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Research Article

Exploratory study of digital competence predicting sustainable development beliefs and behavior: Evidence for an integrated competence framework among pre-service teachers

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ABSTRACT

Digital competences are increasingly recognized as important enablers of education for sustainable development (SD), particularly through their capacity to facilitate access to learning resources and knowledge, support their effective and critical use, and foster innovation in teaching and learning. In recent decades, the concept of digital competence has increasingly incorporated ethical and sustainability-related dimensions, reflecting the need to use digital technologies in ways that are responsible, inclusive, and sustainable. Against this background, the present exploratory study examined the structure and interrelationships of digital competences and SD competences among 368 pre-service teachers, with particular attention to the extent to which digital competence dimensions predicted SD beliefs and behavior. The findings indicate that digital competence significantly predicted sustainable society beliefs, although the overall explanatory effect was small. In contrast, digital competence did not significantly predict gender equity beliefs. Regarding energy saving behavior (ESB), responsible problem-solving made a statistically significant positive contribution to the individual predictor level; however, the overall regression model did not significantly predict ESB. Taken together, these findings suggest that digital competence and sustainability competence should not be viewed as entirely separate constructs. Rather, they appear to represent increasingly interconnected dimensions of competence that may contribute to responsible participation in contemporary society. At the same time, the relatively small explanatory effects observed in the present study indicate that digital competence alone is insufficient to account for substantial variation in sustainability-related beliefs and behaviors. This highlights the importance of considering digital competence alongside broader personal, social, educational, and contextual factors in efforts to strengthen education for SD.

Keywords: digital competences, sustainable development, pre-service teachers, higher education, predictors, digital literacy, sustainable development literacy

INTRODUCTION

With the transition from the industrial to the knowledge society, digital technology was considered an enabler of knowledge accumulation, accessibility, and exploitation, while digital technology resources were not addressed with sustainability caution and contribution to sustainable development goals (SDGs) and its consumption's effects on natural resources and social ecosystems (Stuermer et al., 2016). Conditions for sustainable digital technology include shared tacit knowledge as a necessity for enabling participatory culture throughout the lifecycle of digital artefacts, decentralized governance, and the involvement of the wider society in line with global SDGs (Stuermer et al., 2017). Digital sustainability is discussed within the environmental sustainability of the resource-based view, energy saving, environmental protection, energy-intensive consumption, and ethical concerns (Meinhold et al., 2025).

At the policy level, the European Union identified the need to foster digitalization in all sectors, including education and climate neutrality, leading to the twin transition goal, connecting sustainability and digital (Gao, 2025), supported by the declaration of the European Green Digital Coalition (2021) members. After that, educational projects for the green-digital transition were launched in Slovenia as part of the COVID-19 recovery and resilience plan. This study is part of the project "Modernization of pedagogical study programs – Modernization of the NOO PSP" financed in 2023/26. The objective is the redesign of higher education pedagogical programs.

The university curriculum merges two distinguished traditions: literacy, the psychometric and knowledge-oriented, and competencies, the performance- and application-oriented (Benner, 2023). The modern higher education curriculum reflects literacy towards concept comprehension and its application through competence mastery. This is manifested in digital development and SD. The authors argue that literacy refers to information access and understanding; competence refers to broader, encompassing knowledge, skills, attitudes, critical thinking, and responsible use of technology (Ferrari, 2013; Jelić et al., 2026; Mieg et al., 2024; Vuorikari et al., 2026). Pre-service teachers' perceptions of sustainability development (SD) education aligned with the Bologna reform examine learning outcomes in relation to SD competences and SD literacy (Cebrián & Junyent, 2015).

The review studies report a gap in the scrutiny of the SD awareness-behavior divide in the area of higher education program curriculum design and its impact (Agboola et al., 2026) and in the integration of SD curricula supported by digital training (Almusharraf, 2026). In 2009, Arbuthnott (2009) supported the argument for an awareness-behavior divide, with a lack of cultivation of mediating factors at a personal level (habits) and contextual level (convenience).

In parallel to the term "sustainability", the term "sustainable development" entered the dictionary of the Slovene literary language relatively late, in the 2014 edition (Gliha et al., 2014), the year before the declaration for SDGs to be achieved by 2023 (United Nations, 2015). This influenced higher education in obligatory and elective course design in the fields of society, education, economy, and environment; however, not sufficiently in pre-service teacher programs (Ferreira et al., 2007, 2014; Terlević et al., 2015). Environmental literacy (Erdoğan et al., 2011; Gayford, 2002; Orbanić & Kovač, 2021; Dolenc et al., 2025) and climate literacy (Dolenc, 2026; Li & Liu, 2022) are examined within SD competences of pre-service teachers.

With digitalization in society, digital competence is examined within SD learning outcomes concerning

(1) educational technology, the digital tools facilitating higher-order learning objectives (García-Hernández et al., 2022; Milkova et al., 2025) and

(2) instructional approaches and digital competence as a basic competence in education (AlDhaen, 2023).

A review study on the contribution of DigCompEd to SD (Colás-Bravo et al., 2021) showed that most studies focus on teaching, followed by student competences and teacher professional competences. While in the 20th century, teacher education reforms introduced digital competences focusing on innovation and enabling potential for pedagogical advancement (Istenič, 2021) towards SD learning objectives (Burbules et al., 2020), competence in the last decade has been discussed as complex and dynamic, facing rapid technological and scientific advancement, bringing uncertainty (Ioannidou et al., 2026).

The research on the contribution of digital literacy programs to SD was enhanced by the ubiquitous Internet and Web 2.0 tools that enable creation and participation (Sharma et al., 2026). Social networking sites facilitated active engagement, connecting the three areas- private, civic, and professional necessary for bridging the gap between awareness and behavior (Istenic Starcic et al., 2018; Mintz & Tal, 2014). Specifically, social networking sites enhanced the lifestyle by providing a space for authentic activities in private, with the civic and professional spheres applied in higher education instruction (Istenic Starcic et al., 2018) and enhancing collaborative learning (Chaudhuri et al., 2025).

In this paper, we examine how much digital competence predicts SD components based on self-reported beliefs and behavior.

Research Questions

RQ1: What is the structure of digital competences (DigComp 2.1) and SD beliefs in our sample?

RQ2: To what extent can digital competences components predict the SD components?

MATERIALS AND METHODS

Research Design, Instrument, and Sample

The exploratory correlational study was utilized to examine the structure of the DigComp 2.1 instrument (Carretero et al., 2017) measuring digital competences among 368 students from the University of Primorska from pedagogical programs.

For the purpose of the study, two instruments, the digital competences and the SD competences, were designed by the evaluation project group ULTRA NOO (ULTRA – University of Ljubljana for Sustainable Society; NOO – Recovery and Resilience Plan). For the digital competences utilized was DigCom 2.1 (Carretero et al., 2017). In the SD competences, the Likert scale measuring beliefs and behaviors in SD competences, climate literacy and energy literacy was analyzed in this study. The five-point Likert scales were scored from 5 – totally agree, 3 – neutral, to 1 – totally disagree. The scales consisted of statements about beliefs and behaviors, capturing the multidimensional nature of SD, the environmental, social, and economic dimensions. The scales in the questionnaire were: two scales of SD competence (15 statements), one scale of climate literacy (17 statements) and two energy literacy scales (17 statements).

In this study, SD beliefs and behavior are examined in relation to digital competence, specifically how digital competence components predict SD components.

Data Analysis

SPSS 29 was used in the study. Principal axis factoring was performed. The number of factors was determined based on eigenvalues, scree graph inspection, and interpretability of the solutions. Items for low loadings or cross-loadings were excluded. The descriptive statistics of factors include means, standard deviations, skewness, and kurtosis. The reliability of the scales was measured utilizing Cronbach's alpha and McDonald's omega. Mean factor scores were computed for checking descriptive statistics and regression analysis.

To identify the predictive role of digital competence, the four factors were utilized in the multiple linear regression enter method. As a precondition, key assumptions (linearity, independence of errors, homoscedasticity, and absence of multicollinearity) were verified.

RESULTS

In the results section, firstly, we present findings from exploratory factor analysis, which reveals dimensions within our sample. Secondly, we present how digital components predict SD components.

Exploratory Factor Analysis of DigComp 2.1 and Sustainable Development Competences

Exploratory factor analysis was performed to examine how digital competence is manifested in the sample of Slovene students in pedagogical programs. Before performing the factor analysis, we checked the suitability of the data for factorization. Principal axis factoring was performed with Oblimin rotation. The sample proved to be suitable, as the KMO = .973, and Bartlett's test of sphericity was statistically significant ($p < 0.001$), which confirms that the correlations between the variables are suitable for factor analysis. Exploratory factor analysis suggested a four-factor solution (**Table 1**). The scree plot showed a clear inflexion after the fourth factor, and the four-factor solution yielded the most interpretable pattern of loadings.

Table 1. Results of DigComp 2.1 exploratory factor analysis after extraction of ten items

Items	DIGIF1 RPS	DIGIF2 ITC	DIGIF3 ODM	DIGIF4 CEMU
RPS1	**.499**	.063	.006	.148
RPS2	**.419**	.285	-.064	.033
RPS3	**.458**	.258	.051	.154
RPS4	**.498**	.180	.121	-.002
RPS5	**.595**	-.060	.003	.174
RPS6	**.415**	.152	.064	.163
RPS7	**.670**	.023	-.056	-.015
RPS8	**.677**	-.079	-.193	.021
RPS9	.649	.063	-.081	-.062
RPS10	**.657**	.085	-.073	-.107
RPS11	**.681**	-.295	-.142	.135
RPS12	**.579**	-.179	-.140	.201
RPS13	**.622**	.023	-.131	.000
RPS14	**.611**	.098	-.036	.044
RPS15	**.618**	.077	-.040	-.168
RPS16	**.541**	.143	-.089	-.024
RPS17	**.635**	.088	.046	.042
ICT1	-.049	**.620**	-.217	.084
ICT2	.104	**.413**	-.300	.082
ICT3	.174	**.389**	-.119	.188
ICT4	-.069	**.647**	-.209	.053
ICT5	.106	**.544**	-.184	.009
ICT6	.060	**.674**	.027	-.091
ICT7	.148	**.556**	-.009	.074
ICT8	.366	**.453**	-.010	-.111
ICT9	.273	**.347**	.288	.207
ICT10	.339	**.431**	.161	-.019
ODM1	.136	.081	**-.411**	.142
ODM2	.132	-.113	**-.530**	.216
ODM3	.123	-.097	**-.582**	.194
ODM4	.117	.295	**-.401**	-.031
ODM5	.171	.194	**-.402**	.084
ODM6	.128	.149	**-.634**	.035
ODM7	.089	.040	**-.469**	.249
ODM8	.111	.071	**-.335**	.264
ODM9	.022	.111	**-.571**	.192
ODM10	.065	.159	**-.589**	.083
ODM11	.087	.024	**-.544**	.259
ODM12	.126	.328	**-.370**	.059
ODM13	.149	.242	**-.455**	.044
ODM14	.155	.231	**-.307**	.201
CEMU1	.186	-.023	-.174	**.316**
CEMU2	.083	-.053	-.242	**.386**
CEMU3	.057	.012	-.131	**.489**
CEMU4	-.065	-.021	-.027	**.647**
CEMU5	-.038	-.175	-.235	**.534**
CEMU6	.107	.047	-.235	**.460**
CEMU7	-.074	.014	-.010	**.725**
CEMU8	-.007	.065	.009	**.744**
CEMU9	-.027	.012	.007	**.773**
CEMU10	.010	.097	-.024	**.690**
CEMU11	.111	.072	-.243	**.402**
CEMU12	.235	.206	-.068	**.366**
CEMU13	.341	-.041	.108	**.494**
Eigenvalues	18.836	4.447	3.940	2.837
Percent of explained variance (%)	33.900	7.243	2.970	1.884

Note. Extraction method: Principal axis factoring; Rotation method: Oblimin with Kaiser normalization; Rotation converged in 16 iterations; KMO measure of sampling adequacy = .973; Bartlett's test of sphericity approximation Chi-square = 35,452.086; df = 1,431; Significance < .001

Although a five-factor solution was explored in line with the DigComp 2.1 framework (information & data literacy, communication & collaboration, digital content creation, safety, problem-solving), the fifth factor lacked conceptual coherence and substantial primary loadings. A four-factor solution showed superior interpretability and a clearer simple structure, whereas the fifth factor lacked sufficient loadings and conceptual coherence. After Oblimin rotation, four factors were extracted, which together explained 45.997% of the total variance. The first factor explained 33.900% of the variance. Cronbach's alpha indicates excellent internal consistency reliability for the first (.900) and the third factors (.894). The internal consistency reliability is good for the second (.861) and the fourth factors (.850).

Extracted items were from information & data literacy: I know that different search engines can give different search results because they are influenced by commercial factors. In the second round, the extracted item was: I can find a website that I have already visited (e.g., searching using the browser history and searching using the previous web page view).

From communication & collaboration, extracted items were: I know that many communication services and social media are free for the user because they are paid for by advertisers. I know that many public services are available online (e.g., ordering a health visit and other e-government services). I can pay for goods and services that I buy online (e.g., by direct bank transfer, credit/debit cards, and other online payment systems). I can prevent or limit cookies in the browser. In the second round, the extracted item was: I am willing to share digital content that I think could be interesting and useful to others.

From digital content creation, the extracted item was: I know how to choose the right type of digital media according to my audience and my goal (e.g., using social media to promote a project). In the second round, the extracted item was: I create new digital content by combining and modifying existing digital sources (e.g., presenting photos and audio clips I find online).

From the safety extracted in the second round was: I know how to restore digital data and other content (e.g., photos and contacts) from a backup copy. In the third round, the following was extracted: I am aware of the importance of updating the operating system, antivirus software and other software to prevent security problems.

In the sample of Slovenian students in pedagogical courses, the DigComp 2.1 does not present a clear original factor solution. The first factor, responsible problem-solving (RPS), merges items from problem-solving (all of them) and safety (seven from twelve). The second factor, innovative technical competence (ITC), merges items from content creation (seven from eleven) and three items from safety (of twelve). The third factor, operational digital media use (ODM), merges three factors: information & data literacy, communication & collaboration, and content creation. The fourth factor, critical and ethical media use (CEMU), is very clearly formed from items from the original factors information & data literacy (four items from eight), communication & collaboration (five statements from thirteen), and two items from safety (of twelve). The final statements for the factor analysis are presented in **Appendix A**.

Exploratory Factor Analysis of Sustainable Development Competences

A principal axis factoring analysis was conducted to examine the dimensional structure of the SD competence scale. Preliminary analyses indicated that the data were suitable for factor analysis. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .902, indicating excellent sampling adequacy, and Bartlett's test of sphericity was significant, $\chi^2(378) = 60{,}85.61$, $p < .001$. Three factors (sustainable society beliefs [SSB] – SDF1; gender equity beliefs [GEB] –- SDF2; energy saving behavior [ESB] – SDF3) were extracted (**Table 2**), explaining 48.16% of the total variance. The first factor accounted for 30.98% of the variance, the second for 9.40%, and the third for 7.78%. Following rotation, the variance was redistributed across the three factors, facilitating interpretation of the underlying competence dimensions. During the process of factor analysis, a total of 21 items were excluded, and the final statements for the factor analysis are presented in **Appendix B**. The first factor included beliefs about sustainability in society, the second included beliefs about gender equity, and the third captured energy-saving behavior. Cronbach's alpha in case of the first factor shows excellent internal consistency reliability (.919). McDonald's omega shows good internal consistency reliability in the case of the second (.892) and the third factors (.816) (**Table 3**). Descriptive statistics are presented in **Table 3**.

Table 2. The PCA identified three factors after extracting 21 items

Items	SDF1 SSB	SDF2 GEB	SDF3 ESB
SSB1	**.539**	-.047	.020
SSB2	**.475**	-.002	.192
SSB3	**.609**	.026	-.121
SSB4	**.611**	.043	-.100
SSB5	**.652**	.016	.002
SSB6	**.576**	.126	-.166
SSB7	**.453**	.014	.306
SSB8	**.848**	.022	-.125
SSB9	**.814**	-.070	-.176
SSB10	**.858**	-.031	-.146
SSB11	**.505**	.034	.073
SSB12	**.615**	-.015	.161
SSB13	**.589**	.004	.148
SSB14	**.480**	.075	.289
SSB15	**.566**	.043	.313
SSB16	**.656**	-.029	.212
SSB17	**.569**	.013	.272
SSB18	**.636**	-.092	.253
GEB1	.056	**.621**	-.023
GEB2	-.016	**.878**	.033
GEB3	-.028	**.920**	.016
GEB4	-.042	**.826**	.023
ESB1	.157	.051	**.423**
ESB2	.261	.000	**.497**
ESB3	-.106	.063	**.750**
ESB4	-.146	.027	**.793**
ESB5	.022	-.033	**.603**
ESB6	.148	-.008	**.618**
Eigenvalues	9.195	2.932	2.696
Percent of explained variance (%)	30.977	9.399	7.784

Note. Extraction method: Principal axis factoring; Rotation method: Oblimin with Kaiser normalization; Rotation converged in 6 iterations; KMO measure of sampling adequacy = .902; Bartlett's test of sphericity approximation Chi-square = 6,085.610; df = 378; Signficance < .001

Table 3. Descriptive statistics of factors

	Cronbach's alpha/McDonald's omega	M	SD	Skewness	Kurtosis
DIGI F1 RPS	.900	2.6221	.64042	-.379	-.002
DIGI F2 ITC	.861	2.4128	.78819	1.081	1.240
DIGI F3 ODM	.894	3.1547	.53405	-.193	-.152
DIGI F4 CEMU	.850	3.3751	.42408	-.931	-.165
SD1 SSB	.919	4.0969	.49876	-.899	3.784
SD2 GEB	.892*	3.1764	.95226	.120	-.379
SD3 ESB	.816*	3.3910	.72633	-.157	.116

Note.*McDonald's omega; M: Mean; & SD: Standard deviation

Results of Regression Analysis

Multiple linear regression analysis enter method was conducted to examine whether the four dimensions of digital competence are associated with sustainable society beliefs (SSB) (SDF1) (**Table 4**). The overall regression model was statistically significant, $F(4, 362) = 4.48$, $p = .002$, indicating that the four digital competence dimensions jointly predicted SSB (SDF1). The model explained 4.7% of the variance in SSB ($R^2 = .047$; adjusted $R^2 = .037$). The model explained 4.7% of the variance in SSB ($R^2 = .047$); adjusted ($R^2 = .037$). The corresponding Cohen's effect size was ($f^2 = .049$), indicating a small overall effect according to Cohen's conventional criteria. Thus, although the regression model was statistically significant, the four digital competence dimensions accounted for only a modest proportion of the variability in SSB.

Among the four predictors, only DIGIF4 CEMU was a statistically significant predictor of SSB ($B = 0.322$, $\beta = .274$, $t = 3.62$, $p < .001$). This positive association indicates that students with higher levels of CEMU tend to report more positive beliefs toward a sustainable society. The remaining digital competence dimensions were not statistically significant predictors. The collinearity diagnostics indicated no evidence of problematic

Table 4. Linear model of predictors of SSB predicted by digital competences components

	b	Standard error B	β	p
Constant	3.457	0.219	-	< .001
DIGIF1 RPS	-0.034	0.054	-0.043	.536
DIGIF2 ITC	-0.036	0.036	-0.056	.327
DIGIF3 ODM	-0.087	0.072	-0.093	.229
DIGIF4 CEMU	0.322	0.089	0.274	< .001

Note. R = .217; R^2 = .047; Adjusted R^2 = .037; Standard error of the estimate = .490

Table 5. Linear model of predictors of GEB predicted by digital competences components

	b	Standard error B	β	p
Constant	3.051	0.426	-	<.001
DIGIF1 RPS	0.090	0.106	0.061	.393
DIGIF2 ITC	0.137	0.070	0.114	.052
DIGIF3 ODM	-0.129	0.140	-0.072	.357
DIGIF4 CEMU	-0.011	0.173	-0.005	.952

Note. R = .105; R^2 = .011; Adjusted R^2 = .000; Standard error of the estimate = .952

Table 6. Linear model of predictors of ESB predicted by digital competences components

	b	Standard error B	β	p
Constant	3.188	0.322	-	< .001
DIGIF1 RPS	0.229	0.080	0.202	.004
DIGIF2 ITC	0.078	0.053	0.084	.145
DIGIF3 ODM	-0.115	0.106	-0.084	.281
DIGIF4 CEMU	-0.066	0.131	-0.039	.613

Note. R = .160; R^2 = .026; Adjusted R^2 = .015; Standard error of the estimate = .720

multicollinearity. Tolerance values ranged from 0.44 to 0.80, while variance inflation factor (VIF) values ranged from 1.25 to 2.26, all well below commonly accepted thresholds.

The Durbin-Watson statistic of 1.83 suggested that the residuals were sufficiently independent. One issue requiring attention was the presence of extreme standard residuals with standard residuals ranging from -6.37 to 2.41, indicating the presence of at least one extreme negative outlier. Because standardized residuals exceeding ±3 are generally considered unusual, this observation was further examined through Cook's distance (min = .000, max = .510). Overall, the presence of the outlying residual did not materially alter the interpretation of the regression model.

A multiple linear regression, the enter method, was conducted to examine whether the four dimensions of digital competence predicted gender equity beliefs (GEB) (SDF2) (**Table 5**). The regression model was not statistically significant $F(4, 362) = 1{,}009$, $p = .403$, indicating that the four digital competence dimensions had virtually no explanatory power for this dependent variable. The model explained 1.1% of the variance in GEB ($R^2 = .011$). At the individual predictor level, RPS (DIGIF1 RPS), ITC (DIGIF2 ITC), online digital management (DIGIF3 ODM), and DIGIF4 CEMU were not statistically significant predictors of GEB. Overall, the findings suggest that the dimensions of digital competence made little contribution to explaining differences in students' GEB.

A multiple linear regression was conducted to examine whether the four dimensions of digital competence predicted energy saving behavior (ESB) (SDF3) (**Table 6**). The overall regression model was not statistically significant, although it approached significance, $F(4, 362) = 2.38$, $p = .052$. The model explained 2.6% of the variance in ESB ($R^2 = .026$; adjusted $R^2 = .015$), indicating that the four digital competence dimensions had very limited explanatory power. Among the predictors, RPS (DIGIF1 RPS) made a statistically significant positive contribution to the model ($B = 0.229$, $\beta = .202$, $t = 2.87$, $p = .004$). The effect of RPS was small ($f^2 = .023$), indicating that it accounted for approximately 2.2% of the unique variance in ESB after controlling for the other three dimensions of digital competence. This indicates that students with higher levels of RPS competence tend to report higher levels of ESB. Collinearity diagnostics indicated no serious multicollinearity concerns. VIF values ranged from 1.25 to 2.26, well below the commonly accepted threshold of 5, and tolerance values ranged from 0.44 to 0.80, suggesting acceptable independence among predictors. The Durbin-Watson statistic of 1.97 indicated that the residuals were independent.

Across the three regression models, the effect sizes were consistently small. Digital competences demonstrated a significant but modest association with SSB, whereas the model did not significantly predict GEB or ESB. These findings suggest that, while certain dimensions of digital competence, particularly CEMU, are related to sustainability beliefs, digital competence explains a small proportion of variance in SD outcomes. The relatively small explanatory effects observed in the present study indicate that digital competence alone is insufficient to account for substantial variation in sustainability-related beliefs and behaviors. This highlights the importance of considering digital competence alongside broader personal, social, educational, and contextual factors in efforts to strengthen education for SD.

DISCUSSION

Authors argue for the multifaceted nature of the DigComp instrument measuring digital competences, referring to knowledge, skills, and attitudes, and discussing the taxonomical structure and its manifestation in its cognitive and practical application (Jelić et al., 2026; Mieg et al., 2024; Vuorikari et al., 2026). In practice, the instrument conceptual taxonomy may reveal diverse patterns and associations. In empirical measurement, the dimensions may not demonstrate independent instead show multidimensional or bifactorial dimensions (Vuorikari et al., 2026).

Factor analysis of DigComp 2.1 indicates transition from original five factor structure to four factor structure merging. In our study, the first factor, RPS, merges items from problem-solving and safety. A related study in a sample of students from Germany, Lithuania, Austria, and the UK, by Mieg et al. (2024), exhibits empirical convergence of problem-solving and safety. The study by Mieg et al. (2024) highlights problem-solving and safety as the main focus of the short version of the DigComp scale, which they tested and retained a unidimensional overall digital competence score.

The second factor, ITC, merges items from content creation and safety. The third factor, ODM, merges three factors: information & data literacy, communication & collaboration, and content creation. The fourth factor, CEMU, is very clearly formed from items from the original factors information & data literacy, communication & collaboration, and safety.

Historically, the construct of digital competence has reflected technological development and its impact on access to information, communication, and collaboration; consequently, measurement instruments focused on operational ICT skills, information retrieval, and digital communication. However, current developments and modes of technology use require the construct to move beyond measuring operational and technical skills and instead be grounded in ethics and sustainability, including ethical decision-making and responsibility for sustainable development.

Factor analysis of SD manifests three factors: SD society beliefs, GEB, and ESB. They manifest the SDGs (United Nations, 2015) beyond environmental protection, including gender equality, social justice, cultural diversity, inclusion, and responsible consumption.

The results showed that the technical dimensions of digital competence were not associated with sustainability outcomes. The regression model indicates from 1.1 to 4.7 % of variance explained with a small exploratory effect; CEMU significantly predicted SSB. CEMU refers to evaluating online information, recognizing misinformation, ethical use of digital technologies, responsible participation in digital society, and understanding social consequences of technology. SSB refers to sustainability, responsible citizenship and critical, ethical, informed decision-making.

Our study of digital competence predicting sustainability shows that critical evaluation and ethical use are more relevant for sustainability than purely technical digital skills, e.g., innovative use or operational use. This is in line with DigComp 2.2 (Vuorikari et al., 2022) and the UNESCO digital literacy framework (UNESCO, 2020). GEB were not predicted by either dimension of digital competence. ESB shows an individual predictive role of RPS; however, there was no significant overall prediction. This may suggest that practical digital problem-solving may support efficient behavior (e.g., using smart devices, monitoring electricity consumption), but digital competence alone does not explain everyday environmental behavior.

In search based on assumptions of digital competences as enablers of knowledge accumulation, accessibility, and exploitation (Stuermer et al., 2017), which predict SD beliefs and behavior, findings show certain transitions in manifestations of both competence areas which may be considered towards integration. The study supports the view that digital competence is not value-neutral but incorporates ethical and social dimensions that are closely aligned with the principles of SD. Sustainability may be considered an inherent characteristic of higher-order digital competence, particularly where digital competence encompasses ethical reasoning, critical evaluation of information, and responsible participation in digital society. The one component of digital competence, the CEMU predicted SSB. That is a more nuanced and theoretically meaningful conclusion, and it aligns well with current frameworks of DigComp 2.2, which includes environmental protection within safety and ethical use for sustainability within interaction with artificial intelligence. Digital (Vuorikari et al., 2022) and SD (UNESCO, 2020) rely strongly on critical thinking, ethical reasoning, responsible citizenship, and informed decision-making. UNESCO's education for SD (UNESCO, 2020) promotes critical thinking, ethical reasoning, responsible citizenship, and informed decision-making.

It also provides a clear rationale for why future measurement instruments should distinguish between dimensions of both digital competence and sustainable development competence rather than relying on a single overall score. The findings have implications for the measurement of both constructs. The differential relationships observed across the study variables support the view that both constructs are inherently multidimensional. Rather than treating digital competence as a single, unified competence, the results indicate that its individual dimensions contribute differently to sustainability outcomes. In particular, CEMU demonstrated a meaningful association with SSB, whereas technical and operational dimensions did not. Similarly, the three dimensions of sustainable development competence, SSB, GEB, and ESB, showed distinct patterns of association with digital competence. These findings suggest that multidimensional measurement provides a more accurate representation of the complex relationship than the use of aggregate scores alone. The two constructs are intertwined; although their historical conceptualization varies depending on the discipline and theoretical approach, dimensions of safety, ethics, and sustainability predominate in both. Future construct conceptualization of these notions must consider current developments. The current study has limitations related to sample representativeness, reliance on self-report with no assessment results included and the need for further refinement of the instrument. The regression model focuses on digital competences and sustainable development competences, but it does not address the complex interplay of significant influential factors stemming from students' broader competence profiles, their demographic and personality characteristics, instruction, and other contextual factors. The sample involves students from one of the three Slovene faculties of education, which limits the generalizability of findings. The self-reporting instrument may introduce the risk of subjective bias and may be influenced by social desirability or confidence bias. These limitations are acknowledged to guide future improvements and research directions.

CONCLUSIONS

The strongest predictor was CEMU, with items assessing ethical decision-making in digital environments, recognition of misinformation and disinformation, critical evaluation of online information, responsible online participation, understanding the societal consequences of digital technologies, and digital citizenship. These competencies appear more closely linked to SD than technical proficiency alone.

Current digital competence scales are not so much concerned with whether people use digital technologies in environmentally or socially responsible ways. Responsible citizenship requires critical thinking, ethical reasoning, responsible citizenship, and informed decision-making, participating in a sustainable society and care for social and natural environments. Social and technological processes involve digital working and learning environments. This is manifested in contemporary conceptualizations of digital competence, such as DigComp 2.2 (Vuorikari et al., 2022), which, in the area of digital competence, demands environmental protection and social sustainability.

The study does not show that digital competence predicts sustainable development competences. Rather, it suggests that evolution of digital competence frameworks mirrors the evolution of sustainable development competence frameworks. The two constructs have shifted from narrow, skills-based models to holistic competence models that integrate knowledge, skills, values, ethics, and responsible action. The findings provide empirical support for this conceptual convergence by demonstrating that the shared ethical and critical dimensions appear where the strongest relationships between digital and sustainability are observed.

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Ethics declaration: This study was approved by the Ethics Committee of Faculty of Education at University of Ljubljana on 2 February 2026 with approval number 11/2026. All participants were fully informed of voluntary participation (asked to participate voluntarily with no effect on grading and the possibility of withdrawing at any time during the study). When applying instruments and procedures, special care was taken in order to follow personal data minimization principle and ensure the data anonymization. All participants were assured of anonymity and informed about why the research was conducted, how their data would be used, and that there were no risks associated.

AI statement: Grammarly was used in this study to improve readability and grammatical clarity.

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Data availability: Data generated or analyzed during this study are available from the authors on request.

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APPENDIX A

Table A1. The statements of DigComp 2.1 exploratory factor analysis after extraction of ten items

	STAT	NF
CEMU1 - I know which keywords to use to quickly find what I need (e.g., for searching online).	IDL	CEMU
CEMU2 - I distinguish between advertised content and other content I find or receive online (e.g., recognizing an advertisement on social media or search engines).	IDL	CEMU
CEMU3 - I recognize the purpose of online information (e.g., to inform, influence, entertain or sell).	IDL	CEMU
CEMU4 - I know that some information online is false (e.g., fake news).	IDL	CEMU
ODM1 - I know about different data storage media (e.g., internal or external hard drive, USB memory, memory card).	IDL	ODM
ODM2 - I can organize digital content (e.g., documents, images, videos) using folders or tags to find them later.	IDL	ODM
ODM3 - I can copy and move files (e.g., documents, images, videos) between folders, devices or in the cloud.	IDL	ODM
ODM4 - I can manage and analyze data using software (e.g., sorting, filtering, calculations, using Excel).	IDL	ODM
CEMU5 - I can send, reply to and forward emails.	CC	CEMU
ODM5 - I can use advanced video conferencing features (e.g., moderating, recording audio and video).	CC	CEMU
CEMU6 - I know which communication tools and services (e.g., phone, email, video conferencing, text messaging) are appropriate to use in different situations.	CC	CEMU
ODM6 - I can use cloud services (e.g., Google Drive, DropBox, and OneDrive) to share my files.	CC	ODM
ODM7 - I know how to set who I want to share content with (e.g., friends, friends of friends, everyone).	CC	ODM
ODM8 - I can apply for a job using a digital platform (e.g., fill in a form, upload a CV and a photo).	CC	ODM
ODM9 - I can edit a shared online document.	CC	ODM
ODM10 - I can invite others and give them the appropriate permissions to collaborate on a shared document.	CC	ODM
CEMU7 - I am aware that I should ask a person for permission before posting or sharing a photo of them.	CC	CEMU
CEMU8 - I can identify online messages and behaviors that attack specific groups or individuals (e.g., hate speech).	CC	CEMU
CEMU9 - I know how to behave online depending on the situation (e.g., formal or informal).	CC	CEMU
CEMU10 - I know that my digital identity is everything that defines me in online environments (e.g., usernames, likes and posts on social media, petitions, signatures, online, what others post about me).	CC	CEMU
CEMU11 - I can create a profile in a digital environment for personal or professional purposes.	CC	CEMU
ODM11 - I can create and edit digital text files (e.g., Word, OpenDocument, Google Docs).	DCC	ODM
ODM12 - I can express myself by creating digital content on the Internet (e.g., blog post, YouTube video).	DCC	ODM
ODM13 - I can create a multimedia presentation with text, images, audio and video elements.	DCC	ODM
ICT1 - I know that some digital content can be legally reused and repurposed (e.g., public domain or creative commons licenses).	DCC	ITC
ICT2 - I can edit digital content created by others (e.g., insert text into an image, edit a wiki).	DCC	ITC
ODM14 - I can create something new by combining different types of content (e.g., text and images).	DCC	CEMU
ICT3 - I can recognize when digital content is available illegally (e.g., software, films, music, books, TV).	DCC	ITC
ICT4 - I know that there are different types of licenses for using digital content (e.g., creative commons licenses).	DCC	ITC
ICT5 - I know that programming languages (e.g., Python, Visual Basic, Java) are used to instruct a digital device to perform a task.	DCC	ITC
ICT6 - I can write scripts, macros, and simple applications to automate tasks.	DCC	ITC
ICT7 - I know that there are different algorithmic solutions to perform a specific computer task (e.g., editing and searching).	DCC	ITC
CEMU12 - I understand the benefits and security risks of using devices or systems connected to the Internet (e.g., smart watches, smart home devices).	S	CEMU
ICT8 - I know how to set up a firewall on different devices.	S	ITC
RPS1 - I know how to limit or deny access to my geographical location.	S	RPS
RPS2 - I know how to check whether a website asking me to provide personal information is secure (e.g., https pages, security logo or certificate).	S	RPS
CEMU13 - I know which personal information I should not share and display online (e.g., on social networks).	S	CEMU
ICT9 - I am careful or attentive when checking the privacy policies of the digital services I use.	S	ITC
RPS3 - I know how to protect myself from unwanted and malicious online encounters and content (e.g., spam, identity theft emails).	S	ITC
ICT10 - I know digital tools that can help the elderly or people with special needs.	S	ITC
RPS4 - I look for ways in which digital technologies can help me live and work in a more environmentally friendly way.	S	RPS

Table A1 (Continued).

	STAT	NF
RPS5 - I know how to reduce the energy consumption of my devices (e.g., change settings, close applications).	S	RPS
RPS6 - I know the 'green' behaviors that I should follow when buying or using digital devices (e.g., buy devices with an eco-label, avoid unnecessary printing, do not leave mobile phones and laptop chargers plugged in without the device).	S	RPS
RPS7 - When faced with a technical problem with digital devices, I try to identify the problem step by step.	S	RPS
RPS8 - When I encounter a technical problem, I am able to find solutions online.	PS	ODM
RPS9 - I know how to configure the operating system of my digital devices to solve technical problems (e.g., automatically stop/start services, change registry keys).	PS	ODM
RPS10 - I usually try to find out if there is a technological solution that could help me solve personal or professional challenges.	PS	RPS
RPS11 - I know the main functions of the most common digital devices (computer, tablet, smartphone).	PS	RPS
RPS12 - I can choose the right tool, device, or service to perform a given task (e.g., choosing a smartphone for my needs, choosing a tool for a professional video call).	PS	RPS
RPS13 - I know technical solutions that can improve the accessibility of digital tools, such as language translation, magnification, and text-to-speech functionality.	PS	RPS
RPS14 - I know that digital technology can be used as a powerful tool to innovate processes and products.	PS	RPS
RPS15 - I am interested in new digital devices and applications and am happy to try them out whenever I find the opportunity.	PS	RPS
RPS16 - I can use online learning tools and environments to improve my digital skills (e.g., video tutorials, online courses).	PS	RPS
RPS17 - I know new trends in the digital world and their impact on my personal or professional life.	PS	RPS

Note. Items marked according to original scale dimensions and new factor solutions in Slovene sample; STAT: Statements according to original scale dimension; NF: New factor in Slovene sample; IDL: Information and data literacy; CC: Communication and collaboration; DCC: Digital content creation; S: Safety; & PS: Problem-solving

APPENDIX B

Table B1. The statements of SD exploratory factor analysis after excluding 21 statements

Statement
SSB1 - Our generation must ensure that we preserve natural resources for future generations.
SSB2 - I am willing to actively contribute to the transition to greener (sustainable) modes of transport.
SSB3 - I treat everyone with the same respect, even if they have a different cultural background than mine.
SSB4 - I support the work of humanitarian organizations or non-governmental organizations.
SSB5 - I support the work of organizations or groups that strive to preserve the environment.
SSB6 - I show equal respect to men and women, boys and girls.
SSB7 - I believe I can help reduce global warming.
SSB8 - Global warming is a serious danger to humans.
SSB9 - Global warming is a serious threat to plants.
SSB10 - Global warming is a serious threat to animals.
SSB11 - Life on Earth will continue without major disruption only if we take immediate and decisive action to reduce it.
SSB12 - I believe that by working with others, I can help reduce global warming.
SSB13 - We should produce more electricity from renewable sources.
SSB14 - With appropriate energy-related decisions and actions, I can contribute to solving energy problems.
SSB15 - In collaboration with others, I can contribute to solving energy problems.
SSB16 - Saving energy is beneficial for preserving the environment.
SSB17 - Saving energy is good for my health.
SSB18 - Every individual should accept responsibility for saving energy in order to protect the environment.
GEB1 - Women and men in Europe have equal opportunities for education.
GEB2 - Women and men in Slovenia have equal employment opportunities.
GEB3 - Women and men in Slovenia have equal opportunities for advancement at work.
GEB4 - Women and men are paid equally for equal work in Slovenia.
ESB1 - I'm trying to reduce the number of kilometers I drive.
ESB2 - I feel guilty when I waste energy unnecessarily.
ESB3 - Many of my daily decisions are influenced by my thoughts about energy use.
ESB4 - I encourage my family to turn down the heating to save energy.
ESB5 - I encourage my family to buy energy-efficient LED light bulbs.
ESB6 - I am willing to buy fewer things to save energy.