.8%), Mediterranean Region (n=46; 12.0%), and Eastern Anatolia Region (n=30; 7.8%). This regional distribution was derived based on the institutional affiliation of each participant. The sample demographics are presented in Table 1.

Table 1. Demographic characteristics of the participants

Gender			Field of Teaching		
	n	%		n	%
Male	90	23.5	Science teaching	51	13.3
Female	293	76.5	Spanish language teaching	51	13.3
Age _(min-max)			Turkish language teaching	46	12.0
	$\bar{X}$	SD	Primary school teaching	39	10.2
18 _{min} - 43 _{max}	22.11	3.59	Social studies teaching	35	9.1
Type of University			Pre-school teaching	34	8.9
	n	%	Psychological guidance and counselling	28	7.3
State	367	95.8	English language teaching	28	7.3
Foundation	16	4.2	Religious education teaching	22	5.7
Year of Study			Art teaching	14	3.7
	n	%	Special education teaching	11	2.9
1 st	114	29.8	Physical education teaching	10	2.6
2 nd	89	23.2	Information technologies teaching	6	1.6
3 rd	61	15.9	German language teaching	4	1.0
4 th	93	24.3	Music teaching	3	0.8
5 th and more	26	6.8	French language teaching	1	0.3
Total	383	100	Total	383	100

Table 1 displays the distribution of the participants based on different demographic variables. 76.5% of the pre-service teachers were female (n=293) while 23.5% were male students (n=90). Regarding the age variable, the average age of the sample was around 22.11 years (SD=3.59). Concerning the distribution of pre-service teachers based on the type of university they were attending, the majority were studying at state universities (n=367; 95.8%). As for the year of study at university, the majority of the participants were in their initial year (n=114), constituting 29.8% of the total whereas 2nd-year participants made up 23.2% (n=89), 3rd-year participants represented 15.9% (n=61), and 4th-year participants comprised 24.3% of the total (n=93). There was a respectively smaller group of 6.8% consisting of students studying in their 5th year and more (n=26). Finally, the participant profile demonstrated a diverse range of teaching fields among pre-service teachers. Notably, science teaching and Spanish language teaching each accounted for 13.3% of the participants (n=51), closely followed by Turkish language teaching at 12.0% (n=46). Primary school teaching and social studies teaching encompassed 10.2% (n=39) and 9.1% (n=35) respectively, while pre-school teaching made up 8.9% (n=34) correspondingly. Both psychological guidance and counselling and English language teaching comprised 7.3% each (n=28). Furthermore, religious education teaching, art teaching, special education teaching, and physical education teaching contributed smaller shares at 5.7% (n=22), 3.7% (n=14), 2.9% (n=11), and 2.6% (n=10), respectively. The remaining fields, including information technologies teaching (n=6; 1.6%), German language teaching (n=4; 1.0%), music teaching (n=3; 0.8%), and French language teaching (n=1; 0.3%), collectively form a minor portion of the participant pool.

Instruments

In this quantitatively designed study, a questionnaire form was used as configured in three sections: demographics, the scales of DL and T21C. First, pre-service teachers were asked about their demographic profile with the items including the variables of gender, age, type of university, year of study, and field of teaching. Second, to determine the level of pre-service teachers' DL, the DL scale developed by Ng (2012) and adapted to Turkish language and culture by Ustundag et al. (2017) was conducted with its 10 items in a single-factor structure using a 5-point Likert scale with the options of "strongly disagree" (1), "disagree" (2), "neither agree or disagree" (3), "agree" (4), and "strongly agree" (5). The reliability of the DL scale was tested with Cronbach's alpha coefficient and calculated as 0.86, which demonstrated "good internal consistency of the items" (George & Mallery, 2003; Gliem & Gliem, 2003). Finally, the T21C scale developed by Jia et al. (2016) and adapted to the Turkish language and culture by Ozyurt (2020) was implemented to investigate the level of pre-service teachers' capabilities of T21C. It consisted of 10 items organized in a three-factor structure, including UOT with three items, CO with three items, and IP with four items. A 7-point Likert scale ranging from "not at all confident" (1) to "completely confident" (7) was employed in assessing responses on the T21C scale. Regarding the reliability of the T21C scale, Cronbach's alpha coefficient, as a whole, was calculated as 0.90, which revealed "excellent internal consistency of the items". As for the sub-factors, UOT and CO showed "acceptable internal consistency" ($\alpha=0.74$; $\alpha=0.78$), whereas IP indicated "good internal consistency" ($\alpha=0.83$) (George & Mallery, 2003; Gliem & Gliem, 2003).

Data Collection

Before data collection, the permission for scientific and ethical compliance, documented on 30.03.2023 with project number 346, was received from the Board of Ethics for Human Studies in Social Sciences and Humanities to conduct the study. The questionnaire, comprising three sections in its authorized form, was set up on an online data-gathering platform, which ensured

anonymity and confidentiality of the responses. Informed consent was sought from all the participants involved in this study, and the respondents were informed electronically at the beginning of the online questionnaire about the research objectives, data collection methods, and their rights as participants to withdraw at any time without consequences. It was also confirmed that participation in the study was voluntary, data confidentiality was ensured, and only those who acknowledged and agreed to this information were allowed to proceed with the questionnaire. The link to the questionnaire was shared with the prospective sample of the study in the 2022-2023 academic year. Out of more than 500 deliveries, valid responses were collected from 383 pre-service teachers studying at different faculties of education in different Turkish universities across the country.

Data Analysis

To address and explore the RQs and formulated hypotheses, SPSS 21.0 and AMOS 21.0 software programs were employed by utilizing a confidence level of 95%. For categorical variables, frequency and percentage measurements were performed to provide insight into the data through the calculation of minimum, maximum, mean, and standard deviation values. Additionally, Cronbach's alpha coefficients were assessed to ensure reliability, and confirmatory factor analysis (CFA) was conducted to establish the validity of the scales. Subsequently, scale scores were computed, and the Pearson correlation test was employed to explore the relationships between these scores. The effects between the scale scores were further examined using the AMOS program, which contributes to a comprehensive analysis of the RQs and hypotheses.

RESULTS

In line with the quantitative research design of this study, the primary objective was to examine the DL levels of pre-service teachers (RQ1) and their capabilities in T21C (RQ2), as well as to ascertain any potential effects of DL on T21C (RQ3: H_1 , H_2 , and H_3). The results of the analyses are presented in sequence aligning with the research model.

Pre-service Teachers' Level of Digital Literacy

To assess the level of DL among pre-service teachers (RQ1), descriptive analyses were carried out using SPSS 21.0. The results of the DL scale analyses are illustrated in Table 2.

Table 2. Descriptive results for the DL scale

DL		n	%	$\bar{X}_{\min}$	$\bar{X}_{\max}$	$\bar{X}$	SD
		383	100	1.70	5.00	3.84	0.59
Level	Low	53	13.8	1.70	3.25	2.87	0.36
	Moderate	278	72.6	3.26	4.42	3.85	0.33
	High	52	13.6	4.43	5.00	4.74	0.20

According to Table 2, the overall level of the pre-service teachers' DL was found "moderate" ($\bar{x}=3.84$; $3.25 < \bar{X}_{DL} < 4.43$). 53 pre-service teachers' DL level accounting for 13.8% was identified as "low" ($\bar{x}=2.87$; $1.70 < \bar{X}_{DL} < 3.26$), whereas 278 pre-service teachers' DL levels constituting 72.6% of the total were detected as "moderate" ($\bar{x}=3.85$; $3.25 < \bar{X}_{DL} < 4.43$). Finally, similar to the number of participants with a low level of DL, 52 pre-service teachers' DL level comprising 13.6% of the total was found "high" ($\bar{x}=4.74$; $4.42 < \bar{X}_{DL} < 5.00$).

Pre-service Teachers' Level of Capabilities of Teaching 21st-Century Skills

To measure the level of pre-service teachers' capabilities in T21C (RQ2), descriptive analyses were performed on SPSS 21.0 in addition to the capabilities in UOT (RQ2.1), CO (RQ2.2), and IP (RQ2.3). The results of the T21C scale analyses are depicted in Table 3.

Table 3. Descriptive results for the T21C scale

T21C	Level	n	%	$\bar{X}_{\min}$	$\bar{X}_{\max}$	$\bar{X}$	SD
		383	100	2.20	7.00	5.44	0.98
UOT	Low	50	13.1	1.33	4.00	3.39	0.68
	Moderate	272	71.0	4.33	6.33	5.41	0.61
	High	61	15.9	6.67	7.00	6.85	0.17
CO	Low	50	13.1	1.00	4.33	3.60	0.73
	Moderate	266	69.5	4.67	6.67	5.73	0.61
	High	67	17.5	7.00	7.00	7.00	0.00
IP	Low	55	14.4	2.00	4.00	3.44	0.51
	Moderate	266	69.5	4.25	6.25	5.34	0.61
	High	62	16.2	6.50	7.00	6.83	0.21

As indicated in Table 3, the overall level of the pre-service teachers' capabilities in T21C was found "moderate" ($\bar{x}=5.44$; $4.50 < \bar{X}_{T21C} < 6.40$). Regarding their capabilities in UOT, it was revealed that 50 pre-service teachers had a low level of UOT accounting for 13.1% of the total ($\bar{x}=3.39$; $2.20 < \bar{X}_{UOT} < 4.40$), 272 of the participants were detected of having a moderate level of UOT comprising 71.0% of the sample ($\bar{x}=5.41$; $4.50 < \bar{X}_{UOT} < 6.40$), and 61 pre-service teachers were indicated with a high level of UOT constituting 15.9% of the total ($\bar{x}=6.85$; $6.50 < \bar{X}_{UOT} < 7.00$). As for the capabilities in CO, it was identified that 50 pre-service teachers had a low level of CO accounting for 13.1% of the total ($\bar{x}=3.60$; $2.20 < \bar{X}_{CO} < 4.40$), 266 of the participants had a moderate level of CO comprising 69.5% of the sample ($\bar{x}=5.73$; $4.50 < \bar{X}_{CO} < 6.40$), and 67 pre-service teachers were detected with a high level of CO constituting 17.5% of the total ($\bar{x}=7.00$; $6.50 < \bar{X}_{CO} < 7.00$). According to the results for IP, it was measured that 55 pre-service teachers had a low level of IP representing 14.4% of the sample ($\bar{x}=3.44$; $2.20 < \bar{X}_{IP} < 4.40$), 266 of the participants were identified with a moderate level of IP comprising 69.5% of the total ($\bar{x}=5.34$; $4.50 < \bar{X}_{IP} < 6.40$), and 62 pre-service teachers were detected with a high level of IP accounting for 16.2% of the study group ($\bar{x}=6.83$; $6.50 < \bar{X}_{IP} < 7.00$).

Effect of Pre-service Teachers' Digital Literacy on Teaching 21st-Century Skills

To explore the effect of pre-service teachers' level of DL on their capabilities in T21C (RQ3), at first, the CFA was carried out for the DL scale as illustrated in Figure 2. The model fit indices for CFA of the DL scale were calculated as $\chi^2/df=2.25$ (<5), GFI=0.96 (>0.90), AGFI=0.93 (>0.90), CFI=0.97 (>0.90), RMSEA=0.06 (<0.08), and RMR=0.03 (<0.08), which met the criteria for acceptable fit aligning well with established thresholds (Bentler, 1990; Bentler & Bonett, 1980; Browne & Cudeck, 1993; Hu & Bentler, 1999). This robust model performance validated the DL scale's reliability and the roadmap derived from the CFA results confirmed the consistency of these fit indices, which proved the scale's validity and reliability (Brown, 2015).

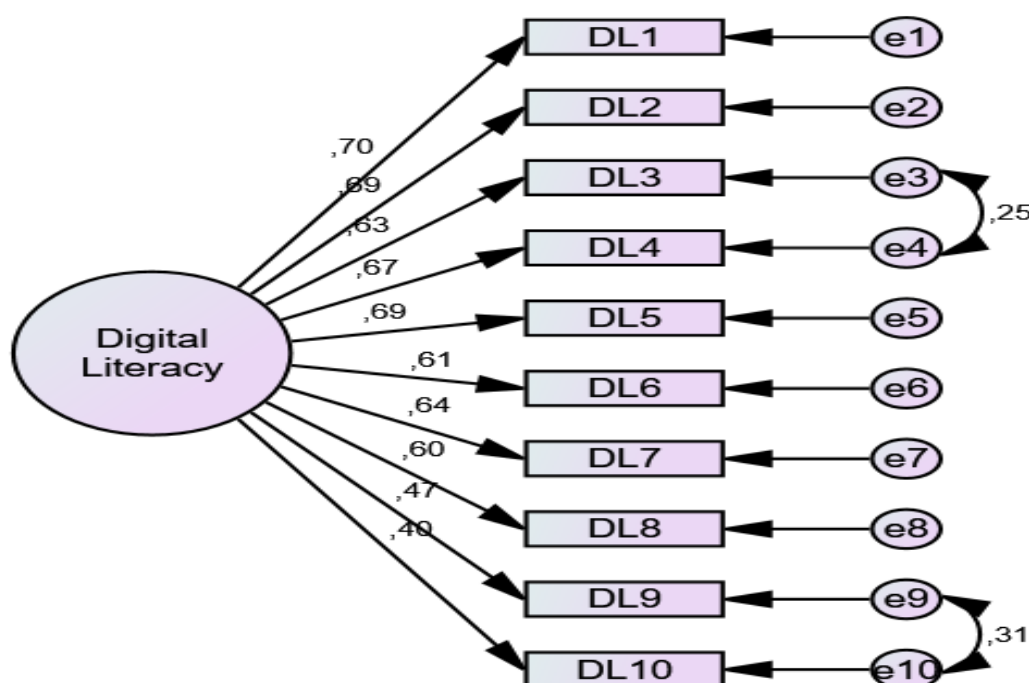


Figure 2. The roadmap of CFA results for the DL scale

The findings for item analysis as a result of CFA for the DL scale are presented in Table 4 with the estimates, standard errors (S.E.), critical ratios (C.R.), and p-values for each item. All item loadings showed statistical significance at $p < 0.001$, and a strong relationship was observed between the items and the DL construct. These findings confirmed the validity of the measurement model by demonstrating that the items effectively measure the DL construct.

Table 4. Item loadings of the DL scale

Items		Estimate	S.E.	C.R.	p
DL1	<--- DL	.700			
DL2	<--- DL	.695	.079	12.097	***
DL3	<--- DL	.629	.090	10.974	***
DL4	<--- DL	.671	.096	11.664	***
DL5	<--- DL	.687	.093	11.973	***
DL6	<--- DL	.607	.104	10.689	***

Items			Estimate	S.E.	C.R.	p
DL7	<---	DL	.636	.081	11.167	***
DL8	<---	DL	.605	.099	10.648	***
DL9	<---	DL	.469	.075	8.355	***
DL10	<---	DL	.396	.101	7.077	***

***p<0.001

Subsequently, CFA was performed for the T21C scale, including three factors of UOT, CO, and IP, as demonstrated in Figure 3. The model fit indices for CFA of the T21C scale were calculated as $\chi^2/df=4.01$ (<5), GFI=0.94 (>0.90), AGFI=0.90 (≥ 0.90), CFI=0.95 (>0.90), RMSEA=0.08 (≤ 0.08), and RMR=0.07 (<0.08). Although some indices met the criteria for acceptable fit such as CFI and GFI, which exceeded 0.90, others fell slightly outside the ideal range. Specifically, RMSEA and RMR were slightly above the recommended threshold of 0.08. Nonetheless, this comprehensive analysis confirmed that, on the whole, the T21C scale demonstrated acceptable model fit, thereby supporting its validity as a measurement tool for assessing T21C (Bentler, 1990; Bentler & Bonett, 1980; Brown, 2015; Browne & Cudeck, 1993; Hu & Bentler, 1999).

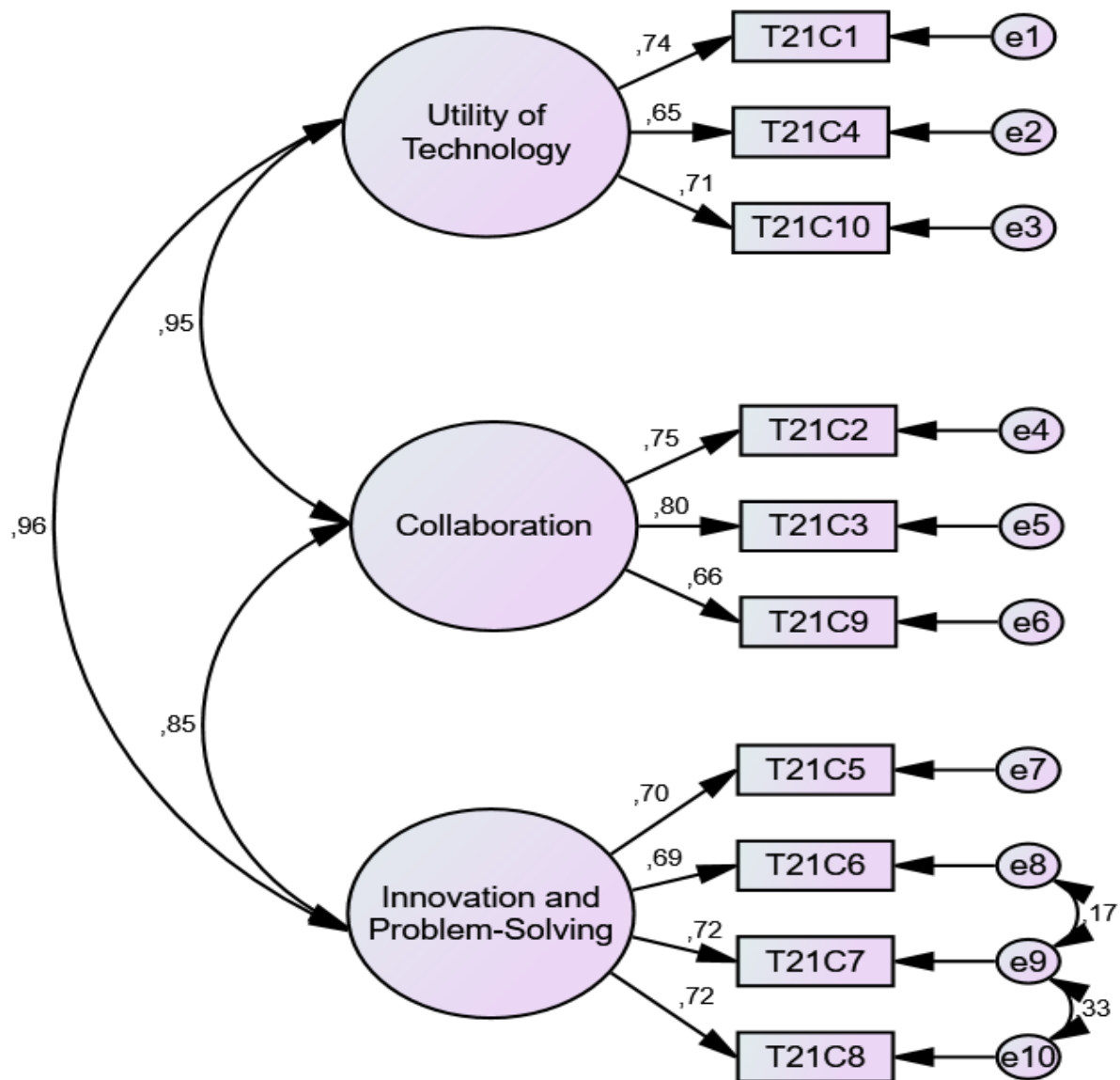


Figure 3. The roadmap of CFA results for the T21C scale

The CFA results for item analysis for the T21C scale are presented in Table 5 with the estimates, S.E., C.R., and p-values for each item. Accordingly, the UOT construct with all three items (UOT1, UOT2, UOT3) demonstrated strong and statistically significant relationships with the latent construct and p-values less than 0.001, which indicated that these items effectively measured the UOT construct within T21C. Similarly, for the CO construct, all three items (CO1, CO2, CO3) exhibited significant and robust loadings on the latent variable, evidenced by p-values less than 0.001, which suggested that these items accurately captured the CO construct in T21C. Lastly, for the IP construct, all four items (IP1, IP2, IP3, IP4) displayed highly significant

associations with the latent construct, as detected by p-values less than 0.001, which showed that these items effectively measure the IP construct within T21C. Overall, the CFA results for the T21C scale confirmed that the measurement items had strong and significant relationships with their respective latent constructs and supported the validity of the measurement model (Brown, 2015).

Table 5. Item loadings of the T21C scale

	Items		Estimate	S.E.	C.R.	p
UOT1	<---	UOT	.738			
UOT2	<---	UOT	.651	.074	12.364	***
UOT3	<---	UOT	.709	.071	13.521	***
CO1	<---	CO	.755			
CO2	<---	CO	.804	.069	15.080	***
CO3	<---	CO	.663	.061	12.411	***
IP1	<---	IP	.703			
IP2	<---	IP	.694	.099	12.044	***
IP3	<---	IP	.723	.088	12.362	***
IP4	<---	IP	.718	.091	12.415	***

***p<0.001

After the CFA confirmation of the DL and T21C scales, the possible correlation between DL and T21C mean scores was investigated to test the formulated hypotheses. Accordingly, the Pearson correlation test was performed to explore the relationships between these scores, and the results of the analysis are demonstrated in Table 6.

Table 6. Relationship between DL and T21C

	T21C		UOT		CO		IP	
	r	p	r	p	r	p	r	p
DL	.543**	.000	.581**	.000	.439**	.000	.452**	.000

**p<0.01

The analysis in Table 6 revealed several statistically significant positive correlations between the construct DL and various components of T21C. Firstly, a substantial and positive correlation also existed between pre-service teachers' DL and the broader construct of T21C ($r=0.543$; $p<0.01$), which signified that as their DL levels rose, there was a corresponding inclination towards enhanced proficiency in T21C. Secondly, there was a substantial and positive correlation between pre-service teachers' DL and the perceived UOT ($r=0.581$; $p<0.01$), which implied that as pre-service teachers' level of DL increased, they tended to be more capable of using technology more beneficially while teaching 21st-century skills. Furthermore, a significant positive correlation was also observed between pre-service teachers' DL and CO ($r=0.439$; $p<0.01$), which suggested that as their DL improved, there was a concurrent tendency for increased CO skills within the context of T21C. Similarly, a significant positive correlation emerged between pre-service teachers' DL and IP ($r=0.452$; $p<0.01$), which indicated that heightened DL corresponded to a proclivity for greater IP capabilities. Overall, the results demonstrated a clear and significant relationship between the DL levels of teacher candidates and their capacity to effectively teach 21st-century skills.

Before testing the hypotheses, the risk of multicollinearity between independent variables in the regression analysis was controlled to ensure the statistical robustness of the model. To examine the presence of multicollinearity, collinearity statistics were evaluated for the independent variable DL across three regression models as presented in Table 7. The variance inflation factor (VIF) was calculated as 1.000, and the tolerance value was found to be 1.000 in all the models, which indicated no multicollinearity issue. Based on widely accepted criteria, multicollinearity was not a concern in the analysis, as the VIF values were below 5 and the tolerance values exceeded 0.20 (Hair et al., 2009). The results confirmed that DL did not exhibit any collinearity problems when predicting UOT, CO, and IP, which supports the statistical robustness of the regression models.

Table 7. Correlation and collinearity statistics between DL and sub-factors of T21C

Dependent Variables (T21C)	Independent Variable	Correlations			Collinearity Statistics	
		Zero-order	Partial	Part	Tolerance	VIF
UOT	DL	0.581	0.581	0.581	1.000	1.000
CO	DL	0.439	0.439	0.439	1.000	1.000
IP	DL	0.452	0.452	0.452	1.000	1.000

Finally, the impact of pre-service teachers' DL on their T21C was examined to test the formulated hypotheses. The path diagram is depicted in Figure 4, and the results of the regression analysis are presented in Table 8 along with the beta coefficients (β), S.E., C.R., and p-values.

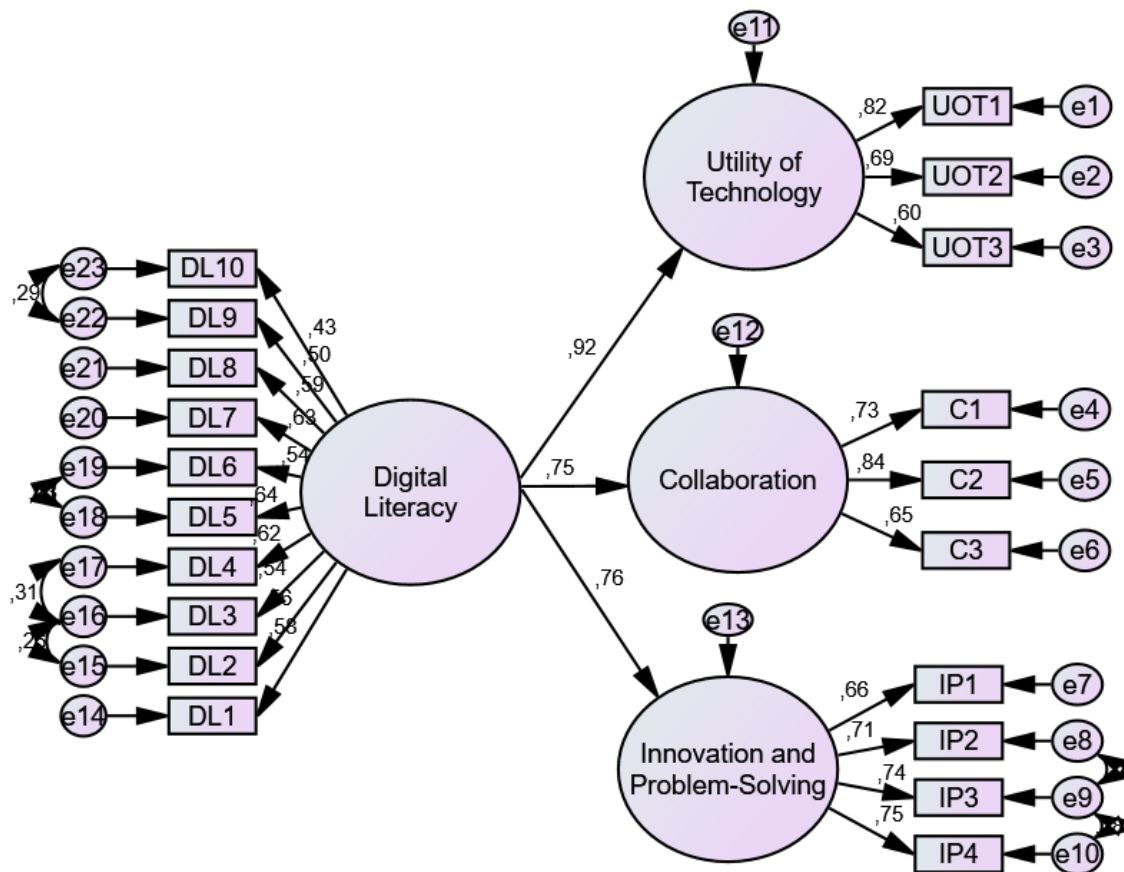


Figure 4. The path diagram for DL and T21C

As illustrated in Figure 4 and Table 8, H_1 posited that pre-service teachers' DL would positively influence their capabilities in the UOT aspect of T21C. The results strongly supported this hypothesis with a significant positive effect observed ($\beta=0.916$; $p<0.001$), which indicated that higher DL levels were associated with a greater perceived UOT in T21C. H_2 proposed that pre-service teachers' DL would positively influence their capabilities in CO when teaching 21st-century skills. This hypothesis was also substantiated by the data as a significant positive effect was detected ($\beta=0.750$; $p<0.001$), which signified that increased DL corresponded to enhanced CO skills in the context of teaching 21st-century skills. Similarly, H_3 suggested that pre-service teachers' DL would positively impact their capabilities in IP of T21C. The findings confirmed convincing evidence in favor of this hypothesis by revealing a significant positive effect ($\beta=0.759$; $p<0.001$), which proved that higher levels of DL were associated with increased proficiency in fostering innovation and problem-solving skills while teaching 21st-century skills.

Table 8. Results of DL impact on T21C

T21C			β	S.E.	C.R.	p
CO	<---	DL	.750	.177	9.158	***
IP	<---	DL	.759	.152	8.659	***
UOT	<---	DL	.916	.194	11.053	***

*** $p<0.001$

In summary, the results confirmed the acceptance of all three hypotheses and demonstrated that pre-service teachers' DL indeed positively influenced their capabilities in UOT, CO, and IP when teaching 21st-century skills. Notably, it was revealed that DL had the most substantial impact on the UOT variable, whereas its effects on CO and IP skills were relatively similar.

DISCUSSION

DL has emerged as a fundamental component of teaching and learning across various educational stages and has notably been emphasized within the realms of open, distance, and digital education since the late 20th century (Marin & Castaneda, 2023); therefore, it has become critical, especially for T21C. In this respect, this study investigated the DL and teaching aptitude for

21st-century skills among pre-service teachers in addition to examining whether their DL level has an impact on their ability to teach these skills.

The results of the descriptive analyses to find out the pre-service teachers' DL levels revealed that the majority of pre-service teachers exhibited a moderate level of DL, but with a smaller proportion falling into the categories of low or high DL. Even though a relatively balanced distribution of DL skills within the sample was evident, it is significant to provide targeted interventions or support tailored to individuals with lower or higher levels of DL. This aligns with the existing literature that emphasizes the importance of assessing and enhancing DL among pre-service teachers as well as educators (Kara & Mede, 2023; Singh et al., 2022; Usart et al., 2024) because DL facilitates the ability to use digital technologies effectively to support a variety of processes such as learning, problem-solving, and information retrieval (Ng, 2012). Usart et al. (2014) also highlighted the significance of the knowledge about the digital proficiency of pre-service teachers because it enables faculties of education to formulate future initiatives aiming to enhance this critical skill with specifically tailored requirements and characteristics of individual students.

Concerning pre-service teachers' capabilities of T21C in terms of UOT, CO, and IP, the overall level of T21C was detected as moderate, while the majority of pre-service teachers had a moderate level of capabilities in UOT, CO, and IP, but a smaller proportion was categorized as low or high. These findings suggest the need for teacher education programs to focus on not only traditional pedagogical methods but also cultivating digital navigation and integration skills among pre-service teachers. Diquito et al. (2022) identified pre-service teachers with a high level of acquisition of 21st-century skills, including "digital literacy, collaboration, social skills, creativity, communication, critical thinking skills, and leadership" (p. 59). Especially, CO and IP skills, as evident in this study, must be emphasized more in teacher education since these skills are beneficial in addressing complex challenges in technology-based learning environments. Consistently, Caena and Redecker (2019) pointed out the need for innovative pedagogies that leverage technology to address 21st-century issues, encourage peer learning among educational systems worldwide, and spark the growth of critical transversal competencies such as creativity, collaboration, and problem-solving.

Finally, the effect of pre-service teachers' DL on their capabilities of T21C was examined, and the findings identified a significantly substantial and positive correlation, which means that as their DL levels increased, there was a corresponding tendency towards their enhanced proficiency in T21C including the constructs of UOT, CO, and IP. In other words, pre-service teachers' DL positively affected their capabilities in UOT, CO, and IP when teaching 21st-century skills. However, it is notable that DL had the most substantial impact on the UOT variable, whereas its effects on CO and IP were found relatively similar. These findings align with the existing literature emphasizing the crucial role of DL in enhancing teaching practices (Arstop, 2021; Brown, 2015; Campbell & Kapp, 2020; Darling-Hammond, 2017). Niyazova et al. (2023), in their study investigating the relationship between pre-service teachers' digital skills and ICT competency as one of the 21st-century skills, similarly detected a positive correlation among these variables and pointed out the significance of tailored strategies for the promotion of digital and ICT skills to meet the demand in the 21st century. Due to the positive effect of pre-service teachers' DL on T21C, teacher education programs should effectively meet the needs of pre-service teachers with varying levels of DL and ensure that they are well-equipped in terms of DL and T21C to fulfill the potential of digital technologies with appropriate pedagogical practices in their future teaching careers.

CONCLUSIONS AND IMPLICATIONS

This study examined pre-service teachers' DL, their teaching aptitude for 21st-century skills, and whether their DL level has an impact on their ability to teach these skills. The findings proved the significance of pre-service teachers' DL in T21C. The results contribute to the existing literature on the relationship between pre-service teachers' DL and their capabilities in T21C. It was found that integration of DL skills development into teacher education programs prepares educators better for the demands of the 21st-century classroom. The necessity was implied for professional development to continually enhance pre-service teachers' capabilities in digital pedagogies so that rapid technological developments are followed in a synchronized way.

As evident in this research, pre-service teachers should be provided with digital competencies and pedagogies to effectively integrate digital tools into their teaching practices so that their students are engaged and empowered to succeed in the 21st century. This can be achieved by transforming teacher education with a focus on digital pedagogies. Starkey (2020) pointed out, in her review on teacher preparation in the digital age, that technology integration into all the courses in the curricula is significant by recommending that pre-service teachers' DL should be considered and a variety of pedagogical practices should be offered in teacher education programs.

Teaching practices can be changed by incorporating 21st-century skills into instruction (Meneses et al., 2023). Therefore, traditional pedagogical approaches should be re-evaluated after digital pedagogies are adapted into the curricula of teacher education programs. The integration process of DL and 21st-century skills into teacher education should involve theoretical and practical knowledge through technical training and the development of skills such as critical thinking, creativity, collaboration, and communication within the digital environment. Accordingly, the comprehensive incorporation of digital technologies into teaching and learning processes can result in changes in classroom dynamics, interpersonal connections, and instructional

practices, which potentially disrupt traditional teacher patterns (Christopher Blundell & Nykvist, 2019). Thus, pre-service teachers and practitioners should be equipped with the necessary skills and strategies so that they can effectively navigate these changes and leverage digital technologies to enhance learning outcomes.

Based on the DL level of pre-service teachers, considerable opportunities for mentorship and ongoing professional development should be arranged to continuously enhance their DL and instructional abilities. Thereby, teacher education programs can hold a crucial function in shaping the future of education by investing in the digital readiness of pre-service teachers and promoting the adoption of digital pedagogies as well as making students succeed in a rapidly evolving technological landscape.

Limitations and Future Considerations

In the interpretation of the findings of the present study, some limitations should be considered, resulting from the sampling population of the study. Because of the implementation of convenience sampling, the respondents may not represent the international characteristics of pre-service teachers. Moreover, the digital advancements in the country may also be at different levels compared with the internationally recognized standards. Therefore, it is recommended for future research to sample a wider profile with more international characteristics and consider contextual factors. Another limitation of the study is related to the demographic composition of the sample, which may affect the generalizability of the findings. The sample included a disproportionately high number of female participants (76.5%), which can raise the risk of gender bias in interpreting pre-service teachers' DL and capabilities for T21C. The gender imbalance in the sample, with a majority of female participants, may reflect broader societal trends in which women are more likely to select teaching as a profession.

As the questionnaire was distributed via an online platform, the sample may be biased towards pre-service teachers with better access to digital tools and internet connectivity. This limitation could have led to the overrepresentation of individuals with higher levels of DL, which can potentially influence the generalizability of the results.

Despite the overall robustness of the statistical analyses and acceptable model fit indicators, one limitation of the study may result from the marginal values observed in the CFA for the T21C scale. Specifically, the RMSEA value of 0.08 and the RMR value of 0.07 fell within the threshold of borderline acceptability. While these indices were still considered within acceptable limits (Browne & Cudeck, 1993; Hu & Bentler, 1999), they suggested that the model fit may not be optimal. This borderline fit could be attributed to the complexity of the construct being measured or to sample-specific characteristics such as the large proportion of female participants and the convenience sampling method used. Therefore, future research may benefit from refining the model and validating the scale with a more diverse and balanced sample. For further considerations, mixed-method studies can provide a better understanding of the research topic, such as analyzing pre-service teachers' DL and the existing curricular components in teacher education programs through the lens of 21st-century skills.

Ethics and Consent: Ethical approval for this study was obtained from Istanbul Technical University the Board of Ethics for Human Studies in Social Sciences and Humanities on 30.03.2023 with project number 346.

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