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Adaptation of the Digital Teaching Competence Scale (DTCS) to Turkish: Reliability, validity, measurement invariance and latent mean difference tests

Dijital Öğretim Yeterlik Ölçeği'nin (DTCS) Türkçeye uyarlanması: Güvenirlik, geçerlik, ölçüm değişmezliği ve gizil ortalama fark testleri

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Abstract: There has been a growing focus in educational research on teachers' digital teaching competence. To freshen the relevant literature, this study analyzed the factorial structure of the Turkish version of the digital teaching competence scale (DTCS). We used confirmatory factor analysis to analyze the data collected from 611 primary school teachers in Türkiye who responded to a 32-item DTCS. We also performed tests of measurement invariance and latent mean differences. After deleting three items based on the CFA results, we found an acceptable fit for a 5-factor, 29-item DTCS model, which also demonstrated an acceptable level of internal consistency for each factor and the entire scale. This study supported the measurement invariance of the 29-item DTCS, and the tests of latent mean differences indicated statistical significance in factor score differences across gender, teaching experience, school location, having a multigrade class, and daily use of the Internet. This study contributes to the literature by providing new insights into the digital teaching competence of primary school teachers through the validation of the DTCS in a culturally distinct context from those previously reported.

Keywords: *Digital teaching competence, confirmatory factor analysis, measurement invariance, latent mean difference, primary school teachers*

Özet: Eğitim araştırmalarında öğretmenlerin dijital öğretim yeterliğine yönelik artan bir ilgi bulunmaktadır. Bu alanyazına güncel katkı sunmak amacıyla, bu çalışmada Dijital Öğretim Yeterliği Ölçeği'nin (DTCS) Türkçe formunun faktör yapısı incelenmiştir. Türkiye'de görev yapan 611 ilkokul öğretmeninden toplanan veriler, 32 maddelik DTCS üzerinden doğrulayıcı faktör analizi (DFA) ile analiz edilmiştir. Ayrıca, ölçme değişmezliği ve gizil ortalama farklılıklarına ilişkin testler gerçekleştirilmiştir. DFA sonuçlarına göre üç madde çıkarıldıktan sonra, beş faktörlü ve 29 maddelik DTCS modelinin kabul edilebilir uyum düzeyine sahip olduğu ve her bir faktör ile ölçeğin genelinin iç tutarlılık düzeylerinin yeterli olduğu belirlenmiştir. Çalışma, 29 maddelik DTCS'nin ölçme değişmezliğini desteklemiş ve gizil ortalama farklılıkları testleri, cinsiyet, öğretmenlik deneyimi, okulun konumu, birleştirilmiş sınıf durumu ve günlük internet kullanımı gibi değişkenlere göre faktör puanlarında istatistiksel olarak anlamlı farklar olduğunu göstermiştir. Bu çalışma, daha önceki araştırmalardan kültürel olarak farklı bir bağlamda DTCS'nin geçerliliğini ortaya koyarak, ilkokul öğretmenlerinin dijital öğretim yeterliğine ilişkin literatüre katkılar sunmaktadır.

Anahtar Kelimeler: *Dijital öğretim yeterliği, doğrulayıcı faktör analizi, ölçme değişmezliği, gizil ortalama farkı, ilkokul öğretmenleri*

1. Introduction

Technological advancements have affected all areas of society, including education, where teachers increasingly use digital tools. Studies in education intend to provide insights into successful teaching practices, and recent evidence (Flores, 2020; Goodwin, 2020; Redecker, 2017; ISTE, 2017; OECD, 2019) underscores the importance of digitally

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enhanced teaching activities and pedagogies. Although technology integration is common in education, its rapid evolution makes it more complex and demanding for teachers. In this scenario, teachers must maintain current digital skills and competences to effectively employ technology in their teaching activities.

The reality of digital change in education is undeniable, so are digital teaching competences of teachers. Digital teaching competence (DTC) expands on digital competence and refers to the skills teachers need to carry out their instructional duties effectively (Revuelta-Domínguez et al., 2022). Frameworks such as those by Cabero-Almenara et al. (2020) guide teachers on the skills required and how to apply them in digital teaching. However, the practice of these skills in educational settings still needs exploring in different contexts to unfold necessary initiatives and improvements (Cabero-Almenara et al., 2023; Falloon, 2020; Revuelta-Domínguez et al., 2022). The very first step for further inquiry involves examining the degree of digital teaching competences among teachers; therefore, this study wishes to adapt DTC scale into Turkish and conduct detailed analysis.

2. Literature Review

2.1. Digital Competence

Digital competence refers to the knowledge and skills needed to effectively integrate digital resources into teaching (Gudmundsdottir & Hatlevik, 2018; Hall et al., 2014). Klochko and Prokopenko (2023) explain the components of a teacher's digital competence, including ICT literacy and knowledge, while Skantz-Åberg et al. (2022) conceptualize it by integrating pedagogies. Global literature consistently highlights the importance of digital competence and encourages teachers to improve their digital teaching skills (Flores, 2020; Goodwin, 2020; Redecker, 2017; ISTE, 2017; OECD, 2019) underscore the power of digital competence for teachers and encourage them to enhance their capabilities in digital teaching.

Strengthening teachers' digital competences is essential to increase student engagement, reduce the digital divide, and promote digital literacy (Klochko & Prokopenko, 2023). Furthermore, studies support ongoing research and training to equip teachers with the latest technologies, emphasizing digital content and course design, delivery, and practice (Liesa-Orus et al., 2023; Kasule et al., 2023) Digital technology plays a key role in shaping teacher quality and supporting effective, personalized learning. Therefore, teachers are called to reshape their competence profiles and teaching strategies to align with digital trajectories (Caena & Redecker, 2019).

2.2. Harnessing Teachers' Digital Competence in Teaching: Digital Teaching Competence

Digital teaching competence refers to the essential skills and knowledge educators need to use technology effectively in their teaching. Discussions on DTC have become highly popular and important in educational studies, both to provide deeper understanding and to offer implications for teaching (Cabero-Almenara et al., 2023). Teachers are primarily responsible for creating structured learning environments and opportunities that support student development (Caena & Redecker, 2019). In this sense, digital resources are powerful mediators that allow them to design and deliver explicit instructional activities. Therefore, teachers need strong digital teaching skills to effectively integrate technology into their instruction.

Previous research has established that effective digital teaching has a variety of key components that are similar to digital competences. To exemplify this, teachers should regularly update their digital competences through training (Castañeda et al., 2022; Falloon, 2020). Teachers should adapt their digital teaching by using interactive activities, authentic designs for varied learning styles, real-time feedback, and strategies that promote student engagement (Goodwin, 2020; Redecker, 2017). These conclusions indicate that the more teachers have digital competences the more likely they are to be proficient in digital teaching.

2.3. Landscapes on Teachers' Digital Teaching Competence

In the last decade, many frameworks have been developed to help teachers integrate technology more effectively into education. The European Union's DigCompEdu framework examines the digital teaching competence (DTC) of teachers (Cabero-Almenara et al., 2023), whereas the Higher Education Digital Competence (HeDiCom) framework specifically addresses factors such as teaching practice and professional growth in higher education (Hijón-Niera et al., 2023; Tondeur et al., 2023). TPACK and SAMR are widely used in teacher education programs focused on digital competence (Tondeur et al., 2023), in addition to these specific frameworks. These frameworks emphasize collaboration, technical and professional skills, and effective teaching methods (Mattar et al., 2022). All these introduced frameworks and models serve as leading grounds for educators to enhance teachers' digital teaching competences and capacities as well as measuring these competences.

Together with other researchers, Gao and associates (2023) proposed a five-section scale to assess teachers' digital teaching competences. The dimensions encompassed in this context are digital teaching design competence, digital teaching implementation competence, digital teaching evaluation competence, digital teaching responsibility, and digital teaching attitude. These dimensions align with different phases of instruction. Digital teaching involves teachers making deliberate choices about goals, lesson plans, and resources. The second dimension, digital teaching implementation, takes place during the process of teaching. The evaluation of digital teaching occurs both during and after the teaching procedure itself. Throughout these stages, teachers can engage in immediate feedback sessions and evaluate students' performances via digital tools. The fourth component pertains to the teachers' ethical conduct, while the fifth dimension relates to their behaviors in digital procedures.

By proposing such a scale, Gao et al. (2023) underscores the necessity of the set of skills and attitudes for effectively using technology in the context of teaching They provide a systematic framework for researchers to assess teachers' proficiency and attitudes in digital teaching, consistent with pedagogical principles. Hence, our study drew inspiration from the DTC scale measures proposed by Gao et al. (2023) throughout the development of the instrument.

2.4. Demographics Variables' Roles in the Teachers' Digital Teaching Competence

Recently, considerable evidence has accumulated to show how teachers are competent in digital teaching. Guillén-Gámez et al. (2021) found notable differences between teachers' digital knowledge and their actual use of digital tools. Additionally, they conclude that teachers' age and gender have an impact on predicting their digital teaching competence levels. Gil-Flores et al. (2017) examined how teacher characteristics and school infrastructure affect technology integration in classrooms. Their study shows that school-based opportunities (hardware, internet connection etc.) have no connection to teachers' use of technology in their classrooms. Their study also showed that male teachers use technology more often than female teachers, a finding supported by other research (Grande-de-Prado et al., 2020; Rodríguez-García et al., 2022; Zhao et al., 2021). Additionally, more years of experience were linked to lower use of digital tools in teaching.

There are also studies (Méndez et al., 2022; Pera et al., 2022; Yemchuk, 2022) highlighting the positive impact of teaching experience on digital teaching competences. Though it is not directly focus on digital teaching competence, Krumsvik et al. (2016) underline the effects of teachers' age, years of experience, gender, and ICT training on predicting their digital competence. Also, studies focusing on the impact of internet use on digital teaching competences (Gudmundsdottir & Hatlevik, 2018; Iglesias-Rodríguez & García-Riaza, 2016; Yemchuk, 2022; Yurkiv, 2022) have reached the conclusion that teachers' digital teaching practices are influenced by their daily use of the Internet.

Teaching in rural or multigrade classrooms presents additional challenges. Most of the teachers come from urban areas (Barajas et al., 2005), where they have certain knowledge and capacity to use technology in teaching. However, these teachers have to take on more work than their colleagues in urban areas, where the workload is lower and technology-based facilities are more accessible. The demands of learners' profiles, school settings, and teacher-related factors in such an environment should reshape teachers' digital competences (Barajas et al., 2005). Studies (Imasiku et al., 2022; Taole, 2024) often emphasize that multigrade settings, time constraints, limited resources, and lack of local support hinder teachers' ability to integrate technology.

Thus far, a number of studies have examined types of factors that are related or predict teachers' digital competences and pedagogical implications. Therefore, we see increased impetus for further research in examining potent variables affecting primary school teachers' digital teaching competences in Turkish context to enrich the relevant literature with fresh insights.

2.5. Purpose of the Study

The study aimed to examine the factor structure of the Turkish DTCS among a sample of primary school teachers. Additionally, it sought to determine whether there were any measurement invariances or latent mean differences in the DTCS scores based on variables such as gender, years of teaching experience, school location, having a multigrade class, and daily Internet use. Consequently, the present study did not establish precise hypotheses, but instead posed them as research questions:

1. What is the factorial structure of the DTCS when applied to a sample of primary school teachers in Türkiye?
2. Is the DTCS invariant by gender, years of teaching experience, school location, having a multigrade class, and daily use of the Internet?
3. Are there significant differences in the factor mean scores of the DTCS by gender, years of teaching experience, school location, having a multigrade class, and daily use of the Internet?

3. Method

3.1. Participants

A total of 611 primary school teachers from different region in Türkiye participated in this study. Over half of the participants (71.2%) were female primary school teachers, and the average age of all of them was 32.465 (SD = 7,848, Min = 20, Max = 66). 30% of them worked in rural areas and 12.1% had multigrade classes. The mean of teaching experience was 8.687 (SD = 8.116, Median = 6, Min = 1, Max = 16), and it was 3.815 (SD = 2.046, Median = 3, Min = 1, Max = 16) for daily Internet use. Table 1 shows the demographic profiles of primary school teachers.

In structural equation modelling (SEM), minimum sample size is associated with the number of observed and latent variables, minimum effect, power, and significance (Westland, 2010). Minimum sample size for this study was calculated as 376 by using the web agent, developed by Soper (2021), with 0.2 effect size, 0.8 statistical power, and 0.05 probability level. These estimations confirm that number of participants in the study is suitable.

Table 1

Demographic Information about the Primary School Teachers

Characteristic	Category	N	%
Gender	Male	176	28.8
	Female	435	71.2
Teaching experience	High (> 6)	295	48.3
	Low (≤ 6)	316	51.7
School location	Urban area	428	70.0
	Rural area	183	30.0
Having multigrade class	Yes	74	12.1
	No	537	87.9
Daily use of the Internet	High (> 3)	289	47.3
	Low (≤ 3)	322	52.7

Note. N = number of respondents; % = percentage of participants.

3.2. Instrument

The measurement used in this study is the DTCS developed by Gao et al. (2023). It is a self-report tool intended to gauge the opinions of primary and secondary teachers regarding their competency in digital teaching. Gao and colleagues developed and assessed the DTCS with a total sample of 1047 primary and secondary teachers. A 32-item, five-component scale was developed based on the findings of the exploratory (n = 473) and confirmatory factor analyses (n = 574). The factors include digital teaching design competence (six items: e.g. "I can design instructional activities that integrate digital technology resources"), digital teaching implementation competence (seven items e.g. "I can use digital technology to organize teaching activities and increase student participation"), digital teaching evaluation competence (seven items: e.g. "I can reasonably select and use digital tools to collect academic performance of students"), digital teaching responsibility (six items: e.g. "I can abide by the Internet laws and regulations, consciously regulate online behavior") and digital teaching attitude (six items: e.g. "I recognize that digital technology can drive innovation in education"). Higher scores indicate higher levels of digital teaching competence. Gao et al. (2023) found that the internal consistency was high, as indicated by Cronbach's alpha values ranging from .880 to .904.

Participants in this study provided their responses to the Turkish version of the DTCS. The items underwent a translation and back-translation process to confirm the validity of the scores received from the Turkish DTCS. Two linguists from the faculty were asked to perform the task of translating the English items into Turkish. Upon the conclusion of the translation process, three experienced primary school teachers were invited to collaborate and deliberate on the Turkish version of the data collection instrument, with the aim of rectifying any potential errors. Following, the Turkish version of the measurement tool was forwarded to a proficient bilingual expert who had not previously scrutinized the initial English items. The expert was then requested to render a translation of the Turkish version back into English. A comparison and clarification of the original and translated versions of the questionnaire were conducted. Consensus was achieved on 20 items in the survey. The survey questions employed a 5-point Likert scale (1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=strongly agree) to rate the level of agreement among participants with the items. The survey is listed in Appendix 1.

3.3. Procedure

Before commencing the study, ethical approval was obtained from the Human Research Ethics Board. On ethical approval, the measurement tools were compiled on the Google Forms platform. The data were collected via online responses. Using social networks, participants were sent a link to respond to the online items. Participants who agreed to participate first filled out the consent form, then rated the items in the survey, including sociodemographic section.

To be consistent with ethical issues, the study was based on eagerness; therefore, all the participants voluntarily participated in the study and responded to the data collection tools. Before data collection, participants received an explanation about the study. They were literally informed that they did not have to fill out the survey and/or could withdraw at any stage of the study. Data collection was conducted anonymously and participants were not offered any rewards or financial incentives.

3.4. Data Analysis

Although the recommended practice in scale validation involves conducting an exploratory factor analysis (EFA) prior to confirmatory factor analysis (CFA), this study directly employed CFA for several reasons. First, the DTCS has an established and theoretically grounded five-factor structure, as proposed and validated by Gao et al. (2023). Second, the aim of this study was not to explore new dimensions but to test the applicability and validity of the existing structure in a Turkish context. Therefore, CFA was deemed appropriate to assess the model fit and confirm the factorial structure. This approach aligns with previous validation studies that utilize CFA when adapting well-established instruments to new populations.

Because the DTCS is an established measure with a fixed factorial structure, confirmatory factor analysis (CFA) was conducted to examine the structure of the DTCS (Finch & French, 2015). CFA was performed using lavaan package (Rosseel, 2012) with R. There are various methods for estimating the parameters of the model tested with CFA. Among these methods, the most frequently used method is Maximum Likelihood (ML). However, to use this method, the data must meet the assumption of multivariate normality (Kline, 2016). As suggested by Gana and Brock (2019), the assumption of multivariate normality was made by examining Mardia's kurtosis coefficient. The results of the Mardia test showed that multivariate normality was not achieved ($b2d = 1339.075$, $z = 66.552$, $p<.000$). In cases where multivariate normality cannot be achieved, ML estimates the standard errors of the model parameters incorrectly. Therefore, following Gana and Broc (2019), the Robust Maximum Likelihood (MLR) estimator was used instead of the ML estimator to estimate the parameters and fit indices of the model. Different indices and threshold values were used to evaluate the goodness of fit of the model. The ratio of chi-square to degrees of freedom ($\chi2/df$) < 3.00 (Kline, 2016); root mean square error of approximation (RMSEA) < .08 and Standardized root mean residual (SRMR) < .06 (Hu & Bentler, 1999); comparative fit index (CFI) > .90 and Tucker-Lewis's index (TLI) > .90 (Hair et al., 2019). Subsequently, the psychometric properties of DTCS were examined in terms of validity and reliability. To this end, Cronbach's alpha, Composite Reliability (CR), McDonald's omega and average variance extracted (AVE) values were examined. All these values were obtained from the reliability function of the semTools package.

Using multi-group CFA analysis, measurement invariance across gender, teaching experience, school location, having multigrade class, and daily use of the Internet was tested with a sequence of configural invariance, metric invariance, and scalar invariance tests (Brown, 2015). The first step is to test a base model that includes cross-group equivalence of the factor structure. This stage, known as the configural invariance (CI) test, is the least restrictive model in which no equality restrictions are placed on the groups. In other words, if the CI shows good fit, the underlying factor structure is equivalent across groups. If CI is achieved, the next stage to evaluate is measurement invariance (MI). MI refers to the situation where factor loadings are equivalent across groups. The presence of MI means that latent variables are measured in the same way for members of the population subgroups under study (Kline, 2016). A nonsignificant $\Delta\chi2$ statistic was performed comparing the MI against the CI model, ΔCFI ≤ .01, ΔRMSEA ≤ .015, and ΔSRMR ≤ .03 indicates measurement invariance across different groups (Chen, 2007). After establishing metric invariance, scalar invariance (SI) was tested. SI assumes cross-group equivalence of factor loadings and item intercepts. When the SI is valid, it can be concluded that any mean differences in observed indicators between groups are due to differences in the latent variable mean (Finch & French, 2015). A nonsignificant $\Delta\chi2$ statistic was performed comparing the SI against the MI model, ΔCFI ≤ .01, ΔRMSEA ≤ .015, and ΔSRMR ≤ .01 indicates measurement invariance across different groups (Chen, 2007). If full scalar invariance is not achieved, partial scalar invariance can be tested by removing the restriction on the intercept of each item to identify non-invariant items (Brown, 2015). If partial scalar invariance is achieved, further invariance tests can be performed or latent means can be compared (Steenkamp & Baumgartner, 1998).

In the end, the latent means scores were examined for the factors of gender, teaching experience, school location, having a multigrade class, and everyday Internet use. When comparing the average values of latent means between different groups, it is necessary to set the average value to zero in one of the groups in order to accurately determine the model. This comparison does not allow for the estimation of the exact average in each group, but instead estimates the difference in average values of the latent variables between the groups. The latent mean comparisons were conducted using the z-value. A large z-value for the mean difference implies significant statistical differences in the means ($p < 0.05$).

4. Results

4.1. Descriptive Statistics

The scores for all thirty-two items in the DTCS were examined for their distributional properties with means and standard deviations ranged from 3.445 to 4.607 and 1.006 to 1.229, respectively. Almost all the mean scores of the structures for the entire sample were higher than the mid-point. Similarly, the standard deviation of all variables was less than 1.230. The skewness and kurtosis values were between −1.988 and 4.528 and within the acceptable limits of |3| and |8| in support of univariate normality (Kline, 2016).

4.2. Confirmatory Factor Analysis

An initial CFA analysis of the five-factor, 32-item model revealed a poor fit ($\chi2$=1481.854, df=454, p<.001; $\chi2$/df=3.264; TLI=.899; CFI=.907; RMSEA=.061, 90% CI [.058-.064]; SRMR=.053. In accordance with Brown's (2006) recommendation, an examination of the matrix of standardized residual covariances was conducted to identify any localized areas of ill fit, indicated by standardized covariances of residuals over 2.00. It was found that DTI5 “I deal with emergencies caused by technical glitches during lessons”, DTI6 “I construct mind maps and generalize knowledge structures through techniques” and DTI7 “I encourage all students to actively participate in the formalized lessons” were found to have the highest number of covariances of residuals with values greater than 2.00. As a result, these three items were excluded from further analysis. A further test on the remaining 29-item with three error covariances (DTI1~~DTI2, DTE1~~DTE2, and DTID1~~DTID2) revealed a well-fitting model ($\chi2$=1073.431, df=364, p<.001; $\chi2$/df=2.949; TLI=.923; CFI=.931; RMSEA=.056, 90% CI [.053 - .060]; SRMR=.048). The inter-factor correlation among the five factors ranges from .403 to

.746. Since there were significant relationships among the five factors, a second-order CFA was conducted to see whether the digital teaching competence, which is the second-level latent factor, could explain these five structures. Second-order CFA analysis revealed a good fit ($\chi2=1245.780$, $df=369$, $p<.001$; $\chi2/df=3.376$; TLI=.907; CFI=.915; RMSEA=.068, 90% CI [.064-.073]; SRMR=.078).

The reliability and validity of the items used to measure each variable were assessed using statistical measures such as Cronbach's alpha (α), Composite Reliability (CR), McDonald's omega, and average variance extracted (AVE). The items are considered reliable and valid when the Cronbach's alpha, Composite Reliability (CR), and McDonald's omega (ω) levels exceed .70, and the Average Variance Extracted (AVE) is above .50 (Hair et al., 2019). Furthermore, it is anticipated that the factor loading for item reliability in each design will be equal to or greater than .50 (Hair et al., 2019). Table 2 presents compelling evidence of the items' robust reliability and validity.

Table 2

Results of the CFA

Construct	Item	Standardized factor loading	α	ω	CR	AVE
Digital Teaching Instructional Design (DTID)	DTID1	.669	.914	.897	.898	.630
	DTID2	.811				
	DTID3	.837				
	DTID4	.802				
	DTID5	.860				
	DTID6	.805				
Digital Teaching Implementation (DTI)	DTI1	.762	.872	.841	.838	.610
	DTI2	.792				
	DTI3	.795				
	DTI4	.775				
Digital Teaching Evaluation (DTE)	DTE1	.765	.937	.926	.926	.665
	DTE2	.752				
	DTE3	.808				
	DTE4	.790				
	DTE5	.841				
	DTE6	.884				
	DTE7	.855				
Digital Teaching Responsibility (DTR)	DTR1	.734	.888	.889	.889	.574
	DTR2	.772				
	DTR3	.846				
	DTR4	.706				
	DTR5	.716				
	DTR6	.779				
Digital Attitude (DA)	DA1	.704	.883	.878	.883	.560
	DA2	.837				
	DA3	.820				
	DA4	.674				
	DA5	.727				
	DA6	.749				

Note. α: Cronbach's alpha; ω: McDonald's omega; CR: Composite Reliability; AVE: Average variance extracted.

4.3. Tests of Measurement Invariance and Latent Mean Differences

Statistical analyses were conducted using the R programming to assess multigroup invariance. The estimations were performed using Robust Maximum Likelihood (MLR) methodology. Multiple hierarchical orderings of nested models exist for measurement invariance, including configural invariance, metric invariance, and scalar invariance. The results of all models are reported in Table 3.

Table 3

Invariance Models

Model	χ2	df	Δχ2	Δdf	CFI	RMSEA	SRMR	ΔCFI	ΔRMSEA	ΔSRMR
Invariance across genders										
M1	1547.688	728	–	–	.924	.064	.054	–	–	–
M2	1571.340	752	23.652	24	.924	.064	.054	.000	.000	.000
M3	1606.960	776	35.620	24	.924	.064	.054	.000	.000	.000
Invariance across teaching experience (high and low)										
M1	1494.811	728	–	–	.928	.064	.051	–	–	–
M2	1511.765	752	16.954	24	.929	.062	.054	.001	-.002	.003
M3	1533.331	776	21.556*	24	.928	.062	.054	-.001	.000	.000
M3.1	1545.097	774	33.332	22	.928	.062	.054	-.001	.000	.000
Invariance across school location (urban and rural)										
M1	1558.536	728	–	–	.923	.065	.053	–	–	–
M2	1587.884	752	29.348	24	.923	.065	.056	.000	.000	.003
M3	1619.792	776	31.908	24	.922	.064	.057	-.001	-.001	.001
Invariance across having multigrade class (yes and no)										
M1	1684.517	728	–	–	.916	.069	.053	–	–	–
M2	1704.204	752	19.687	24	.916	.067	.053	.000	-.002	.000
M3	1729.622	776	25.418	24	.917	.066	.053	.001	-.001	.000
Invariance across daily use of the Internet (high and low)										
M1	1576.717	728	–	–	.921	.067	.052	–	–	–
M2	1599.070	752	22.353	24	.922	.065	.055	.001	-.002	.003
M3	1632.782	776	33.712	24	.921	.065	.055	-.001	.000	.000

Note. * $p < .001$; 1=Configural Invariance Model; 2=Metric Invariance Model; 3=Scalar Invariance Model; 3.1=Partial Scalar Invariance Model

The initial model tested was the configural model, known as the baseline model. The results of this least restrictive model showed a good fit to the data for different groups (gender, teaching experience, school location, having multigrade class, and daily use of the Internet in Model 1s in Table 1), indicating the same items measured the same construct for groups. Next, the metric invariance was tested by constraining the factor loading to be equal. The results from the χ2 difference (Δχ2) with the previous model (Model 1s vs. Model 2s) revealed that the increase in χ2 value was not statistically significant. Examination of the changes in CFI, RMSEA and SRMR values showed that these indices were small and within the recommended guidelines. Together with the results of the χ2 difference test, metric invariance was supported across all groups, which means the factor loadings are equivalent across all the groups.

The scalar invariance was tested by constraining the factor loading and intercepts to be equal (Model 3s). The results from the χ2 difference (Δχ2) with the previous model (Model 2s vs. Model 3s) revealed that full scalar invariance was achieved in all groups, except teaching experience. Changes in CFI, RMSEA and SRMR values also supported invariance. Based on full strict invariance across these groups, latent mean comparisons can be also made between them.

For teaching experience, scalar invariance between the high and low groups was not achieved ($\Delta\chi2$ = 21.556, Δdf = 24, $p < .05$). Therefore, Byrne's (2010) strategy was used to identify the noninvariant path. Finally, the partial scalar invariance model (M3.1 with DTR4 "I can teach students about the Internet ethics" and DA3 "I am willing to take the initiative to participate in digital teaching training to improve my teaching efficiency" being freed) and M2 were compared using the $\chi2$ difference, indicating no statistically significant difference between them. Changes in CFI, RMSEA and SRMR values also provided empirical support for partial scalar invariance. The partial scalar invariance allowed the comparison of latent means between primary school teachers with low and high teaching experience (Steenkamp & Baumgartner, 1998). Table 4 shows the results of latent mean differences.

Table 4

Tests of Latent Means Difference

Group	Factor	Mean Difference Estimate	z-value
Gender (0: Female, 1: Male)	DTID	-0.096	-1.337
	DTI	-0.142	-2.207*
	DTE	-0.119	-1.638
	DTR	-0.067	-1.071
	DA	0.003	0.073
Teaching experience (0: High, 1: Low)	DTID	0.054	0.845
	DTI	0.039	0.650
	DTE	0.019	0.297
	DTR	-0.064	-1.142
	DA	0.096	2.267*
School location (0: Urban area, 1: Rural area)	DTID	-0.219	-2.951**
	DTI	-0.227	-3.205**
	DTE	-0.241	-3.228**
	DTR	-0.122	-1.945
	DA	0.043	0.962
Having multigrade class (0: No, 1: Yes)	DTID	-0.280	-2.495*
	DTI	-0.328	-2.953**
	DTE	-0.353	-3.145**
	DTR	-0.159	-1.603
	DA	-0.054	-0.739
Daily use of the Internet (0: High, 1: Low)	DTID	-0.042	-0.654
	DTI	-0.086	-1.456
	DTE	-0.134	-2.070*
	DTR	-0.019	-0.328
	DA	-0.120	-2.832**

Note. * $p < .05$; ** $p <.01$; DTID: Digital Teaching Instructional Design; DTI: Digital Teaching Implementation; DTE: Digital Teaching Evaluation; DTR: Digital Teaching Responsibility; DA: Digital Attitude

When the latent means were compared by gender, a statistically significant difference was found only in DTI (z-value =-2.207, $p<.05$). This finding means that the reference group of female primary school teachers had significantly higher digital teaching implementation competence than their male counterparts.

As for teaching experience, statistically significant differences were found only in DA (z-value=2.267, $p<.05$). Since the reference group was high, this finding means that primary school teachers with low teaching experience had significantly higher digital attitudes than those with high teaching experience.

When the latent means were compared according to school location, statistically significant differences were found in DTID (z-value =-2.951, p<.01), DTI (z-value =-3.205, p<.01) and DTE (z-value =-3.228, p<.01). Since the reference group was urban area, this finding implies that primary school teachers working in rural areas had significantly lower digital teaching instructional design, digital teaching implementation and digital teaching evaluation competence than those working in urban areas.

As for having a multigrade class, statistically significant differences were found in DTID (z-value=-2.495, p<.05), DTI (z-value =-2.953, p<.01) and DTE (z-value=-3.145, p<.01). Since not having multigrade classes was the reference group, this finding implies that primary school teachers having multigroup classes had significantly lower digital teaching instructional design, digital teaching implementation and digital teaching evaluation competence than those having independent classes. Considering that teachers in rural areas have multigrade classes, this finding supports the significant difference by school location.

The latent mean comparison results by daily use of the Internet showed statistically significant differences only in DTE (z-value=-2.070, p<.05) and DA (z-value =-2.832, p<.01). This finding implies that the reference group of primary school teachers with higher average on daily Internet use had significantly higher digital teaching evaluation and digital attitude competence than those with lower average daily Internet use.

5. Discussion

The aim of this study was to analyze the factorial structure of the DTCS when conducted with a sample of primary school teachers in Türkiye. We also performed tests for measurement invariance and latent mean difference across gender, teaching experience, school location, having a multigrade class, and daily use of the Internet. The results may provide several important insights into the factor structure of the DTCS. First, the CFA result showed moderate correlations between the factors. Rather than treating digital teaching competence as one variable, future studies could view it as five related constructs: instructional design, implementation, evaluation, responsibility, and attitude. The findings suggest that these five constructs differ, so using a single overall score may not accurately reflect digital teaching competence. Therefore, it would not be appropriate to examine this variable by calculating only an overall score of digital teaching competence. To capture full scale information, future researchers could operationalize digital teaching competence as a generic construct and five related constructs.

This study also concluded that all five DTCS factors achieved measurement invariance with the variables gender, teaching experience, school location, having a multigrade class, and daily use of the Internet. Additionally, we found significant differences in all five DTCS factors, except DTR, based on gender, teaching experience, school location, having a multigrade class, and daily Internet use. Unlike Gil-Flores et al. (2017), this study found that female teachers scored higher in digital teaching implementation. Their study found that male teachers were more likely to use digital resources in their teaching. The gender-based result of the study can be associated with the demographic frequency (females, 71.2%). There are also studies emphasizing that male teachers tend to have more positive perceptions of digital competences for teaching when compared to females (Grande-de-Prado et al., 2020; Rodríguez-García et al., 2022; Zhao et al., 2021). These findings indicate that gender is an influential factor in teachers’ digital teaching competence.

However, the study found that less experienced teachers had a higher mean DA. It is similar to what other researchers (Liesa-Orus et al., 2023; Zhao et al., 2021) conclude in their studies. In this context, it could be attributed to the fact that younger teachers are more likely to have experience using digital resources in their daily lives. This may be due to their recent pre-service training, which often emphasizes technology-integrated teaching. In the same vein, teachers who use the Internet frequently in a day have higher mean DTE and DA. Previous studies (Gudmundsdottir & Hatlevik, 2018; Iglesias-Rodríguez & García-Riaza, 2016; Yemchuk, 2022; Yurkiv, 2022) collaborate that the more teachers use the Internet, the more likely they are to integrate technology into teaching and develop positive attitudes.

This study highlights the significance of school-based obstacles, complementing the existing body of literature on teachers' digital teaching. The results show that teachers working in rural areas and teaching in multigrade classrooms have lower mean DTID, DTI, and DTE. The COVID-19 pandemic has proven the crucial role of school resources and environment in enhancing digital teaching competence among teachers (Méndez et al., 2022). Teachers are more likely to use digital teaching effectively when they work in well-equipped, less crowded classrooms with students of similar learning levels (Heine et al., 2022).

In addition to its theoretical contributions, the findings of this study have practical implications for educational policy and teacher development. The significant differences observed in digital teaching competence based on school location and multigrade classroom contexts suggest a need for targeted support. Teachers in rural and multigrade settings may benefit from tailored professional development programs that address their unique challenges, such as limited access to digital infrastructure and diverse student needs. Policymakers should consider allocating resources to improve digital equity across schools, ensuring that all teachers—regardless of location—have access to the tools and training necessary for effective digital instruction. Furthermore, integrating digital competence modules into pre-service and in-service teacher education programs can help bridge gaps and foster more inclusive digital teaching practices.

5.1. Limitations and Future Directions

As in all studies, this study also has some limitations. First, we did not test the external validity of the DTCS. To increase the scale's validity and generalizability, further studies may include obtaining important evidence by examining the relationship between related variables such as teacher self-efficacy and TPACK self-efficacy perception. Second, this study removed three items at the CFA stage, which did not affect model identification, fit, or prediction. However, it remains unclear whether the high covariances of these three items with the other items stem from translation errors or factors specific to primary school teachers in Türkiye. The findings of this study could serve as a foundation for future research to conduct replication studies in order to assess the validity of the results across other cultures. Similarly, researchers may like to discover the higher-level factor structure of the DTCS with additional samples. In this study, we conducted the measurement invariance and latent mean difference tests of the DTCS exclusively using data from primary school teachers in Türkiye. Future studies could validate the DTCS among different types of teachers (middle school and high school) in different countries using measurement invariance and latent mean difference tests.

Although there are limitations, an important role of this study is the implementation of a strong confirmatory factor analysis to validate the five-factor structure of the DTCS. Additionally, measurement invariance and latent mean difference tests were employed to enhance the reliability of each item and obtain more accurate measurements of gender differences, teaching experience, school location, having a multigrade class, and daily Internet usage. The current study can serve as an empirical model for future research aimed at determining the construct validity of the DTCS.

Beyond its psychometric contributions, this study offers several practical and policy-oriented insights. The significant differences observed in digital teaching competence based on school location and multigrade classroom contexts highlight the need for targeted interventions. Teachers in rural and multigrade settings may benefit from specialized digital training programs that consider their unique challenges, such as limited infrastructure and diverse student needs. Policymakers should prioritize equitable access to digital resources and professional development opportunities, especially in underserved regions. Additionally, integrating digital competence modules into pre-service and in-service teacher education programs can help bridge the gap in digital readiness. These findings underscore the importance of context-sensitive strategies to enhance digital teaching competence across diverse educational environments.

6. Conclusion

Following the pandemic, there has been a surge in popularity for research on digital teaching competence, viewed as a crucial skill for teachers to possess. This study validates a self-report scale for digital teaching competence using data from primary school teachers in Türkiye, providing empirical evidence. The findings also show that the five-factor structure of the theoretical model underlying the DTCS has cross-cultural validity. This study also discovered that the five DTCS factors—digital teaching instructional design, implementation, evaluation, responsibility, and attitude—demonstrated measurement invariance across various demographic groups, including gender, teaching experience, school location, having a multigrade class, and daily Internet use. Furthermore, the study found significant differences in all five DTCS factors, except DTR, based on gender, teaching experience, school location, having a multigrade class, and daily Internet use. All in all, this study contributed to the literature by generating new insights on the digital teaching competence of primary school teachers through validating the DTCS in a culture different from those reported in the current literature.

Declaration of Conflicts of Interest

Authors declare none.

Declaration of Generative AI Use

Generative Artificial Intelligence (AI) tools were used solely for language editing purposes to improve the clarity, coherence, and readability of the manuscript. The authors reviewed and verified all content to ensure the accuracy and integrity of the final version. No AI tool was used for data analysis, interpretation, or generation of original research content.

Ethical Statement

This study involved collecting data from human participants through surveys. The research was approved by the Social and Human Sciences Ethics Committee of Muğla Sıtkı Koçman University (Protocol No: 240031, Decision No: 47, Date: 19 March 2024). Informed consent was obtained online from all participants. All research procedures were carried out in accordance with the ethical standards of the committee and the principles of the 1964 Declaration of Helsinki and its later amendments.

Author Contributions

All authors contributed to the design of the study. Data collection and analysis were conducted by (Halit Karalar and Alper Yorulmaz). The development of the theoretical framework and the discussion section was contributed by (Bilge

Aslan Altan). All sections of the manuscript were collaboratively reviewed and revised by all authors. All authors have read and approved the final version of the manuscript.

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Appendix 1

List of Constructs and Corresponding Items

Factor	Item	English
Digital Teaching Instructional Design (DTID)	DTID1	I can design instructional activities that integrate digital technology resources.
	DTID2	I can use digital technology to break through the limitations of time and space and create a digital learning environment.
	DTID3	I can choose and make digital teaching resources according to teaching needs.
	DTID4	I can use digital tools to analyze students' knowledge preparation and learning ability.
	DTID5	I can use digital tools to manage teaching resources.
	DTID6	I can use digital teaching techniques and resources to make the material clearer.
Digital Teaching Implementation (DTI)	DTI1	I can use digital technology to organize teaching activities and increase student participation.
	DTI2	I can use digital technology to facilitate communication between students and teachers and classmates.
	DTI3	I was able to use digital technology to find differences among students and provide targeted guidance.
	DTI4	I was able to use digital tools to collect feedback from students in real time and improve teaching behavior.
	DTI5	*I deal with emergencies caused by technical glitches during lessons.*
	DTI6	*I construct mind maps and generalize knowledge structures through techniques.*
	DTI7	*I encourage all students to actively participate in the formalized lessons.*
Digital Teaching Evaluation (DTE)	DTE1	I can reasonably select and use digital tools to collect academic performance of students.
	DTE2	I was able to use digital tools to visualize student achievement.
	DTE3	I conduct students' tests and exercises on mobile devices and network teaching platforms.
	DTE4	I show evaluation results to colleagues, parents and students by multimedia tools.
	DTE5	I develop personalized assessment schemes for each student by technological resources.
	DTE6	I can reasonably use digital tools for process evaluation of students.
	DTE7	I can use digital tools to improve student performance based on student evaluation results.
Digital Teaching Responsibility (DTR)	DTR1	I can abide by the Internet laws and regulations, consciously regulate online behavior.
	DTR2	I can pay attention to data security maintenance when collecting data of students and parents at work.
	DTR3	I can respect intellectual property rights and properly use digital resources on the Internet.
	DTR4	I can teach students about Internet ethics.
	DTR5	I can treat technology rationally and do not over-rely on it or abuse it.
	DTR6	I protect students' privacy while using technology to understand students.
Digital Attitude (DA)	DA1	I recognize that digital technology can drive innovation in education.
	DA2	I am willing to take the initiative to learn new digital technologies.
	DA3	I am willing to take the initiative to participate in digital teaching training to improve my teaching efficiency.
	DA4	I am capable of digital teaching.
	DA5	I am willing to take the initiative to discuss digital teaching strategies with colleagues.
	DA6	In the future, I will firmly use digital teaching.

Note. Items written in italics (DTI5, DTI6, and DTI7) were removed from the model as a result of CFA.