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The effect of the learning environment on students' self-perceived digital and sustainability competencies

El efecto del entorno de aprendizaje en las competencias digitales y de sostenibilidad autopercibidas de los alumnos

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Abstract:

This study investigates the impact of students' perceptions of the learning environment on their self-assessed digital and sustainability competencies. The study involved 433 final-year students in Slovenian wood science and technology educational programs. We distinguished between generic competencies, which were assessed using the DigComp and GreenComp frameworks, and profession-specific competencies. Learning environment factors were assessed using the "What Is Happening in This Class?" (WIHIC) questionnaire. Linear regression analysis revealed that the factor 'Investigation' predicted both Generic and Profession-Specific Digital and Sustainability Competencies, and that 'Involvement' predicted Generic Digital Competencies, while 'Teacher Support' had a negative effect on both Generic Digital and Sustainability Competencies. Paired t-tests showed significant discrepancies between students' actual and preferred learning environments. The results highlight the importance of promoting inquiry-based and active learning, while supporting student autonomy and individualization, as well as considering students' preferences regarding the learning environment to facilitate the better development of students' digital and sustainability competencies.

Keywords: learning environment, sustainability competencies, digital competencies, education, learning outcomes, self-assessment.

Resumen:

Este estudio investiga el efecto de las percepciones de los alumnos del entorno de aprendizaje en sus competencias digitales y de sostenibilidad según su propia autoeva-

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luación. En el estudio participaron 433 alumnos de último curso de programas educativos de Ciencia y Tecnología de la Madera de Eslovenia. Distinguimos entre competencias genéricas, que pueden evaluarse con los marcos DigComp y GreenComp, y competencias específicas de la profesión. Los factores del entorno de aprendizaje se evaluaron utilizando el cuestionario «What Is Happening in This Class?» o WIHIC (¿Qué está pasando en esta clase?). El análisis de regresión lineal reveló que el factor 'Investigación' predecía tanto competencias digitales y de sostenibilidad genéricas como específicas de la profesión, y que 'Implicación' predecía competencias digitales genéricas, mientras que 'Apoyo del profesor' tenía un efecto negativo en las competencias digitales y de sostenibilidad genéricas. Las pruebas t pareadas mostraron discrepancias significativas entre el entorno de aprendizaje real y el entorno preferido por los alumnos. Los resultados destacan la importancia de promover el aprendizaje activo y basado en la investigación, apoyando la autonomía del alumno y la individualización, y de tener en cuenta las preferencias de los alumnos respecto al entorno del aprendizaje para facilitar un mejor desarrollo de sus competencias digitales y de sostenibilidad.

Palabras clave: entorno de aprendizaje, competencias de sostenibilidad, competencias digitales, educación, resultados de aprendizaje, autoevaluación.

1. Introduction

Until now, society has been driven by socio-economic development efforts, hoping that increasing productivity and income would solve other development problems (Vintar Mally, 2020), which has led to significant environmental consequences (UNEP & IRP, 2024). As a result, the imperative of sustainable development has gained prominence over the past three decades and was formally articulated in the 1987 Brundtland Report of the World Commission on Environment and Development (WCED, 1987). Since then, sustainable development has become an integral part of many development agendas (Vintar Mally, 2021) and received further impetus in 2015 when the United Nations (UN) adopted the 2030 Agenda for Sustainable Development (UN, 2015). Alongside sustainability, digitalization has become a crucial concept for operating in today's modern information society (Rachinger et al., 2019) and is a key element for achieving sustainability (Xu et al., 2022).

Despite growing awareness and progress in some areas, the world remains off course, particularly in relation to social and environmental challenges (Halkos & Gkampoura, 2021). Addressing these challenges effectively requires not only a shift in values (Whitley et al., 2018) and attitudes (Zsóka et al., 2013), but also recognition of the crucial role of education (Blais et al., 2011). The belief that education can change nations has been a fundamental principle of pedagogical theory since the early 20th century (Verhaeghe, 2016). Therefore, it is essential that education, as one of the fundamental factors of development (Ozturk, 2008), fosters students' identities, including self-knowledge, values, goals, orientation, and competencies for personal and social transformation, as suggested by Kaplan and Flum (2012). Although education can be provided by many institutions and through various life experiences, systematic education is most commonly offered by schools and universities (Bloom, 1976). These are vital for generating knowledge, cultivating innovative ideas, and developing the minds and attitudes of individuals (Roos et al., 2020). However, effective learning requires consideration of various factors that impact learning outcomes (Chaudhary & Singh, 2022).

This study examines how students' perceptions of the learning environment affect their self-assessed digital and sustainability competencies. In the following section of the literature review, we therefore focus on various factors that influence the development of digital and sustainability competencies, examining the impact of the learning environment, with a particular emphasis on psychosocial aspects, on students' learning outcomes.

1.1. Literature review

In line with competence-based education, two important European frameworks have been developed, the Digital Competence Framework for Citizens (DigComp) and the European Sustainability Competence Framework (GreenComp). DigComp defines digital competence as the safe, critical, and responsible use of digital technologies for learning, work, and participation in society (Vuorikari et al., 2022), while GreenComp outlines a set of sustainability competencies aimed at fostering empathy, responsibility, and care for the planet, social equity, and public well-being (Bianchi et al., 2022). Both frameworks provide structured, widely recognized definitions of key competencies relevant to the so-called "twin transition", the simultaneous societal shift towards digitalization and sustainability. These frameworks serve as the basis for ongoing curriculum renewal efforts in Slovenia, where digital and sustainability competencies are prioritized alongside other areas at all levels of education, including VET (Ahačič et al., 2024; Skubic Ermenc et al., 2024), higher VET (Mali et al., 2025), and higher education (Vlada Republike Slovenije, 2022).

These ongoing reforms are based on the principles of competence-based education (CBE), although it is unrealistic to expect success solely through the formal implementation of CBE at the national or institutional level or by simply transferring existing didactic practices to this new paradigm. CBE also represents a comprehensive pedagogical approach that requires significant changes and adaptations in both curriculum design and classroom implementation (Makovec Radovan, 2025). Importantly, CBE does not view the development of competencies from different areas as separate, but as developing simultaneously, often within the same learning activities.

In the following subsections of the literature review, we first examine specific factors that influence the development of digital and sustainability competencies. We then turn to the learning environment, which is also a crucial factor in the context of competence-based education and is the central focus of this article, particularly in terms of its effect on students' self-perceived digital and sustainability competencies.

1.1.1. Influences on Students' Digital and Sustainability Competencies

Differences in the self-perception of students' digital competencies were found to vary according to gender, educational level, place of residence, previous education, and age (Schmölz et al., 2023; Zhao, Sánchez Gómez, et al., 2021), with younger students generally overestimating their competencies. Similarly, Draganac, Jović, and Novak (2022) reported that high school students rate their competencies higher than university students. López-Meneses et al. (2020) report varying levels of competence at European universities. Personal innovation and digital competence (He & Zhu, 2017), as well as cultural differences (He & Li, 2019), influence digital informal learning. Students' digital competencies also correlate with digital informal learning, academic engagement (Heidari et al., 2021), prior experience (Martzoukou et al., 2020), motivation, family background, mastery orientation, books at home, teachers' professional development culture (Hatlevik et al., 2015), personal factors, learning structure, teachers' digital competence, and external conditions (Litiņa et al., 2022). However, despite the importance of these factors, only 15% of studies examine their influence on digital competencies (Zhao, Pinto Llorente et al., 2021).

Researchers are also increasingly focusing on sustainability competencies. Chaikovska et al. (2024) used facilitation methods in English classes to successfully improve both sustainability competencies and English language proficiency. This shift towards sustainability education aligns with the work of Lozano et al. (2019) and Lozano et al. (2022), who emphasize the importance of adapting traditional pedagogical approaches to achieve sustainability. Several studies have investigated the influence of disciplinary background on sustainability learning. Sánchez-Carracedo et al. (2022) found that although education students initially reported more knowledge, by the end of their studies, both education and engineering students achieved similar levels of sustainability competencies. Similarly, Leal Filho et al. (2021) investigated how higher education teachers in various institutions perceive the importance of sustainability competencies, whereas Cebrián et al. (2019) found no significant difference in students' perceived competencies across different disciplines. Several studies highlight factors that influence the development of sustainability competence. Savage et al. (2015) found that personal reflection and exploration significantly improved student learning in the Sustainability Leadership Certificate program. Remington-Doucette & Musgrove (2015) reported that the development of sustainability competencies is influenced by gender, disciplinary background, and age. In terms of motivation and attitudes, Zsóka et al. (2013) found a strong correlation between participation in environmental education and positive environmental attitudes, attributing this to the intrinsic motivation of committed students. Finally, Lambrechts et al. (2018) classified students into four groups based on their sustainability beliefs and attitudes, emphasizing the need for diverse teaching approaches.

1.1.2. The Influence of the Learning Environment on Learning Outcomes

The study of learning environments has been a focus of educational research for many decades, drawing primarily on psychology, such as Lewin's (1935) force field analysis and Murray's (1938) personality research. However, given the importance of the (educational) environment for learning, the term "learning environment" only gained prominence in educational literature a few decades ago (Radovan & Makovec, 2015). Its emergence is often attributed to Walberg, who developed the Learning Environment Inventory (Walberg & Anderson, 1968), and Moos, whose research on human environments (including education) led to the Classroom Environment Scale (Moos, 1974). Research on the learning environment is quite interdisciplinary and refers to all aspects that promote learning (Joyce & Calhoun, 2024), e.g. pedagogical approaches (Hao et al., 2021), social interactions (Morin, 2020; Olofsson & Lindberg, 2006; Walberg, 1969), psychological factors (Maslow, 1943), psychosocial dynamics (Fraser & Treagust, 1986; Moos & Trickett, 1974), and also the physical environment (Tanner, 2008; Weinstein, 1981).

Over the years, researchers have not only identified the psychosocial factors that influence the learning environment and student learning outcomes but have also made significant methodological advances in understanding the complex relationships between student perceptions of classroom climate, student learning outcomes, and innovative teaching practices (Khine, 2021). They have also shown that participants' perceived learning environment can be reliably measured and that fostering a positive classroom environment significantly improves student learning outcomes (Zandvliet & Fraser, 2018). In the field of learning environments, a variety of valid and widely applicable questionnaires exist that can be used to assess students' perceptions of the classroom environment (Fraser, 1998). One of the most commonly used questionnaires is What Is Happening In This Class? (WIHIC) (Brito Santiago & Silva, 2023), which not only incorporates the dimensions of previous instruments, but also addresses other aspects of classroom learning, such as Equity and an emphasis on comprehension over memorization (Fraser et al., 1996).

Numerous studies emphasize the relationship between the learning environment and educational outcomes. Fraser & Fisher (1982) and McRobbie & Fraser (1993) confirmed the relationship between students' perceptions of the classroom environment and their cognitive and affective learning outcomes. A study conducted at a Canadian university found that cognitive demands and social support significantly influenced students' perceived academic control and coping strategies, which, in turn, affected their academic performance (Clifton et al., 2004). Similarly, a study of fifth-grade mathematics classes in Singapore found a correlation between perceived psychosocial climate and student outcomes (Goh et al., 1995). A meta-analysis found that students with learning difficulties in inclusive settings had cognitive advantages, although psychosocial outcomes were not significantly affected

(Krämer et al., 2021). Psychosocial factors, including self-efficacy, social support, and self-regulated learning, were correlated with academic success in medical education, with no significant differences observed between traditional and problem-based curricula (Schauber et al., 2015). Galán-Casado et al. (2020) found that New Environment Learning improves student engagement and visual appeal compared to traditional classrooms, contributing to education for sustainable development. Studies have also found links between the learning environment and non-cognitive factors such as students' epistemological beliefs, self-efficacy, and anxiety (Ali et al., 2023). Jennings & Greenberg (2009) emphasized the importance of teachers' social and emotional competence in fostering a positive classroom climate, which supports effective classroom management, enhances teacher-student relationships, and improves students' social, emotional, and academic outcomes. Dorman (2001) emphasized the positive effects of classroom environment on mathematical performance, with Student Cohesion, Teacher Support, and Task Orientation having the strongest effects. Chionh & Fraser (2009) found that better exam results in mathematics and geography were associated with higher levels of Student Cohesiveness, while positive attitudes and self-esteem correlated with greater Teacher Support, Task Orientation, and Equity. Cross-national studies also linked Teacher Support and Task Orientation to reduced self-handicapping behaviors (Dorman et al., 2002). Teacher Support, Investigation, and Equity were also positive predictors of student achievement in high school biology classes, while Student Cohesiveness showed a negative relationship (Rita & Martin-Dunlop, 2011). The physical, pedagogical, and psychosocial dimensions of the learning environment were closely related and influenced students' learning experiences (Closs et al., 2022). A study of parent and student perceptions of the classroom environment found that students wanted more Investigation, while parents favored greater Teacher Support, with Task Orientation strongly related to student outcomes and attitudes (Allen & Fraser, 2007). A positive learning environment has also been shown to improve student motivation and engagement (Cayubit, 2022). Both physical and psychosocial aspects play a role in technology-rich environments, with factors such as Student Autonomy and Task Orientation being critical for student satisfaction and outcomes (Liu et al., 2012; Zandvliet & Straker, 2001).

1.2. Objective of the Present Study

This study focuses on students enrolled in wood science and technology education programs in Slovenia. The choice of this area was primarily motivated by the authors' affiliation with wood science and technology education, as well as our particular interest in understanding competence development within these educational programs, especially in view of the ongoing curricular reforms that also affect this field of education.

While previous research has investigated various factors that influence students' digital and sustainability competencies, relatively little attention has been paid to the role of the learning environment. Therefore, the overarching aim of this study is to investigate how the perceived learning environment affects students' self-perceived digital and sustainability competencies, distinguishing between generic and profession-specific competencies. In line with previous research where self-assessment is the most commonly used approach to assess students' digital (Laanpere, 2019; Sillat et al., 2021) and sustainability competencies (Redman et al., 2021), we used self-assessment as a method to capture students' self-perceived level of competence and their views on the actual and preferred learning environment. This approach was also chosen to foreground the learners' perspective, as the aim was not to measure objective performance but rather to understand students' subjective experiences and insights regarding their own learning and conditions. The main research questions (RQ) were:

RQ1 – What is the effect of students' perceived learning environment on their self-perceived level of digital and sustainability competencies?

RQ2 – Are there discrepancies between students' perceptions of the actual learning environment and their preferred learning environment?

The rest of this article is structured as follows. First, we present the methodology, including the sample, the measurement instruments, and the process of data preparation and analysis. We then present and discuss the main findings, situating them within the context of current educational reforms, with a particular focus on competency-based education. Finally, we address the study's limitations and provide concluding remarks.

2. Methods

2.1. Sample

To answer the research question, the study focused exclusively on students enrolled in wood science and technology education programs in Slovenia. Accordingly, we used a purposive sampling method, a non-probability method, which is best suited for studying a specific group (Tongco, 2007). The study involved 433 final year students of Slovenian wood science and technology programs at various levels of education, representing approximately 82% of the population in Slovenia. The sample was predominantly male (97%), which also reflects the current demographics in the sector. We included all educational qualifications, except for short vocational education and doctoral studies: 3 years of vocational education (ISCED 353) for "Carpenters"; 4 years of technical vocational education (ISCED 354) for "Technicians"; 2 years of technical education (ISCED 354), that enable graduates of a three-year VET program to obtain an upper secondary technical level of education; 2 years of higher vocational education (ISCED 554) for "Engineers"; 3 years of vocational and academic bachelor's degree programs (ISCED 645 & 655) for "Bachelors of Wood Engineering" and 2 years of master's degree program (ISCED 767) for "Masters of Wood Science and Technology". To ensure the relevance and accuracy of our results, careful attention was paid to representativeness across academic levels and qualifications.

The data was collected through in-person surveys from March to May 2024. During this period, we visited all educational institutions in Slovenia that offer the educational programs examined in this research. This corresponded to 35 final-year classes of students within the wood science and technology education programs. The surveys were completed by the students on the school computers in Slovenian, with us present in person. This allowed us to give them precise instructions and ensure that all respondents received the same guidance throughout the survey.

Finally, ethical approval was not required, as it is not necessary according to Slovenian regulations for educational research using surveys. Nevertheless, the study was conducted in full compliance with ethical standards and the principles of informed participation. Verbal consent to participate in the study was obtained from the participants.

2.2. Measures

The questionnaire consisted of three content sections and a demographic section. In the first content section, students rated their own digital and sustainability competencies, as well as other aspects not covered in this study. In the second and third sections, we examined various aspects, including students' assessments of the actual and preferred learning environment at their school/university.

2.2.1. Assessment of digital and sustainability competencies

To assess competencies, we included 21 digital competencies from the DigComp framework (Vuorikari et al., 2022) and 12 sustainability competencies from the GreenComp framework (Bianchi et al., 2022). Since these competencies are mostly generic, we also included 24 profession-specific competencies related to digitalization and sustainability tailored to the wood and furniture industry (Goropečnik et al., 2024). Students self-assessed their competencies based on 8 proficiency levels defined in DigComp 2.1 (EC et al., 2017).

Table 1. Descriptive statistics for the assessment of competencies.

Area of competencies	**N_{items}**	**M**	**DE**	***n***	α
Generic Digital Competencies	21	4,68	1,18	421	0,94
Generic Sustainability Competencies	12	4,58	1,26	428	0,92
Profession-Specific Competencies	24	4,33	1,22	415	0,96

Note: M = mean, SD = standard deviation, *n* = sample size, α = Cronbach's alpha

Table 1 presents descriptive statistics and Cronbach's Alpha (α) for three areas of competencies. On average, students' self-perceived competence levels range from 4.325 to 4.680 on a scale of 1 to 8. This places their self-perceived level of competence roughly in the middle, suggesting they can handle well-defined, non-routine problems independently and according to their needs. The standard deviations (SD), between 1.183 and 1.257, indicate moderate variability across all competence areas. This is expected since the sample is large and includes participants at different educational levels. Cronbach's Alpha values are very high (0.917-0.957), indicating excellent internal consistency in all competence areas.

2.2.2. Assessment of actual and preferred learning environment

We used the "What Is Happening in This Class?" (WIHIC) scale (Aldridge et al., 1999) to determine the students' actual and preferred learning environment. The questionnaire consists of 7 subscales: Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity, which together comprise 56 items. Students were asked to reflect on the educational program they were enrolled in at the time and evaluate the overall learning environment. In other words, they had to form an overall picture, representing the average of all subjects, teachers, classmates, and so on. They rated how they perceive the actual learning environment based on their experiences, namely how often certain things happen, and what their preferred learning environment would look like, namely how often they would like certain things to happen. This was done using a 5-point Likert scale: "1 – almost never", "2 – seldom", "3 – sometimes", "4 – often", and "5 – almost always".

Using confirmatory factor analysis, we analyzed the underlying structure of our questionnaire to determine whether the 56 items are grouped into the 7 expected subscales. Essentially, we aimed to determinate whether these items measured different aspects of the learning environment as intended and to confirm the accuracy of our translation of the questionnaire. We chose Principal Axis Factoring as the extraction method because WIHIC measures latent constructs, and Oblimin with Kaiser Normalization as the rotation method because it allows the factors to be correlated. The results of the factor analysis indicate that the subscales of the WIHIC questionnaire correspond to the constructs they are intended to measure, both for the actual (Appendix 1) and preferred (Appendix 2) learning environments. However, the Stu Coh 6 item loaded on a different factor when assessing the actual learning environment, although the false loading was not significant. This item also had the lowest factor loading in the study by Skordi and Fraser (2019).

TABLE 2. Descriptive statistics for the learning environment scale.

WIHIC scale		**N_{items}**	**M**	**DE**	***n***	α
Actual Learning Environment	Student Cohesiveness	8	3,79	0,60	414	0,82
	Teacher Support	8	3,03	0,81	411	0,90
	Involvement	8	3,07	0,69	417	0,85
	Investigation	8	2,90	0,72	416	0,88
	Task Orientation	8	3,58	0,63	418	0,81
	Cooperation	8	3,46	0,70	414	0,87
	Equity	8	3,65	0,88	423	0,93
Preferred Learning Environment	Student Cohesiveness	8	4,07	0,67	412	0,87
	Teacher Support	8	3,73	0,83	411	0,91
	Involvement	8	3,35	0,75	417	0,88
	Investigation	8	3,34	0,79	415	0,90
	Task Orientation	8	4,12	0,78	418	0,91
	Cooperation	8	3,81	0,75	418	0,91
	Equity	8	4,08	0,85	423	0,95

Note: M = mean, SD = standard deviation, n = sample size, α = Cronbach's alpha

As shown in Table 2, the participants' average scores for the actual learning environment range from 2.90 to 3.79, and for the preferred environment, from 3.34 to 4.12, indicating a moderately positive perception with a desire for improvement. The Cronbach's Alpha values (0.81 to 0.93 for the actual environment and 0.87 to 0.95 for the preferred environment) indicate good to excellent internal consistency.

2.3. Data preparation and analysis

Data analysis was conducted in SPSS using linear regression to assess the impact of the actual learning environment on students' digital and sustainability competencies. Paired-samples t-tests were also conducted to compare the actual and preferred learning environments, with effect sizes calculated using Cohen's d.

The assumptions for the regression analysis were tested and confirmed as follows: Normality was verified with non-significant Kolmogorov-Smirnov and Shapiro-Wilk tests, homoscedasticity and linearity were supported by scatter plots, and independence of errors was confirmed with a Durbin-Watson value close to 2. Furthermore, no multicollinearity was detected (VIF < 10, tolerance > 0.1), and no influential points were identified based on Cook's Distance.

3. Results

Since all assumptions for the regression analysis were satisfactorily met, we proceeded with the analysis to test the relationship between the actual learning environment factors and competencies.

Table 3. Correlation matrix for competencies and actual learning environment factors.

	1	2	3	4	5	6	7	8	9	10
1. Generic Digital Competencies	--									
2. Generic Sustainability Competencies	0,74	--								
3. Profession-Specific Competencies	0,67	0,70**	--							
4. Student Cohesiveness	0,12*	0,13**	0,13**	--						
5. Teacher Support	0,06	0,11*	0,12*	0,32**	--					
6. Involvement	0,23**	0,25**	0,23**	0,42**	0,46**	--				
7. Investigation	0,26**	0,29**	0,33**	0,30**	0,45**	0,53**	--			
8. Task Orientation	0,19**	0,20**	0,23**	0,38**	0,41**	0,36**	0,46**	--		
9. Cooperation	0,15**	0,21**	0,18**	0,52**	0,50**	0,53**	0,41**	0,44**	--	
10. Equity	0,07	0,13**	0,10*	0,36**	0,58**	0,35**	0,30**	0,40**	0,49**	--

Note: *p < 0.05, **p < 0.01

The Spearman correlation matrix in Table 3 shows statistically significant relationships between many factors of the actual learning environment and the competencies. Generic Digital Competencies correlate mainly with Investigation (ρ = 0.26) and Involvement (ρ = 0.23). Generic Sustainability Competencies correlate mainly with Investigation (ρ = 0.29), Involvement (ρ = 0.25), Cooperation (ρ = 0.21), and Task Orientation (ρ = 0.20). The profession-specific competencies show the strongest correlation with Investigation (ρ = 0.33) and correlate with Involvement (ρ = 0.23) and Task Orientation (ρ = 0.23). Based on the statistically significant correlations found in the Spearman correlation matrix, we proceeded with linear regression modeling to assess the partial effects of students' perceived learning environment factors on their self-perceived competence levels.

3.1. Regression Analysis of Learning Environment Factors on Competencies

The multiple linear regression analysis for predicting self-perceived competencies based on the actual learning environment was statistically significant in all models. Model 1 (Generic Digital Competencies) was significant, $F(7, 402) = 6.206$, $p < 0.001$, and explained a substantial part of the variance (SS = 55.807). Model 2 (Generic Sustainability Competencies) showed even stronger significance, $F(7, 402) = 7.596$, $p < 0.001$, with a larger SS (75.546). And Model 3 (Profession-Specific Competencies) showed the highest significance, $F(7, 401) = 9.037$, $p < 0.001$, and a SS of 82.067.

TABLE 4. Model summaries for regression predicting competencies.

Models	R	R^2	Adj. R^2	Std. Error
1. Generic Digital Competencies	0,312	0,098***	0,082	1,133
2. Generic Sustainability Competencies	0,342	0,117***	0,101	1,192
3. Profession-Specific Competencies	0,369	0,136***	0,121	1,139

Note: ***p < 0.001

Predictors: Actual Learning Environment: Equity; Investigation; Student Cohesiveness; Task Orientation; Involvement; Teacher Support; Cooperation

As shown in Table 4, Model 1 (Generic Digital Competencies) explains 9.8% of the variance, indicating modest explanatory power. Model 2 (Generic Sustainability Competencies) explains 11.7%, indicating a slightly better fit, while Model 3 (Profession-Specific Competencies) has the strongest fit, explaining 13.6% of the variance, indicating the strongest correlation. The relatively low explained variance (R^2) in our models aligns with expectations in social science research, where students' outcomes are influenced by numerous factors, and the primary goal is often not to achieve high predictive power, but to determine whether certain predictors have a statistically significant effect. In this context, R^2 values around 10% are generally considered acceptable (Ozili, 2022).

TABLE 5. Coefficients for regression models predicting competencies.

	Generic Digital Competencies			Generic Sustainability Competencies			Profession-Specific Competencies		
	B	SEB	β	B	SEB	β	B	SEB	β
(Constant)	3,159	0,386		2,662	0,406		2,484	0,388	
Student Cohesiveness	-0,065	0,107	-0,035	-0,078	0,113	-0,040	-0,026	0,108	-0,014
Teacher Support	-0,248	0,094	-0,173**	-0,224	0,099	-0,147*	-0,146	0,095	-0,099
Involvement	0,214	0,109	0,130*	0,187	0,114	0,106	0,142	0,109	0,084
Investigation	0,321	0,103	0,200**	0,394	0,109	0,231***	0,507	0,104	0,307***
Task Orientation	0,179	0,109	0,101	0,173	0,114	0,092	0,183	0,109	0,101
Cooperation	0,074	0,105	0,046	0,132	0,110	0,078	0,0004	0,105	0,0002
Equity	0,011	0,079	0,008	0,031	0,083	0,023	-0,048	0,079	-0,036

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

The coefficients of three separate regression models predicting competencies are shown in Table 5. Although some predictors show small or non-significant effects, they were retained because they originate from the validated WIHIC scale, with each subscale representing a theoretically distinct dimension of the learning environment (Fraser, 1998). This structure was also confirmed on our sample by factor analysis (Appendix 1 and 2).

In the model predicting Generic Digital Competencies, Investigation (β = 0.200) and Involvement (β = 0.130) were significant positive predictors, while Teacher Support (β = -0.173) was a significant negative predictor. The other factors, including Student Cohesiveness, Task Orientation, Cooperation, and Equity, showed no significant effects, suggesting that their effect on Generic Digital Competencies was not significant in this model.

For the model predicting Generic Sustainability Competencies, Investigation (β = 0.109) was the only significant positive predictor. Teacher Support (β = 0.099) again showed a significant negative effect. Involvement and the other factors, namely Student Cohesiveness, Task Orientation, Cooperation, and Equity, were not significant predictors in this model.

In the model predicting Profession-Specific Competencies, the Investigation (β = 0.307) was again the only significant predictor, showing a strong positive effect on Profession-Specific Competencies.

3.2. Perception of Actual Learning Environment Compared to Preferred Learning Environment

To assess the differences between students' perceptions of their actual and preferred learning environments, a series of paired-samples t-tests was conducted. Significant positive correlations were found between the actual and preferred learning environments for all factors ($p < 0.001$), with correlation coefficients ranging from 0.531 (Teacher Support) to 0.744 (Student Cohesiveness). These correlations suggest that students who perceive their actual learning environment more positively also tend to have higher preferences for the same environmental factors.

Table 6. Paired samples T-test results comparing actual and preferred learning environment factors.

	Paired Differences						
			95% CI				
Learning environment factors	ΔM	SD	Lower	Upper	t	p	Cohen's d
Pair 1: Actual – Preferred Student Cohesiveness	-0,27	0,46	-0,31	-0,23	-11,91	<0,001	0,46
Pair 2: Actual – Preferred Teacher Support	-0,72	0,79	-0,79	-0,64	-18,36	<0,001	0,79
Pair 3: Actual – Preferred Involvement	-0,27	0,60	-0,32	-0,21	-8,92	<0,001	0,60
Pair 4: Actual – Preferred Investigation	-0,44	0,58	-0,50	-0,38	-15,22	<0,001	0,58
Pair 5: Actual – Preferred Task Orientation	-0,54	0,55	-0,60	-0,49	-20,10	<0,001	0,55
Pair 6: Actual – Preferred Cooperation	-0,34	0,57	-0,40	-0,29	-12,29	<0,001	0,57
Pair 7: Actual – Preferred Equity	-0,44	0,70	-0,51	-0,37	-12,91	<0,001	0,70

Paired-samples T-tests revealed significant differences between students' perceptions of the actual and preferred learning environments for all factors (Table 6). The difference was greatest for Teacher Support (ΔM = -0.72, Cohen's d = 0.79), indicating a strong unfulfilled preference among students. Task Orientation (ΔM = -0.54, d = 0.55), Investigation (ΔM = -0.44, d = 0.58), Equity (ΔM = -0.44, d = 0.70), and Cooperation (ΔM = -0.34, d = 0.57) also showed significant gaps with moderate to large effect sizes. Student Cohesiveness and student Involvement showed smaller but still significant gaps (ΔM = -0.27, d = 0.46 and 0.60).

4. Discussion

While the influence of the learning environment on learning outcomes is well known, and researchers have explored various aspects that affect the development of competencies, this study aims to investigate how factors within the learning environment impact students' self-perceived generic and profession-specific digital and sustainability competencies. Our results show that students' perceived learning environment has a significant effect on their self-perceived digital and sustainability competencies, both in terms of generic and profession-specific competencies. In particular, the factors of Investigation, Involvement, and Teacher Support proved to be the most impactful in our study.

Factor Investigation, which focuses on inquiry skills, processes, and their application in problem-solving, proved to be a significant positive predictor for all three groups of competencies in our study, namely Generic Digital, Generic Sustainability, and Profession-Specific Competencies related to digitalization and sustainability. This result underscores previous studies that emphasize the crucial role of problem-solving and inquiry-based learning in the development of digital (Scholkmann, 2017) and sustainability (Carrió Llach &

Llerena Bastida, 2023; Meyer, 1977) competencies. Kolb's (1984) experiential learning theory further supports this by assuming that learning through direct experience and reflection promotes greater competence and mastery. These approaches enable students to engage with real-world problems and enhance their ability to analyze, evaluate, and apply knowledge in diverse, complex scenarios, which is crucial for effectively addressing global challenges.

The Involvement factor, which reflects students' attentive interest, active participation in discussions, completion of additional assignments, and general enjoyment of the class, proved to be a significant predictor of students' self-assessed Generic Digital Competencies. These findings can be supported by theories of active learning, which emphasize that students learn more effectively when they are actively engaged in the learning process (Bonwell & Eison, 1991). Empirical studies support these findings. Hake (1998) found that students achieve a better conceptual understanding in active, discussion-based learning environments, a finding also confirmed by Freeman et al. (2014), who found that students performed significantly better in active classrooms. Additionally, Romero-García, Buzón-García, and de Paz-Lugo (2020) found that active participation in collaborative learning activities supported by digital tools improves students' digital competencies. However, Lucas (2019) emphasizes that the facilitation of activities by teachers, supported by digital tools, is crucial for developing these competencies.

Teacher Support, which indicates the extent to which the teacher helps, befriends, trusts, and takes an interest in students, showed a significant negative effect on self-perceived levels of both Generic Digital and Sustainability Competencies, which may seem counterintuitive. However, this could suggest that students who have more autonomy and less direct support engage more intensively with relevant tools and concepts themselves, leading to a higher perceived level of competency in these areas. This is consistent with self-determination theory, which states that autonomy is a critical factor in intrinsic motivation and skill development (Deci & Ryan, 2000). In addition, the negative impact of perceived Teacher Support on self-perceived competencies may also be related to the concept of self-efficacy—the student's belief in their own ability to successfully accomplish certain tasks (Bandura, 1997). Research suggests that an overly supportive environment can sometimes lead to lower self-efficacy as students become dependent on external reassurance and assistance rather than developing confidence in their own abilities (Schunk & Pajares, 2002). In such cases, students may perceive their competencies as lower, especially in areas such as digitalization and sustainability, where independent problem-solving is crucial. An alternative explanation could be social comparison theory (Festinger, 1954), where students who receive more support from the teacher compare themselves to peers who appear to need less support. This comparison could lead to feelings of inadequacy or lower self-esteem, which could also have a negative impact on their self-assessment of competencies.

As the study employs a cross-sectional design, it is not possible to determine causality, i.e., whether greater teacher support leads to lower self-perceived competence or whether students with lower self-perceptions receive more teacher support and vice versa. Therefore, the negative effect of perceived Teacher Support on self-perceived competencies may also reflect a positive and pedagogically meaningful outcome. In contrast, a plausible interpretation is that teachers provide more support and attention to students who face greater challenges and/or perceive themselves as less competent. This suggests that teachers are responsive to students' different learning needs in terms of their readiness, interests, and learning profiles, which reflects and supports the development of a more inclusive educational environment (Gheyssens et al., 2023) and is also an important element of competence-based education (Makovec Radovan, 2025). This interpretation is also supported by our T-test results, which indicate that students would prefer more support from teachers. While these findings reflect a positive focus at the classroom level, their effectiveness often depends on broader institutional frameworks that support and reinforce individualized approaches rather than leaving them solely to individual teachers (Skubic Ermenc et al., 2020). This is another challenge that can be addressed within the framework of competence-based education.

The non-significant results for factors such as Student Cohesiveness, Task Orientation, Cooperation, and Equity suggest that, despite their importance in creating a supportive and equitable learning environment, we did not find a direct impact on the development of Digital and Sustainability Competencies in this study. Nevertheless, our results show that students are also striving for improvement in these areas. The fact that the actual learning environment does not match students' preferences is consistent with the findings of previous studies (Fraser, 1998; Rita & Martin-Dunlop, 2011). This discrepancy underscores the importance of addressing students' needs to create a supportive and empowering learning environment, as Fraser & Fisher (1983) emphasize that students tend to perform better when their actual and preferred learning environments match.

Based on these findings, it is essential to consider how they align with the ongoing shift toward competence-based education, which serves as the foundation for current national educational reforms. These reforms also explicitly emphasize the development of key competencies in areas such as digitalization and sustainability (Mali et al., 2025; Skubic Ermenc et al., 2024; Vlada Republike Slovenije, 2022). In competence-based education, teachers focus on developing students' competencies, leading to a shift toward learner-centered planning and instruction, which also changes the pedagogical process itself (Makovec Radovan, 2025). In this context, the learning environment plays a crucial role. Our study, which identified Investigation, Involvement, and Teacher Support as key predictors of both generic and profession-specific digital and sustainability competencies, highlights the value of learning situations based on inquiry, collaboration, and problem-solving, while emphasizing the importance of student autonomy and individualization. There is no one-size-fits-all pedagogical approach, as certain methods and forms of work may be better suited to the development of certain competencies than others. Nevertheless, pedagogical approaches that promote the learning environment factors identified in our study as influential on students' self-perceived digital and sustainability competencies include problem-based, project-based, experiential, and collaborative learning (Makovec Radovan, 2025). These approaches should also incorporate authentic learning situations based on real-world work and life contexts, promoting connections between school and work-based learning, in line with the principles of modular, flexible, and professionally relevant program design (MZI, 2024).

4.1. Limitations and Future Research

This study is subject to certain limitations that should be taken into consideration. First, the use of self-assessments may lead to biases. Although self-assessment provides valuable insights into learners' perceptions and reflections, it represents only one perspective. Future research should therefore consider the use of triangulation methods, such as teacher evaluations, analyses of curriculum content, or performance-based assessments that include practical tasks or exams. Second, the cross-sectional design of the study limits the ability to draw causal inferences between the learning environment and competencies. Therefore, longitudinal or experimental studies are needed to determine the direction and causality of these relationships. The generalizability of the results is also limited. The study focused exclusively on Slovenian students in one field of education, which may limit the transferability of the conclusions to other national contexts or fields of education. In addition, while the gender imbalance in the student sample (97% male) reflects the current demographics of the field, it also limits the generalizability of the findings. Future research could replicate the study in other educational fields, in multiple countries, and with more balanced samples to test the robustness and relevance of the findings in different contexts.

5. Conclusions

This study highlights the crucial role of the learning environment in fostering students' digital and sustainability competencies, which are recognized as key competencies in current national educational reforms. In particular, the perceived learning environment factors of

Investigation, Involvement, and Teacher Support showed a significant effect on students' self-perceived digital and sustainability competencies, both generic and profession-specific.

The Investigation showed a positive effect on all types of competencies: generic digital, generic sustainability, and profession-specific digital and sustainability competencies, while Involvement only had a positive effect on generic digital competencies. Teacher support, on the other hand, had a negative effect on generic digital and sustainability competencies, which may seem counterintuitive. However, we discuss possible explanations that may even reflect a positive pedagogical response to students' individual learning needs.

Therefore, based on the influencing factors of the learning environment, it would be beneficial to focus on promoting learning situations that emphasize inquiry, collaboration, and problem-solving, while also emphasizing student autonomy, individualization, and consideration of student preferences for the learning environment. This requires a move away from subject-centered education and traditional frontal teaching, which still dominate. One promising avenue is competence-based education, which is not new, but its implementation depends on how each school incorporates it into its curriculum. It is a pedagogical and didactic approach that requires significant changes in both the design and implementation of the curriculum. At its core, it places the profession for which students are to be educated at the center of the learning process, focusing teaching on the development of students' competencies. It promotes diverse teaching methods to achieve specific learning objectives. In light of our findings, approaches such as problem-based, project-based, experiential, and collaborative learning would effectively support the factors of the learning environment to develop students' (self-perceived) digital and sustainability competencies. However, teachers cannot be solely responsible for implementing these changes; they need systematic support and opportunities for professional development.

Author contributions

Luka GOROPEČNIK: Conceptualization; Methodology; Formal analysis; Investigation; Resources; Data curation; Visualization; Writing (original draft); Writing (review and editing).

Danijela MAKOVEC-RADOVAN: Conceptualization; Methodology; Writing (review and editing); Validation; Supervision.

Jože KROPIVŠEK: Conceptualization; Methodology; Resources; Writing (review and editing); Validation; Supervision.

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Appendices

Appendix 1. Factor loadings for the Learning Environment Scale: Evaluation of the Actual Learning Environment.

Item	Factor Loadings						
	1	2	3	4	5	6	7
Stu Coh 1	0,61						
Stu Coh 2	0,56						
Stu Coh 3	0,39						
Stu Coh 4	0,71						
Stu Coh 5	0,69						
Stu Coh 6	(0,29)			-0,34			
Stu Coh 7	0,62						
Stu Coh 8	0,44						
Tea Sup 1		0,66					
Tea Sup 2		0,70					
Tea Sup 3		0,67					
Tea Sup 4		0,73					
Tea Sup 5		0,58					
Tea Sup 6		0,73					
Tea Sup 7		0,54					
Tea Sup 8		0,49					
Invol 1			0,49				
Invol 2			0,59				
Invol 3			0,39				
Invol 4			0,55				
Invol 5			0,41				
Invol 6			0,52				
Invol 7			0,41				
Invol 8			0,36				
Inves 1				-0,59			
Inves 2				-0,56			
Inves 3				-0,74			
Inves 4				-0,62			

Inves 5				-0,61			
Inves 6				-0,60			
Inves 7				-0,56			
Inves 8				-0,65			
Tas Orn 1					0,54		
Tas Orn 2					0,46		
Tas Orn 3					0,36		
Tas Orn 4					0,50		
Tas Orn 5					0,59		
Tas Orn 6					0,48		
Tas Orn 7					0,51		
Tas Orn 8					0,56		
Coop 1						-0,51	
Coop 2						-0,60	
Coop 3						-0,59	
Coop 4						-0,60	
Coop 5						-0,54	
Coop 6						-0,68	
Coop 7						-0,73	
Coop 8						-0,60	
Equity 1							-0,70
Equity 2							-0,64
Equity 3							-0,75
Equity 4							-0,84
Equity 5							-0,76
Equity 6							-0,82
Equity 7							-0,80
Equity 8							-0,74
Eigenvalue	3,17	2,12	15,82	1,47	2,47	1,85	3,97
% Variance	5,67	3,79	28,24	2,63	4,40	3,30	7,09

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
Factor loadings less than 0.35 have been omitted from the table

APPENDIX 2. Factor loadings for the Learning Environment Scale: Evaluation of Preferred Learning Environment.

Item	Factor Loadings						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Stu Coh 1	0,71						
Stu Coh 2	0,61						
Stu Coh 3	0,61						
Stu Coh 4	0,75						
Stu Coh 5	0,73						
Stu Coh 6	0,39						
Stu Coh 7	0,59						
Stu Coh 8	0,44						
Tea Sup 1		0,70					
Tea Sup 2		0,68					
Tea Sup 3		0,69					
Tea Sup 4		0,69					
Tea Sup 5		0,61					
Tea Sup 6		0,73					
Tea Sup 7		0,65					
Tea Sup 8		0,57					
Invol 1			-0,58				
Invol 2			-0,55				
Invol 3			-0,48				
Invol 4			-0,51				
Invol 5			-0,61				
Invol 6			-0,60				
Invol 7			-0,53				
Invol 8			-0,54				
Inves 1				0,59			
Inves 2				0,63			
Inves 3				0,62			
Inves 4				0,65			
Inves 5				0,43			

Inves 6				0,64			
Inves 7				0,44			
Inves 8				0,54			
Tas Orn 1					0,51		
Tas Orn 2					0,62		
Tas Orn 3					0,61		
Tas Orn 4					0,54		
Tas Orn 5					0,67		
Tas Orn 6					0,54		
Tas Orn 7					0,69		
Tas Orn 8					0,70		
Coop 1						-0,61	
Coop 2						-0,65	
Coop 3						-0,58	
Coop 4						-0,66	
Coop 5						-0,50	
Coop 6						-0,70	
Coop 7						-0,63	
Coop 8						-0,59	
Equity 1							-0,76
Equity 2							-0,71
Equity 3							-0,84
Equity 4							-0,87
Equity 5							-0,75
Equity 6							-0,86
Equity 7							-0,74
Equity 8							-0,75
Eigenvalue	2,52	3,07	1,73	1,28	20,50	2,02	3,59
% Variance	4,51	5,48	3,10	2,29	36,61	3,60	6,41

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
Factor loadings less than 0.35 have been omitted from the table

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