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Strengthening Sustainable Higher Education with Digital Technologies: Development and Validation of a Digital Competence Scale for University Teachers (DCS-UT)

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Abstract: The integration of digital competences into higher education is essential for the promotion of effective and sustainable teaching and learning environments. The aim of this study was to develop and validate the Digital Competence Scale for University Teachers (DCS-UT), an instrument to assess key digital competences of teachers. The development of the scale involved the creation of items based on an extensive literature review, followed by rigorous testing for content and face validity. The psychometric properties of the scale were assessed using data from 411 university teachers, with confirmatory factor analysis (CFA) and structural equation modelling (SEM) to examine the underlying structure of the scale. Reliability was assessed using Cronbach's alpha, which confirmed the internal consistency of the instrument (0.974). The analysis revealed a robust four-factor structure: digital literacy, digital skills, digital interaction, and technology integration, which together explained 70.284% of the variance. These findings underscore the value of the DCS-UT as a tool to promote sustainable teaching practises by assessing digital competences. By equipping teachers with essential digital competences, the scale supports the long-term adaptability and effectiveness of higher education institutions in an increasingly digital field.

Keywords: sustainable development; sustainable teaching; information literacy; technological innovations; faculty development; e-learning

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1. Introduction

The integration of digital technologies into higher education has revolutionised pedagogical practises and prompted institutions to adapt their approaches. This shift is particularly significant given the global move towards online and blended learning models, which emphasise the urgent need to equip teachers with robust digital competences. The COVID-19 pandemic has accelerated this shift and emphasised the need for teachers to master information and communication technology (ICT) [1,2]. This shift has redefined educational provision and increased expectations on teachers to navigate a rapidly evolving digital landscape while maintaining high standards of teaching and promoting meaningful student engagement.

Digital competences, broadly defined as the ability to use ICT effectively and efficiently in a professional context, are fundamental to creating engaging, adaptable, and sustainable learning environments [3–5]. However, the adoption of digital technologies in higher education is influenced by various factors that affect teachers' motivations and intentions. Educators who see digital tools as beneficial for improving their teaching are more likely to adopt these technologies because they are easy to use, promote student engagement, and provide opportunities for innovation. Institutional support, such as professional development and access to resources, further encourages the integration of digital technologies into teaching [6,7]. Although digital competences are often treated as a unified concept, their application varies considerably depending on the subject area. For example, teachers in technical and engineering disciplines may need advanced skills in programming, specialised software, and data analysis, while in the humanities and social sciences, they may focus on digital collaboration platforms, multimedia integration, and critical information literacy [8–10]. Research shows that subject-specific needs influence how teachers adopt and integrate digital technologies into their pedagogical practises. In subjects such as engineering and physics, educators often utilise advanced technologies such as AI-based systems and structured teaching–learning sequences to improve problem solving and adaptive learning [11,12]. In the medical and health sciences, digital tools such as simulated patient interactions and telemedicine platforms have become indispensable for teaching diagnostic skills and promoting telemedicine practises [13]. In biotechnology and sports science, digital tools such as virtual reality and augmented reality are used to improve the teaching of practical skills, e.g., in physiotherapy and rehabilitation. These immersive technologies provide realistic simulations and help students to improve their motor skills and learn interactively [14]. In the arts, for example, digital competences revolve around multimedia tools that promote creativity, collaboration, and digital expression. Multimedia platforms are often used in teaching to encourage student engagement with traditional and digital art forms [15].

However, there are several barriers that can make this transition more difficult. Teachers may resist digital technologies because they lack confidence in their abilities, because they fear an increased workload, or because they favour traditional methods. This resistance is often the result of comfort with established practises and the technostress associated with constantly adapting to new tools. The perceived irrelevance of digital tools for certain topics can make experimenting with these technologies even more difficult [7,16]. Understanding these motivators and barriers is crucial for higher education institutions seeking to support their staff in digital transformation. Addressing the specific needs and concerns of educators allows institutions to create an environment that not only facilitates the adoption of digital technologies, but also improves the quality of education overall. Customised professional development and fostering a culture that values innovation are important strategies to help teachers successfully navigate this transition [7].

Promoting the development of digital competences is critical not only for the professional development of teachers, but also for the overall resilience and adaptability of higher education institutions. These competences are crucial for promoting sustainable teaching practises that create adaptive, inclusive learning environments that meet the diverse needs of today's students [17]. In addition, digital competences are increasingly recognised as key to achieving several United Nations Sustainable Development Goals (SDGs), in particular SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 9 (Industry, Innovation and Infrastructure), and SDG 10 (Reduced Inequalities) [18].

Several established frameworks offer structured approaches to improve teachers' digital competences and promote pedagogical innovation. The DigCompEdu framework, for example, was developed specifically to support educators in digital transformation. It identifies six key competency areas, including professional engagement, digital resources, teaching and learning strategies, assessment, learner empowerment, and digital literacy promotion [9,19,20]. Similarly, the UNESCO ICT Competency Framework for Teachers (ICT-CFT) emphasises the role of technology in education, focusing on the intersection of ICT skills and pedagogy. It provides a global standard that aligns digital skills with pedagogical goals and enables educators to use technology to improve student learning outcomes [20].

Despite the increasing importance of digital transformation, many higher education institutions, especially in regions with deep-rooted traditional teaching models, face major challenges in adapting to these changes. In areas with limited access to digital resources and professional development, disparities in faculty digital competences are exacerbated, making the effective integration of digital technologies into teaching a formidable challenge [21]. The persistent gaps in the digital competence of higher education teachers, particularly in developing countries where the digital divide hinders the adoption of ICT, emphasise the urgent need for targeted efforts in this area [9].

For today's generation of students, who are digital natives, the integration of digital competences into teaching practise significantly enhances the learning experience. Students increasingly expect and benefit from interactive, technology-enhanced learning environments that are more engaging and better suited to their learning styles [22]. Research shows that students in digitally enriched environments are more likely to develop critical thinking skills, engage in collaborative learning, and achieve better academic outcomes [23,24]. By promoting the digital competences of teaching staff, universities can ensure that they provide a sustainable, high-quality education that equips students for the challenges of the future [25].

The aim of this study is to develop and validate a tool to assess the digital competences of university teachers. This tool will offer higher education institutions a systematic way to assess and improve the digital competences of their teaching staff, thereby promoting more sustainable, innovative, and equitable educational practise.

2. Materials and Methods

2.1. Scale Development

The development of the Digital Competence Scale for University Teachers (DCS-UT) was conducted in December 2023 and January 2024 in a comprehensive and systematic process. This process included several important steps: (a) creating an initial pool of items and a response scale, (b) assessing content and face validity, and (c) testing the factor structure and reliability of the new scale.

Item Generation Process

In the first phase, an extensive literature review was conducted to identify the key dimensions of digital competence relevant to higher education [2,4,9,19–30]. The review focused on established frameworks and literature that outline the essential competences required by educators in the digital age. All of this formed the theoretical basis for the development of the questionnaire items, ensuring that each item corresponded to a specific dimension of digital competence.

Based on this review, 38 items were developed, reflecting key competences in areas such as technological knowledge, pedagogical use of digital tools, interactivity and collaboration, assessment, and continuous professional development. Each item has been carefully designed to capture specific aspects of these competency areas to ensure comprehensive coverage of the critical dimensions of digital competence required by higher education teachers.

To illustrate the link between the literature-based competency areas and the items created, Table 1 summarises how the key competency dimensions were incorporated into the item development process.

Table 1. Assignment of digital competence areas to task descriptions.

Competence Area	Description
Technological knowledge	Items focused on educators' skills in using a variety of digital tools and platforms.
Pedagogical use of digital tools	These items assessed how teachers integrate technology into their teaching practise to improve learning outcomes.
Interactivity and collaboration in online environments	This category assessed the use of digital platforms to promote student interaction and collaboration.
Assessment and feedback via digital platforms	These items examined how teachers use digital tools to assess students and provide timely feedback.

Table 1. *Cont.*

Competence Area	Description
Continuous professional development in digital technologies	These items addressed the importance of ongoing professional development for teachers to stay current with new digital tools and approaches.
Strategies to ensure digital accessibility and inclusion	These items assessed teachers' awareness and use of digital tools to ensure that all students, regardless of ability, have access to learning.
Frequent use of digital communication platforms	These items measured how teachers interact with students via digital communication platforms.
Integration of digital tools	These items assessed how teachers integrate digital tools into lectures and seminars.
Use of analytics tools	These items assessed how teachers use analytics tools to track student progress.
Digital ethics, data protection, equality, and accessibility	These items ensured that teachers comply with ethical principles in digital education.
Participation in professional development	These items related to ongoing training in new technologies and digital pedagogical approaches.
Development of digital learning modules, e-books, and multimedia elements	These items were used to measure teachers' ability to create digital content and promote independent learning.

2.2. Pilot Study

A pilot study was conducted to assess the initial reliability and validity of the Digital Competence Scale for University Teachers (DCS-UT). This study included a purposive sample of university teachers to refine and validate the items of the scale. This pilot study is crucial to assess the performance of the scale before conducting wider data collection and analysis. A more detailed analysis of the sample and statistical validation procedures are presented in the following sections.

2.2.1. Evaluating the Content Validity

To ensure the validity of the DCS-UT, an assessment of its content validity was carried out. Four experts, two women and two men, from the fields of higher education and digital technologies took part in this process. Their task was to assess the relevance and clarity of each item on the scale. A 4-point Likert scale was used for relevance, and a 3-point Likert scale was used for clarity. The Content Validity Index (CVI) was then calculated for each item. According to Polit and Beck's [31] guidelines, a CVI of 0.78 or higher is considered acceptable when four experts are involved.

2.2.2. Construct Validity and Reliability

In order to assess the construct validity and reliability of the DCS-UT, a confirmatory factor analysis (CFA) was conducted. Prior to conducting the CFA, the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity were applied to assess sample adequacy and the suitability of the data for factor analysis. A KMO value of more than 0.60 and a significant result of the Bartlett's test ($p < 0.05$) indicate that the data are suitable for factor analysis. Reliability was assessed using Cronbach's alpha, with a value of 0.70 or higher generally considered acceptable [32]. In addition, structural equation modelling (SEM) was conducted to validate the factor structure and the relationships between the constructs. Model fit was assessed using several fit indices, including the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA), with CFI values above 0.95 and RMSEA values below 0.08 indicating a good fit between the hypothesised model and the observed data [33].

2.3. Sample

This study used a purposive sample of 411 university teachers who had experience as lecturers in digital educational contexts (distance learning, blended learning, or via learning management systems) or who had integrated digital technologies into traditional lectures and seminars. The sample within the group of university teachers was stratified to include teachers with different academic ranks (lecturer, senior lecturer, assistant professor, associate professor, and full professor). Potential participants were sought in collaboration with public and private universities and independent higher education institutions in Slovenia, which were asked to participate in this study. According to the data for the academic year 2021/2022, 3282 university teachers were employed in Slovenia, of which, 1802 were men and 1480 women. Based on a total population of 3282 university teachers, and considering a hypothetical frequency of the outcome factor of 50% ± 5%, the required sample sizes were calculated for different confidence levels. A sample size of 344 was required for a 95% confidence level, while a sample size of 553 was required for a 99% confidence level. The detailed characteristics of the sample are shown in Table 2.

Table 2. Characteristics of the participants (n = 411).

Characteristic	n	%
Gender:		
Male	174	42.3
Female	237	57.7
Academic ranks:		
Lecturer	75	18.2
Senior Lecturer	51	12.4
Assistant	173	42.1
Associate Professor	70	17.0
Full Professor	42	10.2
Fields of teaching:		
Social sciences	69	16.8
Humanities	12	2.9
Natural sciences	75	18.2
Technical and technological sciences	27	6.6
Medical sciences	49	11.9
Biotechnical sciences	27	6.6
Arts	15	3.6
Sports sciences	48	11.7
Interdisciplinary subjects	12	2.9
Health sciences	77	18.7

2.4. Ethical Considerations

Ethical approval for this study was obtained from the Commission of the University of Primorska for Ethics in Human Subjects Research (Approval No: 4264-16-3/2022). All data were treated confidentially. Informed consent was obtained from all participants who were willing to engage in this study.

2.5. Data Collection

The data for this study were collected via an online survey conducted on the open-source platform 1KA (https://www.1ka.si/d/en, accessed on 28 May 2024). Following ethical approval, potential participants were invited by email, which included a link to the questionnaire and detailed instructions on its purpose and completion. The period of data collection was from April to June 2024. To preserve the anonymity of the respondents, the database created from the survey responses did not contain any personal identifiers. Access to the data was restricted to the study leader to ensure confidentiality throughout the analysis process. Informed consent was obtained from all participants prior to participation in this study, confirming their voluntary participation and understanding of the research objectives.

2.6. Data Analysis

For data analysis, the data set was processed with IBM SPSS version 29.0 (SPSS Inc., Chicago, IL, USA) and JASP version 0.18.3 (Intel, Santa Clara, CA, USA), an open-source statistical software. Descriptive statistics were used to obtain an overview of the characteristics of the sample. Reliability was assessed using Cronbach's alpha to ensure internal consistency. Confirmatory factor analysis (CFA) was conducted to validate the factor structure of the DCS-UT, while structural equation modelling (SEM) was used to examine the relationships between latent constructs. The model's fit was assessed using indices such as the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA). The covariances between the latent factors were analysed within the SEM to understand the relationships between them, setting a statistical significance level of 0.05.

3. Results

The CVI results show that most items of the DCS-UT have high content validity, with CVI values between 0.78 and 1.00. This shows that the majority of items were rated as relevant and clear by the experts. However, three items were identified with lower CVI values, indicating possible problems with their relevance or clarity. Consequently, these items were excluded from the final scale in order to maintain the overall content validity of the DCS-UT. The excluded items were carefully reviewed, and it was determined that their removal would not affect the completeness of the scale.

In order to validate the structure of the measurement model, a CFA was conducted. A factor analysis was conducted using Promax rotation, an oblique rotation method chosen because it allows for correlation of the factors. This approach is in line with the theoretical expectation that the underlying dimensions of university teachers' digital competence are interrelated. Only items with factor loadings above 0.4 were selected for further analysis in order to ensure the robustness and validity of the constructs. The CFA confirmed that all 35 items yielded a robust factor solution with eigenvalues above 1. The factor weight matrix showed that all items had factor loadings above 0.40, confirming their suitability. The KMO measure of sampling adequacy was 0.929 and Bartlett's test of sphericity was significant ($\chi^2 = 4482.833$, $p < 0.001$), supporting the suitability of the data for CFA. In addition, the univariate normal distribution of the indicator variables was assessed by analysing the skewness and kurtosis. The values for the skewness of the variables ranged from −0.847 to 0.447, indicating that the distributions are relatively symmetrical. The kurtosis values ranged from −0.999 to 0.780, indicating that there are no extreme outliers in the data. Therefore, the variables have distribution characteristics that are suitable for CFA, with values for skewness and kurtosis within acceptable ranges. Consequently, the factor analysis resulted in a four-factor structure that describes the basic dimensions of the digital competence scale (Table 2).

Table 3 also shows the z-values and *p*-values for each item, which indicate the statistical significance of the factor loadings. The consistently high z-values and *p*-values below 0.001 confirm that all relationships between the items and their respective factors are statistically significant.

Table 3. Digital Competence Scale for University Teachers (DCS-UT)—confirmatory factor analysis yields a four-factor solution with factor loadings (N = 411).

	Items	Factor Loadings	z-Value	*p*	I-CVI (R, C)
Factor 1	I know how to use analytics tools to monitor student progress.	0.914	106.532	<0.001	1.00
	I use digital tools to better adapt the teaching process to the different learning styles and needs of students.	0.897	100.727	<0.001	0.94
	I can adapt my teaching to the students' technological abilities.	0.894	83.404	<0.001	0.91
	I regularly use multimedia elements such as animations and simulations to better understand complex concepts.	0.888	79.275	<0.001	0.91
	I actively encourage students to use digital tools for independent learning and research.	0.866	77.525	<0.001	0.87
	I develop and use digital learning modules and e-books to supplement traditional teaching materials.	0.863	105.357	<0.001	1.00
	I encourage students to develop their digital skills.	0.862	90.308	<0.001	0.98
	I regularly act as a mentor or counsellor for colleagues who want to improve their digital skills.	0.861	77.801	<0.001	1.00
	I regularly participate in webinars and workshops to improve my digital skills.	0.845	85.542	<0.001	1.00
	I am aware of the importance of digital privacy and uphold it consistently for my students (protecting personal data and information shared or created in a digital environment).	0.827	88.956	<0.001	0.91
	I consistently adhere to the principles of digital ethics and ensure safety in e-teaching.	0.820	64.649	<0.001	1.00
	I participate in research to improve digital pedagogical practises.	0.817	97.672	<0.001	1.00
	I regularly educate myself about new digital technologies and approaches.	0.816	91.989	<0.001	1.00
	I incorporate digital simulations into lessons where appropriate.	0.800	92.288	<0.001	1.00
	I frequently use digital communication platforms to interact with students (e.g., Zoom, Microsoft Teams, Moodle, email, etc.).	0.758	74.126	<0.001	0.98
	Collaborative digital platforms such as Moodle are a key element of my teaching process.	0.747	83.632	<0.001	0.88
	I understand the importance of digital equality and accessibility in education (ensuring equal opportunities for access to digital tools and educational content).	0.691	58.111	<0.001	0.78
Factor 2	I use advanced digital platforms to monitor and support the progress of individual students.	0.930	100.727	<0.001	1.00
	I regularly evaluate and adapt my methods to ensure digital accessibility and inclusion for all students.	0.927	97.324	<0.001	1.00
	I use virtual collaboration tools such as online whiteboards (e.g., Padlet) for group projects and assignments.	0.886	84.357	<0.001	1.00
	I use digital tools for student assessment and feedback.	0.865	95.68	<0.001	1.00
	I effectively integrate online and physical learning environments for hybrid teaching.	0.816	77.069	<0.001	0.98
	I regularly use online tools for surveys and feedback collection to evaluate the effectiveness of my lectures and continuously improve them.	0.808	84.357	<0.001	0.98

Table 3. *Cont.*

	Items	Factor Loadings	z-Value	*p*	I-CVI (R, C)
Factor 3	I use various digital media in the classroom, e.g., videos, infographics, and quizzes.	0.820	95.68	<0.001	1.00
	I encourage students to participate in digital discussions and forums.	0.810	97.221	<0.001	1.00
	I use various digital tools in my lessons without any problems.	0.808	83.632	<0.001	1.00
	I integrate various digital tools into lectures or seminars to complement traditional teaching methods.	0.796	65.726	<0.001	1.00
	My e-lectures are interactive and encourage student participation.	0.793	64.96	<0.001	0.98
	I regularly incorporate digital tools into my lectures and seminars.	0.745	83.404	<0.001	0.98
Factor 4	I encourage and support the use of digital portfolios to document students' academic work (including in Moodle).	0.842	83.632	<0.001	1.00
	I encourage students to use online information critically.	0.798	81.401	<0.001	1.00
	I recognise the importance of continuous professional development in digital skills and careful preparation of e-learning content that enables me to effectively adapt and deliver pedagogical processes in a digital environment.	0.752	83.632	<0.001	0.88
	I promote the use of social media for educational purposes.	0.686	77.069	<0.001	0.88
	I support the use of open educational resources (e.g., open textbooks, open-source educational platforms, free educational videos, and open scientific articles).	0.642	83.632	<0.001	0.88
	I actively participate in online communities and forums related to my teaching field.	0.595	26.503	<0.001	0.78

Note. Accumulated total explained variance = 70%. Bartlett's Test of Sphericity: $\chi 2$ = 4482.833, $p < 0.0001$; Kaiser–Meyer–Olkin value = 0.929; SD—Standard Deviation; Factor 1—Digital literacy; Factor 2—Digital skills; Factor 3—Digital interaction; Factor 4—Technology integration; Factor Rotation: Promax with Kaiser normalisation; Rating is based on five response categories, ranging from 1—strongly disagree to 5—strongly agree; I-CVI (R, C)—Items Content Validity Index (Relevancy, Clarity); Rejected items based on CVI: I use various digital devices in my teaching without any problems; technical difficulties rarely hinder my online teaching; I regularly test and implement new digital technologies to improve the interactivity of my lectures (e.g., Kahoot, Mentimeter, Padlet, . . .).

Table 3 also summarises the total variance explained by the four factors identified by using Promax rotation with Kaiser normalisation. Factor 1, Digital literacy, accounted for the majority of the variance at 55.415%, followed by Factor 2, Digital skills, which explained 8.040% of the variance. Factor 3, Digital interaction, contributed 3.827% of the variance, while Factor 4, Technology integration, accounted for 3.002% of the variance. Together, these four factors explained 70.284% of the total variance, indicating a robust factor structure. The scree plot in Figure 1 illustrates the distribution of eigenvalues and shows the point where the curve flattens out (the "elbow"), indicating that four factors should be retained. This decision was further supported by retaining factors with eigenvalues greater than 1, as is common in factor analysis.

Furthermore, the factor covariances in the structural equation model were analysed in order to understand the relationships between the latent factors. Table 4 shows the covariance values, standard errors, z-values, *p*-values, and 95% confidence intervals for the relationships between the four factors: digital literacy, digital skills, digital interaction, and technology integration.

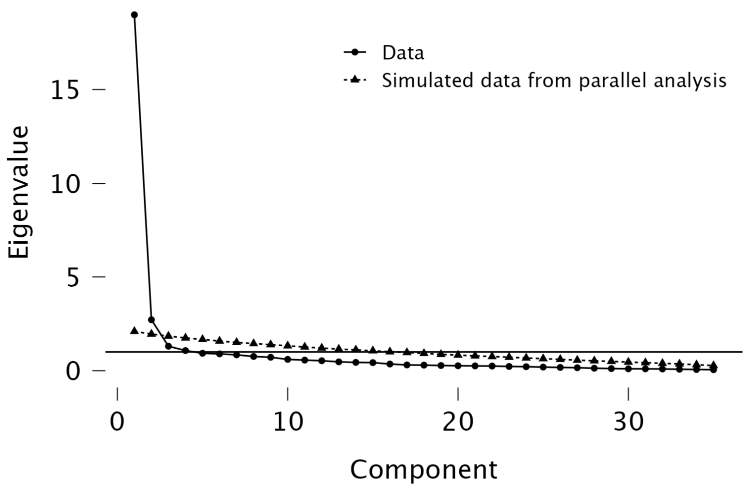

Figure 1. Scree plot of the Digital Competence Scale for University Teachers (DCS-UT).

Table 4. Factorial covariances in the structural equation model.

Factors	Estimate	Std. Error	z-Value	*p*	95% Confidence Interval	
					Lower	Upper
Digital literacy ↔ Digital skills	0.950	0.008	117.169	<0.001	0.934	0.966
Digital literacy ↔ Digital interaction	0.946	0.011	85.052	<0.001	0.924	0.968
Digital literacy ↔ Technology integration	0.620	0.018	34.699	<0.001	0.585	0.655
Digital skills ↔ Digital interaction	0.901	0.015	60.156	<0.001	0.871	0.930
Digital skills ↔ Technology integration	0.688	0.025	27.031	<0.001	0.638	0.738
Digital interaction ↔ Technology integration	0.714	0.027	26.898	<0.001	0.662	0.766

The results in Table 3 shows significant correlations between all factors. The estimates range from 0.620 to 0.950, with all *p*-values less than 0.001, meaning that the relationships are statistically significant. The high z-values further confirm these results. For example, Factor 1 (Digital literacy) and Factor 2 (Digital skills) have a covariance estimate of 0.950, indicating a strong positive relationship. Similarly, Factor 1 and Factor 3 (Digital interaction) have a covariance estimate of 0.946. These high covariance values indicate that these factors are closely related and likely to influence each other.

The fit indices for the overall model indicate a very good fit. The Comparative Fit Index (CFI) is 0.973 and the Tucker–Lewis Index (TLI) is 0.972. Both values are above the recommended threshold value of 0.95 and indicate an excellent fit. The Root Mean Square Error of Approximation (RMSEA) is 0.079 with a 90% confidence interval of 0.072 to 0.087 and a *p*-value indicating a good fit of less than 0.001, which is within acceptable limits. The Standardised Root Mean Square Residual (SRMR) is 0.075, also within acceptable limits.

Table 5 shows the reliability and descriptive statistics of the Digital Competence Scale and its four factors.

The Cronbach's alpha values for the factors are as follows: Digital literacy (α = 0.966), Digital skills (α = 0.929), Digital interaction (α = 0.879), and Technology integration (α = 0.791). The overall Digital Competence Scale for University Teachers (DCS-UT) has a high reliability with a Cronbach's alpha of 0.974. These values indicate that the scale and its subscales have excellent internal consistency and are therefore reliable measures for the assessment of digital competence.

Table 5. Reliability and descriptive statistics of the Digital Competence Scale for University Teachers (DCS-UT) and its four factors.

Factors/Subscales	n	M*dn*	SD	Cronbach α	95% Confidence Interval		*p*
					Lower	Upper	
Digital literacy	17	3.35	0.952	0.966	3.01	3.33	<0.001
Digital skills	6	2.58	1.057	0.929	2.46	2.81	<0.001
Digital interaction	6	3.42	0.765	0.879	3.33	3.59	<0.001
Technology integration	6	3.67	0.627	0.791	3.44	3.65	<0.001
Digital Competence Scale for University Teachers (DCS-UT)	35	3.27	0.801	0.974	3.06	3.33	<0.001

Note. M*dn*—Median; SD—Standard Deviation.

4. Discussion

The Digital Competence Scale for University Teachers (DCS-UT) was developed and validated to meet the growing need for the integration of digital competences into university teaching. The robust factor structure, validated through confirmatory factor analysis (CFA) and further investigated using structural equation modelling (SEM), highlights the scale's effectiveness in measuring four key dimensions: Digital Literacy, Digital Skills, Digital Interaction, and Technology Integration. These analyses confirm the strong construct validity of the scale with Cronbach's alpha values of over 0.70, which is in line with psychometric standards [32]. The nature of the DCS-UT, which covers a wide range of digital competences, from basic skills to advanced technology integration, makes it a valuable tool for both teachers and institutions seeking to improve their digital teaching practises.

Digital literacy is a critical and evolving competency in higher education that goes beyond the basic use of digital tools. It encompasses a range of skills, knowledge, and attitudes that are essential for teachers to effectively integrate digital technologies into their teaching methods. These include the competent use of digital tools, the integration of digital simulations, and the promotion of interaction between students via digital platforms, which are becoming increasingly important in the modern educational landscape [1,9]. The importance of digital literacy is further emphasised by the ongoing digital transformation in higher education, making it a fundamental element of effective teaching. Digital literacy is dynamic and must constantly evolve with the emergence of new technologies. This evolution is critical for promoting equity, inclusion, and lifelong learning, and is in line with global frameworks such as DigCompEdu [34,35]. Our findings confirm the importance of digital literacy as a multidimensional construct that is crucial for addressing the complexity of digital competences in education. Our findings emphasise the importance of digital literacy as a multidimensional construct necessary to address the complexity of digital competencies in education [16].

Digital skills, another essential dimension, focus on the technical skills educators need to use various digital tools and platforms effectively in teaching. These skills include the use of learning management systems, digital collaboration tools, and specialised software that supports online and blended learning environments. As higher education increasingly utilises digital methods, these skills will become indispensable. Teachers must not only be proficient with digital tools, but also integrate them seamlessly into teaching to improve student engagement and learning outcomes. This dimension is in line with the broader framework of digital competences, which emphasises the importance of specific digital skills for effective teaching [4]. The findings of this study emphasise the critical role that these skills play in the successful implementation of digital and blended learning strategies to ensure that teaching methods remain engaging and up to date [35,36].

Digital interaction focuses on the use of digital tools to promote interactive learning environments. This dimension is critical to creating meaningful connections between students, teachers, and content. The ability to use digital platforms for interaction and collaboration is increasingly recognised as fundamental to digital competence, particularly in higher education where student engagement is a key factor in academic success [2,26,37]. This factor aligns with the growing body of research that emphasises the role of digital tools in creating dynamic learning environments that promote active learning and collaboration, especially as higher education institutions increasingly adopt digital and blended learning models [1,21].

Technology integration is about incorporating digital tools and resources into teaching practise to improve learning outcomes. This process requires both technical and pedagogical expertise to ensure that digital tools are used strategically to support learning objectives. As higher education undergoes digital transformation, effective technology integration is becoming a key component of educators' professional competence [2,9]. This dimension encompasses the interplay between technical and pedagogical skills required for effective teaching in the digital age, making it an important focus for educators worldwide [30,37].

The validated Digital Competence Scale for University Teachers (DCS-UT) can be applied across various educational settings to assess and enhance digital competencies. Most items of the DCS-UT scale use a perception-based format (self-assessments), but this approach is widely accepted in measuring digital competence. Previous studies, including those using the DigCompEdu framework and the European Digital Competence Framework (DigComp), have successfully utilised self-assessment instruments to measure teachers' digital skills, competence, and technology integration practises [35,36]. Research shows that perception-based items provide valuable insight into teachers' confidence and perceived abilities in using digital tools, which directly impacts their motivation to integrate technology into their teaching practises [37]. In addition, perception-based assessments allow institutions to identify areas where teachers feel less confident and target their professional development efforts accordingly. Further, gender differences have been identified as an important factor influencing digital competence, particularly in education. Research suggests that female teachers often have lower confidence in using digital technologies compared to their male counterparts, despite having similar technical skills [38]. This gender gap in digital self-efficacy may impact the willingness to integrate new digital tools into teaching practise, especially when institutional support is limited. In contrast, male educators may be more inclined to experiment with advanced technologies, particularly in STEM subjects where digital competence is increasingly important [9].

The DCS-UT can be effectively integrated into professional development programmes to identify areas where teachers need further training. Through workshops and customised resources based on the assessment results, institutions can help educators build important digital literacy and technical skills. In addition, the scale can be used to monitor and improve the use of digital tools in blended and online learning environments. This ensures that teachers not only master these technologies, but also utilise them to create interactive learning experiences.

Future research should explore how these competences can be developed and maintained to support the long-term sustainability of higher education and ensure that institutions remain at the forefront of educational innovation and sustainability [2,4].

Limitations

Although this study provides valuable insights into the digital competences of university teachers, it is not without limitations. Firstly, the sample was limited to university teachers from a specific geographical region, which may limit the generalisability of the findings to other contexts. While the purposive sampling method is effective in targeting experienced teachers, it may also lead to selection bias, as it does not fully represent the diversity of teaching experiences and digital competences in the academic community. Finally, the rapid development of digital technologies means that the competences required for effective digital teaching are constantly changing. As a result, the scale developed in this study may need to be regularly updated to remain relevant in an ever-evolving field of education. Future research should take these limitations and investigate the application of the Digital Competence Scale for University Teachers (DCS-UT) in different educational settings and its adaptability over time, or adapt the scale for use in different cultural contexts.

5. Conclusions

This study highlights the critical role of digital competences in promoting sustainable education practises aligned with the key Sustainable Development Goals (SDGs), including quality education (SDG 4), gender equality (SDG 5), industry, innovation, and infrastructure (SDG 9), and reducing inequalities (SDG 10). The validated Digital Competence Scale for University Teachers (DCS-UT) is a valuable tool for improving teachers' skills and fostering resilient, equitable, and adaptable education systems. Integrating these competences allows higher education institutions to contribute to a more inclusive and sustainable future and ensure that both teachers and students are well prepared to succeed in an increasingly digital world.

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