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Gaps Between Students' Self-Perceived Digital and Sustainability Competencies and the Expectations of the Wood & Furniture Industry

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Abstract

As the wood and furniture industry moves towards the vision of Industry 5.0, a major challenge remains addressing the lack of competencies. This study examines the self-perceived digital and sustainability competencies of 433 final year students at different levels of wood science and technology education in Slovenia and compares them with the expectations of 28 industry stakeholders. Using the established competency frameworks of DigComp and GreenComp, which represent generic competencies, as well as 24 profession-specific competencies related to digitalization and sustainability, the study uses survey data analysis to identify possible discrepancies. The results suggest that students' self-assessment increases only slightly with increasing educational level, while the expectations of industry stakeholders increase significantly more, leading to notable discrepancies. At the secondary level, stakeholders place greater emphasis on developing students' generic digital and sustainability competencies, while at the tertiary level, they place increasing importance on profession-specific competencies. It is worth noting that some stakeholders assessed certain competencies as not required for graduates on certain level of education. The study highlights the need for coherent and vertically aligned curriculum structures that reflect evolving competency expectations at all qualification levels. The study shows several areas in which the discrepancy between students' self-assessments and the expectations of industry stakeholders is particularly pronounced. It highlights the need to better align educational content with the needs identified by industry stakeholders, while recognizing the role of wider social partnership in curriculum development. Such alignment and collaboration is essential to equip graduates with the competencies they need to make a meaningful contribution to the digital and sustainable transformation of the wood and furniture sector.

Keywords: competency gap; students' self-perception; industry expectations; sustainability competencies; digital competencies; wood science and technology education; wood and furniture industry; twin transition

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1. Introduction

While many manufacturing companies are still navigating their transition toward Industry 4.0 [1], with some suggesting that industries like wood and furniture remain

closer to Industry 2.0 [2], the discourse around Industry 5.0 is already rapidly evolving. Industry 5.0, introduced and primarily promoted by the European Commission, emerged as a response to the limitations identified within Industry 4.0. It emphasizes a human-centric approach, sustainability, and resilience, aiming to balance technological advancements with social and environmental considerations [3]. However, manufacturers, including those in the wood and furniture industry, confront considerable challenges in achieving this twin transition. The main challenges include not only financial constraints but also substantial deficits in the knowledge and skills necessary for successful implementation [4–7].

A future-oriented education system plays an important role in preparing individuals for Industry 5.0, by shaping the human foundation on which this transformation depends, primarily through the development of relevant competencies across all levels of professional education. Ozturk [8] emphasizes that education is one of the fundamental factors of development, asserting that sustainable economic progress is unattainable without substantial investment in human capital. Verhaeghe [9] reinforces this perspective, noting that education's power to transform nations has been a fundamental principle of pedagogical theory since the early 20th century. In response to these challenges and to facilitate the industry's advance toward the twin transition, European policy initiatives, such as the European Year of Skills, which emphasizes the need to align educational programmes with industry requirements to address skills shortages and mismatches, particularly in the context of the digital and sustainable transitions [10], have already led to significant educational reforms across all levels of education in Slovenia. These reforms, which encompass both vocational education and training [11,12] as well as higher education [13], emphasize sustainability and digital literacy as core priorities and have already begun shaping the future trajectory of education, including within the field of wood science and technology. In this field, students at lower educational levels typically receive training as carpenters and wood technicians, whereas those pursuing higher education acquire expertise as wood engineers, primarily preparing them for careers within the wood and furniture industry after graduation. Consequently, educational programmes, both at the vocational and higher education levels, must continually adapt to develop profession-specific and generic competencies, preparing individuals for current occupational requirements, as well as broader future changes and challenges [14]. In the European Union, the concept of competencies, defined as the ability to apply learning outcomes effectively across various contexts [15], has become a central reference point for curriculum design and development. It initially permeated vocational and professional training, becoming prominent in higher education with the advent of the Bologna Process [16]. Professional competencies are typically divided into generic competencies, which are transferable across similar professions, and profession-specific competencies, which are unique to individual professions or fields of work [15].

In this study, we focus on digital and sustainability competencies, which aim is to investigate how well students' self-perceived competencies match the expectations of industry stakeholders, with a focus on the wood and furniture sector.

1.1. Literature Review

For our analysis, we draw on two European competence frameworks: the Digital Competence Framework for Citizens (DigComp), which defines digital competence as the safe, critical and responsible use of digital technologies for learning, work and participation in society [17], and the European Sustainability Competence Framework (GreenComp), which outlines a set of sustainability competencies aimed at fostering empathy, responsibility and care for the planet, social equity, and public well-being [18]. These tools provide structured and widely recognised definitions of competencies relevant to the twin transi-

tion and serve as references for various applications, including competency assessments and curriculum design that synergize with the objectives of competence-based education. Importantly, they also form the basis for the current guidelines for curriculum renewal in Slovenia, as digital and sustainability competencies are key areas alongside others such as language and literacy, citizenship, culture and arts; health and well-being; and entrepreneurship [11,12]. Their integration reflects a comprehensive approach to educational reform aimed at equipping learners not only for the demands of the labour market, on which we focus in this study, but also for active and responsible participation in society in the context of rapid socio-economic and environmental change. As both frameworks, DigComp and GreenComp, are rather generic in nature, we have also included some competencies related to digitalization and sustainability that are relevant to the wood and furniture industry, as elaborated in the following sections.

Most studies used self-assessment tools as the main instrument for both digital [19,20] and sustainability competence assessment [21]. However, caution should be exercised when interpreting results based on self-assessments, as effects such as the Dunning-Kruger effect may occur, where less competent individuals tend to overestimate their abilities due to a lack of metacognitive insight, while more competent individuals tend to underestimate their abilities because they better understand the scope of the topic [22]. The Dunning-Kruger effect has been observed in various educational contexts, including tourism education of students for knowledge about environmental sustainability [23], introductory chemistry and physics courses [24,25], civic education in secondary schools [26], in engineering education [27], in information literacy in various disciplines and levels of education [28], and in online learning environments [29].

The question of how students' digital and sustainability competencies match the needs and expectations of industry has already been analyzed in several sectors. A study from Portugal compared students' self-assessed digital competencies with employers' expectations and found clear gaps in workplace readiness and digital problem solving for sustainability [30]. Similarly, a qualitative study from Poland showed a mismatch between the sustainability skills of graduates and the needs of the labour market, highlighting the importance of integrating relevant competencies into higher education programmes [31]. Several studies have also investigated the digital and sustainability competencies required in the manufacturing industry in a broader sense [32,33]. While some earlier efforts have examined the alignment between "Wood Science and Forest Products" curricula and industry expectations in the United States [34], to our knowledge, no empirical research has specifically addressed how students' digital and sustainability competencies align with the evolving needs of the wood and furniture industry. In Slovenia, awareness of this gap led the Chamber of Commerce and Industry to develop a career platform for long-term competency forecasting as early as 2014, with the goal of better aligning educational programmes with actual market needs [35].

1.2. Objective of the Present Study

Despite this growing recognition of the importance of forward-looking competencies, especially for the digital and sustainable transitions, there remains a lack of focused research on how such competencies are addressed within the wood and furniture sectors, particularly in relation to formal education and the preparedness of students for evolving industry requirements. Existing studies have focused primarily on general manufacturing or specific fields, while wood science and furniture-related education remains underrepresented in the literature. Furthermore, few studies have investigated how students' self-perceived competencies match the expectations of industry stakeholders at different levels of education.

This study addresses these gaps by systematically comparing students' self-assessed digital and sustainability competencies with the expectations of industry stakeholders. As far as we know, this is the first such empirical study in this sector. Therefore, the study provides a comprehensive picture of potential discrepancies across the entire education vertical, from secondary to tertiary education. The study is guided by one main research question:

RQ: How do students' self-perceived digital and sustainability competencies compare to the expectations of industry stakeholders for competencies of wood science and technology graduates?

By answering this research question, the study contributes to a more coherent understanding of the competence gaps facing the wood and furniture sector in the light of digitalization and sustainability. At the same time, it provides information for curriculum development to ensure that upcoming education reforms effectively align with the education vertical and better support the twin transformation of the sector.

2. Methods

To address this research question, the study focused exclusively on students enrolled in wood science and technology education programmes in Slovenia, as well as relevant stakeholders from the wood and furniture industry. Accordingly, we used purposive sampling, a method particularly suited to the study of specific groups [36]. 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. In accordance with standard procedures at Slovenian secondary and higher education institutions, students (or their parents in the case of minors) give general written consent to participate in research activities at the time of enrolment. Additionally, before the survey, all participants were informed about the specific purpose of the study and assured that their participation was both anonymous and voluntary. Verbal consent was obtained before participation.

2.1. Sample of Students

The population of students in this study consists of students in their final year of study in Slovenian wood science and technology programmes at various levels of education. We have considered all educational qualifications with the exception of short vocational education and doctoral studies: three years of vocational education (ISCED 353) for "Carpenters"; four years of technical vocational education (ISCED 354) for "Technicians"; two years of technical education (ISCED 354), that enable graduates of a three-year vocational education and training (VET) program to obtain an upper secondary technical level of education; wo years of higher vocational education (ISCED 554) for "Engineers"; three years of vocational and academic bachelor's degree programmes (ISCED 645 & 655) for "Bachelors of Wood Engineering" and two years of a Master's degree program (ISCED 767) for "Masters of Wood Science and Technology".

The student 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 programmes examined in this research. This corresponded to 35 final year classes of students within the wood science and technology education programmes. The surveys were completed in the Slovenian language by the students on the schools' computers, with the authors present in person. This allowed us to give the participants precise instructions and ensure that they all received the same guidance throughout the survey. From the defined population, we surveyed a sample of 433 final-year students, representing approximately 82% of all students enrolled in the final year of the educational programmes

included in our study. The sample was predominantly male (97%), which reflects the current demographics in the sector.

2.2. Sample of Industry Stakeholders

To identify which competencies are important for the digital and sustainable transformation of the wood and furniture industry in Slovenia, we conducted surveys in July and August 2023 among industry stakeholders in the wood sector classified under NACE codes C16 and C31. More precisely, the competencies were assessed by directors/human resources managers (n = 16) in companies and by experts (n = 12), who were individuals from all levels of wood science and technology educational institutions, representatives of the wood and furniture industry and expert consultants in the wood sector (from the Institute of the Republic of Slovenia for Vocational Education and Training). The selection of different stakeholders allowed us to have a comprehensive mix of practical experience in the field and a broader perspective covering all aspects of the sector. For the company representatives, our aim was to involve as many relevant CEOs and HR managers as possible within the given timeframe. In terms of experts, our aim was to ensure as much diversity as possible in terms of institutional affiliation, functions and areas of expertise, which we were primarily able to achieve by reaching out to people in the fields of education, policy and industry support.

2.3. Measures

We used 21 digital competencies from all five areas of the DigComp for the self-assessment of students' competence levels and the industry's assessment of the competencies required by graduates, namely Information and Data Literacy, Communication and Collaboration, Digital Content Creation, Safety, and Problem Solving in Digital Environments [17]—as well as 12 sustainability competencies from the all four domains of the GreenComp, namely Embodying Sustainability Values, Embracing Complexity, Envisioning a Sustainable Future and Acting for Sustainability [18].

As these competencies are mostly generic in nature, we also included 24 profession-specific competencies related to digitalization and sustainability that are tailored to the wood and furniture industry. The process of formulating these competencies took place in several steps. As a starting point, we identified the key competencies that are considered important for graduates in wood science and technology, as outlined in the Implementation document for the development of the Slovenian wood industry until 2030 [37]. These include areas such as design, construction, architecture, cultural heritage preservation, mechanical wood processing, practical training, public relations, and relevant social science and humanities fields. Subsequently, 12 experts from different professional fields defined key competencies within their respective domains, ensuring a link to the previously identified areas and a focus on digitalization and sustainability. Each expert was also asked to describe what each proposed competence should encompass. We then merged similar competencies and created a refined list, followed by rating the importance of each competence for wood science and technology graduates using a four-point Likert scale. This assessment was undertaken by the same group of experts in an extended panel. Based on this, the final set of 24 profession-specific competences was developed and used later in this study for the students' self-assessment of competencies and industry stakeholders' assessment of the competencies required by graduates, as described in the following section.

Both students and industry stakeholders evaluated competencies using the eight proficiency levels (Table 1) defined in DigComp 2.1 [38], which describes increasing levels of competence in terms of task complexity and autonomy. In addition to these levels, industry stakeholders had the option to select '0' if they believed a particular competency was not

necessary for graduates at a specific educational level. This was considered appropriate in the context of companies evaluating required competencies, as it is possible that certain competencies may genuinely not be relevant in specific roles or work environments. However, this option was not included for students, since the lowest level of the scale (level 1) already captures a minimal degree of competence, defined as the ability to perform simple, well-defined tasks under guidance. For consistency with the students' rating scale, responses marked as 0 were excluded from the calculation of average scores. Nevertheless, the number of stakeholders who indicated that a given competency was not required is reported in the results tables and considered in the interpretation of the results.

Table 1. Rating scale for the proficiency level of competencies [38].

Proficiency Levels	1	2	3	4	5	6	7	8
Complexity of tasks	Simple tasks	Simple tasks	Well-defined and routine tasks, and straightforward problems	Tasks, and well-defined and non-routine problems	Different tasks and problems	Most appropriate tasks	Resolve complex problems with limited solutions	Resolve complex problems with many interacting factors
Autonomy	With guidance	Autonomy and with guidance where needed	On my own	Independent and according to my needs	Guiding others	Able to adapt to others in a complex context	Integrate to contribute to the professional practice and to guide others	Propose new ideas and processes to the field

When assessing competencies, both students and industry stakeholders were provided with the name and full description of each competence in the Slovenian language. For the established frameworks (DigComp and GreenComp), we used the official Slovenian translations of the questionnaires. The questionnaire was pre-tested with university students to ensure clarity and comprehensibility, and the terminology was further refined based on their feedback.

2.4. Data Preparation and Analysis

An initial data analysis was conducted in Microsoft Excel to calculate the differences between students' self-assessed competence levels and industry expectations. These differences were calculated by subtracting the mean student self-assessment scores from the mean scores representing stakeholders' expectations for each competency. To complement this analysis and test whether the observed differences between the distributions of scores from the two groups were statistically significant, we performed Mann-Whitney U tests for independent samples for each competency, as the assumption of normality was not met. Levene's test for homogeneity of variance was performed for each competency. The assumption of equal variances was met in the vast majority of cases, and only a small number of competencies within specific educational levels showed some variance differences between groups. IBM SPSS Statistics (version 29) was used for this purpose, as well as for calculating descriptive statistics.

3. Results

3.1. Students' Self-Assessed Competencies and Industry Stakeholders' Expectations

This section presents the results of students' self-assessed competencies (Table 2) and the expectations of industry stakeholders (Table 3) regarding the required proficiency levels of graduates at different educational levels. The competencies are grouped into

three main areas: generic digital competencies, generic sustainability competencies, and profession-specific competencies related to digitalization and sustainability.

Table 2. Descriptive statistics for students' self-assessed competencies.

Area of Competencies	N_{items}	Short VET				Technical VET				Higher VET				Bachelor's				Master's			
		M	SD	*n*	α	M	SD	*n*	α	M	SD	*n*	α	M	SD	*n*	α	M	SD	*n*	α
Proficiency in Generic Digital	21	4.67	1.26	199	0.95	4.65	1.13	169	0.94	4.77	0.88	25	0.91	4.77	1.36	32	0.96	4.83	0.47	11	0.68
Proficiency in Generic Sustainability	12	4.58	1.35	203	0.92	4.49	1.14	173	0.90	4.72	1.09	25	0.93	4.84	1.50	32	0.96	4.89	0.83	11	0.89
Proficiency in Profession Digital and Sustainability	24	4.39	1.29	196	0.96	4.16	1.12	165	0.95	4.55	1.08	25	0.96	4.49	1.36	32	0.97	4.70	0.81	11	0.92

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

Table 2 shows the average students' self-assessed competencies based on an 8-point proficiency scale. The results show that students at all educational levels generally rate their profession-specific competencies lower in comparison to generic digital and sustainability competencies. The mean values indicate that they feel confident in managing various tasks and problems independently and supporting others. Master's students gave the highest average self-assessments (M = 4.70–4.89), which puts them close to advanced levels of competence, with relatively low standard deviations (SD = 0.47–0.83). Bachelor's students (M = 4.49–4.84) and Higher VET students (M = 4.55–4.77) rated themselves similarly to Master's students. Short VET (M = 4.39–4.67) and Technical VET (M = 4.16–4.65) also gave comparable self-assessments. In addition, the high α values (mostly > 0.90) confirm excellent internal reliability. The relatively low α (0.68) for Generic Digital Competencies in the Master's group may be attributed to the small sample size and low response variability, which can affect the stability of reliability estimates.

Table 3. Descriptive statistics for the assessment of competencies by industry stakeholders.

Area of Competencies	N_{items}	Short VET				Technical VET				Higher VET				Bachelor's				Master's			
		M	SD	*n*	α	M	SD	*n*	α	M	SD	*n*	α	M	SD	*n*	α	M	SD	*n*	α
Proficiency in Generic Digital	21	3.21	1.16	28	0.94	4.33	1.22	28	0.95	5.77	1.19	28	0.95	6.78	0.91	28	0.95	7.27	0.78	27	0.94
Proficiency in Generic Sustainability	12	3.26	1.18	28	0.92	4.17	1.49	28	0.95	5.47	1.55	28	0.96	6.42	1.14	28	0.96	7.02	0.97	27	0.95
Proficiency in Profession Digital and Sustainability	24	2.85	1.34	28	0.97	3.79	1.49	28	0.97	5.48	1.47	28	0.97	6.44	1.21	28	0.95	7.03	0.90	27	0.92

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

Table 3 shows average industry stakeholders' assessments of the required competency levels of graduates at different levels of education to enable a smoother digital and sustainable transition in the wood and furniture industry. The results indicate a clear progression of competency expectations for graduates with an increasing level of education in all three competency areas. Industry stakeholders demand the highest competency levels for Master's graduates (M = 7.02–7.27), suggesting that students need to be able to solve complex problems with limited solutions in order to contribute to professional practice and guide others. Bachelor's degree graduates (M = 6.42–6.78) and graduates of Higher VET (M = 5.47–5.77) are also expected to have relatively high competencies, suggesting that these students need to be able to handle diverse and appropriate tasks and problems. In contrast, the required competence levels for graduates of Technical VET (M = 3.79–4.33) and Short VET (M = 2.85–3.26) were significantly lower, reflecting the varied expectations at the different educational levels. The high α values (> 0.90) confirm excellent internal reliability.

3.2. Competence Gaps Between Students' Self-Assessments and Industry Stakeholders' Expectations

Tables 4–6 show the calculated competence gaps between students' self-assessed levels of competencies at different educational levels and the expectations of industry stakeholders, using a customized heat map visualization. The values represent the difference between the competence levels required by industry stakeholders and the students' mean self-assessment. Negative values (blue) indicate that students perceive their competencies to be higher than the expectations of industry stakeholders, while positive values (red) indicate that students perceive themselves as less competent than the expectations of industry stakeholders. The colour intensity in the tables indicates whether the differences between the distributions of students' self-assessment scores and industry stakeholders' expected competence levels are statistically significant, as determined by the Mann-Whitney U test conducted for each competence. Darker shading indicates stronger statistical significance, while no colour (white) indicates there is no statistically significant difference.

Table 4. Gaps between students' self-assessments and industry stakeholders' expectations in generic digital competencies.

Competence Area	Competencies	Short VET	Technical VET	Higher VET	Bachelor's	Master's
Information and data literacy	Browsing, searching and filtering data, information and digital content	−1.74	−0.41	0.55	1.70	1.67
	Evaluating data, information and digital content	−1.57 (4)	−0.29	1.08	1.94	2.14
	Managing data, information and digital content	−2.04 (3)	−0.80 (1)	0.71	1.65	1.94
Communication and collaboration	Interacting through digital technologies	−1.47	−0.20	0.76	1.39	2.03
	Sharing through digital technologies	−1.95 (2)	−0.50	1.08	2.22	2.41
	Engaging citizenship through digital technologies	−1.11 (4)	0.59 (3)	1.56 (1)	2.32 (1)	2.90 (1)
	Collaborating through digital technologies	−2.08 (4)	−0.74 (1)	0.53	1.91	2.28
	Netiquette	−0.60 (1)	0.30 (1)	1.05	1.22	1.41
	Managing digital identity	−0.69 (2)	−0.01 (1)	0.76	2.37	2.37
Digital content creation	Developing digital content	−1.84 (6)	−0.90 (1)	0.97	1.75	2.55
	Integrating and re-elaborating digital content	−1.12 (9)	−0.39 (2)	1.11 (1)	2.42	2.27
	Copyright and licenses	−1.77 (3)	−0.43 (1)	1.43	2.68	3.64
	Programming	−2.10 (16)	−0.62 (7)	1.28 (3)	2.76 (1)	3.69
Safety	Protecting devices	−1.29 (2)	−0.02	1.44	2.21	3.35
	Protecting personal data and privacy	−0.89	0.15	1.29	2.54	3.18
	Protecting health and well-being	−0.23	0.20	0.89	1.48	2.12
	Protecting the environment	−1.63 (4)	−0.56 (3)	0.18	1.39	1.85
Problem solving	Solving technical problems	−1.40 (2)	−0.26	1.16	1.65	2.43
	Identifying needs and technological responses	−1.55 (3)	−0.24	1.06	2.17	1.88
	Creatively using digital technology	−1.81 (6)	−0.56 (1)	1.26	2.04	2.49
	Identifying digital competence gaps	−2.03 (5)	−0.79 (3)	0.80	2.23	2.55
Note: Numbers in parentheses indicate the number of industry stakeholders (n = 28) who rated the respective competencies as not required.						
Heatmap legend (u-test results):	Positive difference:	$p > 0.05$	$p < 0.05$	$p < 0.01$	$p < 0.001$	
	Negative difference:	$p > 0.05$	$p < 0.05$	$p < 0.01$	$p < 0.001$	

With regard to generic digital competencies, Table 4 shows a pattern across all competencies. Students in higher education programmes, particularly at Bachelor's and Master's levels, rated their competencies lower than the levels expected by industry stakeholders, while the self-assessments of students in Short and Technical VET programmes were higher than the stakeholders' expectations.

For the Short VET level, the greatest differences, ones that go beyond two proficiency levels, were found for "Collaborating through digital technologies", "Managing data, information and digital content", "Identifying digital competence gaps" and "Programming". For "Programming", more than half of the stakeholders (n = 16) stated that it was not required at this level, and a third said the same for "Integrating and re-elaborating

digital content". The smallest and non-significant gaps were for "Protecting health and well-being", "Netiquette" and "Managing digital identity".

The Technical VET students' self-perceived competencies were most in line with the expectations of industry stakeholders. The only statistically significant differences were found for "Developing digital content", "Managing data", "Identifying digital competence gaps" and "Collaborating through digital technologies". Even at this level, a quarter of stakeholders considered "Programming" to be unnecessary.

At the Higher VET education level, the results also show that the students' level of competencies in some areas meets the expectations of the stakeholders. However, in contrast to the two lower levels of education, all statistically significant gaps indicated that the self-assessment was below the required level. The most notable gaps occurred in the areas of "Engaging citizenship through digital technologies" and "Protecting devices".

The Bachelor's results showed statistically significant differences between the students' assessments and the stakeholders' expectations in all competencies, with more than half of the students exceeding two proficiency levels. The largest differences were for "Digital content creation" and the smallest, albeit still significant, for the competencies "Netiquette", "Protecting the environment" and "Protecting health and well-being".

The Master's degree had the largest gaps for generic digital competencies, with differences of more than two proficiency levels in almost three quarters of the competencies. Some gaps were even more than three levels, namely for the competencies "Programming", "Copyright and licenses", "Protecting devices" and "Protecting personal data and privacy". As with the Bachelor group, the smallest gaps were for "Netiquette" and "Protecting the environment".

Table 5. Gaps between students' self-assessments and industry stakeholders' expectations in generic sustainability competencies.

Competence Area	Competencies	Short VET	Technical VET	Higher VET	Bachelor's	Master's
Embodying sustainability values	Valuing sustainability	−1.22 (1)	−0.07 (1)	1.43 (1)	1.93	2.33
	Supporting fairness	−0.52	0.42	0.65	1.20	2.00
	Promoting nature	−0.24 (1)	0.22	0.41	1.06	1.40
Embracing complexity in sustainability	Systems thinking	−1.87 (4)	−0.41 (4)	0.62 (1)	1.82	2.27
	Critical thinking	−1.61 (2)	−0.75 (2)	0.26	1.31	1.82
	Problem framing	−1.65 (4)	−0.48 (4)	1.48 (1)	2.25 (1)	2.80 (1)
Envisioning sustainable futures	Futures literacy	−1.51 (5)	−0.39 (4)	0.67 (2)	1.71 (1)	2.20 (1)
	Adaptability	−1.87 (6)	−0.78 (4)	0.88 (3)	1.55 (1)	1.98 (1)
	Exploratory thinking	−2.15 (5)	−1.05 (3)	0.56 (2)	1.05 (1)	1.96 (1)
Acting for sustainability	Political agency	−1.48 (7)	−0.45 (3)	0.98 (1)	2.41 (1)	3.42 (1)
	Collective action	−1.52	−0.34	0.26	0.95	1.23
	Individual initiative	−0.32	0.71	1.08	2.01	2.49
Note: Numbers in parentheses indicate the number of industry stakeholders (n = 28) who rated the respective competencies as not required.						
Heatmap legend (u-test results):	Positive difference:	$p > 0.05$		$p < 0.05$	$p < 0.01$	$p < 0.001$
	Negative difference:	$p > 0.05$		$p < 0.05$	$p < 0.01$	$p < 0.001$

In the area of generic sustainability competencies, Table 5 shows a similar pattern to the generic digital competencies (Table 4). However, the competency gaps identified are slightly smaller compared to those for the digital competencies, which is primarily because industry stakeholders have slightly lower expectations for generic sustainability competencies (see Table 3).

Short VET students rated their level of competence higher than expected by the stakeholders. Statistically significant negative differences were most pronounced for the competencies "Embracing complexity in sustainability" and "Envisioning sustainable futures", while more than a quarter of stakeholders stated that the competency "Political agency" was not required for graduates at this level. In contrast, there were smaller, non-

significant differences for "Promoting nature", "Individual initiative" and "Supporting fairness".

At the level of Technical VET, the differences were relatively small, as students' self-assessments were largely in line with the expectations of industry stakeholders. The only statistically significant negative discrepancy is seen for "Exploratory thinking", followed by a smaller discrepancy for "Adaptability". However, some stakeholders felt that several generic sustainability competences were unnecessary for this level of education.

There were also only a few statistically significant differences overall among students in Higher VET education, which indicates a good match between their self-assessments and the expectations of the stakeholders. However, in cases where significant differences did occur, these were consistently positive, meaning that students rated their competencies lower than industry expectations. The most noticeable positive differences were for the competencies "Valuing sustainability", "Problem framing" and "Individual initiative".

At Bachelor's level, the differences in almost all sustainability competencies showed significant positive gaps, clearly indicating that their self-assessed competencies were below the level of stakeholder expectations. The largest gaps, exceeding two proficiency levels, were found for "Political agency", "Problem framing" and "Individual initiative". The "Collective action" competency was the only one where there was no statistically significant difference.

We observed the greatest differences at Master's level, with positive differences of more than two proficiency levels for most competencies. Besides the same competencies as at the Bachelor's level, the largest gap was for "Political agency", which was more than three proficiency levels. Smaller but significant gaps were found for "Collective action" and "Promoting nature".

Table 6. Gaps between students' self-assessments and industry stakeholders' expectations in profession-specific digital and sustainability competencies.

Competencies	Short VET	Technical VET	Higher VET	Bachelor's	Master's
Sustainable design	−1.81 (2)	−0.87	0.64	1.95	1.67
Wooden constructions	−1.49 (1)	−0.20	0.94	1.60	2.11
Mechanical stress simulations	−1.94 (9)	−0.96 (4)	1.46	2.29	3.87
Computer-aided design	−1.50 (6)	−0.61 (3)	1.07 (1)	1.95 (1)	1.03 (1)
Energy-efficient and smart houses	−1.29 (9)	−0.22 (5)	0.86 (2)	1.97 (1)	2.36 (1)
Smart furniture	−1.72 (7)	−0.23 (4)	0.92 (1)	1.96 (1)	2.15 (1)
Restorative environmental design	−1.37 (8)	−0.06 (5)	0.90 (3)	1.79 (1)	1.80 (1)
Wood pests and wood protection	−1.90 (3)	−0.31 (1)	0.45	1.08	1.58
Cultural heritage	−2.08 (7)	−0.55 (3)	0.32 (3)	1.90 (2)	2.55 (2)
Wood waste	−1.16 (3)	−0.18 (1)	0.67	1.19	1.32
Wood recycling	−0.98 (4)	0.02 (2)	1.00	1.45	1.73
Sustainable consumption and production	−0.95 (6)	0.14 (3)	1.22	2.02	1.74
Autonomous and flexible production	−1.32 (6)	−0.34 (3)	0.82 (1)	2.33	3.14
Human-robot interaction	−0.97 (7)	0.19 (5)	1.22 (4)	2.71 (2)	3.86 (2)
Renewable resources and sustainable energy	−0.87 (5)	0.39 (1)	1.11	2.00	3.11
Alternative products based on biomass	−1.32 (13)	−0.32 (7)	0.75 (4)	2.45 (3)	2.69 (3)
Impact of products on the environment	−1.43 (6)	−0.33 (2)	1.03 (1)	1.99 (1)	2.41 (1)
Circular business model	−1.22 (6)	−0.44 (2)	1.18	1.98	2.70
Sustainability of supply chains	−0.91 (11)	0.19 (6)	1.31	2.63	2.26
Industrial symbiosis	−1.39 (11)	−0.52 (7)	1.35 (4)	1.57 (1)	2.09 (1)
Legal frameworks for sustainability	−1.26 (12)	−0.47 (8)	1.20 (3)	2.34	2.23
Digital technology and operations	−1.74 (7)	0.04 (5)	1.54 (3)	2.23 (2)	3.41 (2)
Digital promotion	−1.77 (13)	−1.04 (6)	0.47 (2)	1.20	1.89
Digitization of consumer behaviour monitoring	−1.66 (15)	−0.78 (10)	0.62 (5)	1.74 (3)	1.76 (2)

Note: Numbers in parentheses indicate the number of industry stakeholders (n = 28) who rated the respective competencies as not required.

Heatmap legend (u-test results):					
	Positive difference:	$p > 0.05$	$p < 0.05$	$p < 0.01$	$p < 0.001$
	Negative difference:	$p > 0.05$	$p < 0.05$	$p < 0.01$	$p < 0.001$

In the area of profession-specific digital and sustainability competencies, Table 6 again shows a similar pattern to that found for the generic digital (Table 4) and sustainability competencies (Table 5).

Short VET students consistently perceive their competencies higher than the levels required by stakeholders in all profession-specific competencies. The largest gaps, approaching two proficiency levels, were found for "Cultural heritage", "Mechanical stress simulations" and "Wood pests and wood protection". The smallest gaps were found for "Renewable resources and sustainable energy", "Sustainability of supply chains", "Sustainable consumption and production", "Human-robot interaction" and "Wood recycling". For many of these competencies, a significant number of stakeholders indicated that they are not required for this level of education. Around half of the respondents were of this opinion for "Digitization of consumer behaviour monitoring", "Digital promotion" and "Alternative products based on biomass".

In Technical VET education, a pattern of smaller, mostly non-significant differences again emerged, indicating a relatively strong correspondence between the students' self-assessments and stakeholders' expectations. Statistically significant gaps remained for areas such as "Digital promotion", "Mechanical stress simulations", "Sustainable design" and "Digitization of consumer behaviour monitoring". Furthermore, quite a few industry stakeholders believe that graduates with this level of education do not need certain competencies, with more than a quarter feeling this way with regard to "Digitization of consumer behaviour monitoring", "Legal frameworks for sustainability", "Alternative products based on biomass" and "Industrial symbiosis".

We observe positive differences in all competencies in the Higher VET students, which indicates that they perceive themselves as less competent than required. However, almost half of these differences were not statistically significant. Gaps where there are notable differences are for "Digital technology and operations", "Mechanical stress simulations", "Industrial symbiosis" and "Sustainability of supply chains". Furthermore, at this level, only a few stakeholders believe that some competencies are not necessary.

At Bachelor's level, we observe statistically significant positive gaps across all competencies, with the largest differences, mostly reaching or exceeding two proficiency levels, occurring for "Human-robot interaction", "Sustainability of supply chains" and "Alternative products based on biomass". The smallest, but still statistically significant, gaps are observed for "Wood pests and wood protection", "Wood waste" and "Digital promotion".

At Master's level, the results again showed the largest competence gaps of all groups. In fact, in almost three quarters of the competencies, the differences amounted to more than two or even three proficiency levels, especially for "Mechanical stress simulations", "Human-robot interaction" and "Digital technology and operations". The smallest, but still significant gaps were observed for "Computer-aided design" and, like the previous education level, for "Wood waste" and "Wood pests and wood protection".

4. Discussion

This study aimed to investigate the extent to which the self-assessments of students at different levels of wood science and technology education in Slovenia match the expectations of stakeholders in the wood and furniture industry in terms of digital and sustainability competencies, and the results show some discrepancies.

At the secondary level (Short and Technical VET programmes), students mostly perceive their competencies as higher than the expectations of the stakeholders, while at the tertiary level (Higher VET, Bachelor's and Master's programmes) they perceive their competencies as lower. These differences appear to be due to the fact that students' self-assessment increases only slightly with increasing educational level (see Table 2), while the

expectations of industry stakeholders increase significantly more (see Table 3). Although we did not find similar studies in the field of wood science and technology, comparable patterns have been reported in other disciplines and countries. For example, Pujol-Jover, et al. [39], found that business graduates in Spain tend to overestimate the requirements of the job and underestimate their own competencies. Similarly, Hisjam, et al. [40] reported that industrial engineering students in Indonesia rated their digital and technical skills lower than expected by the industry. As Braun and Brachem [41] argue, such gaps are often due to educational institutions not clearly defining the competencies expected by the labour market.

A horizontal comparison of the students' self-assessments and the stakeholders' expectations shows an inverse pattern in the three areas of competencies, based on the average values shown in Tables 2 and 3. At the different levels of VET (Short, Technical and Higher VET), students rate themselves highest in generic digital competencies and lowest in profession-specific competencies, related to digitalization and sustainability, while stakeholders have the lowest expectations for generic digital competencies and the highest for profession-specific competencies. This contrast is particularly visible in Short and Technical VET programmes. At Bachelor's and Master's levels, students rate their generic sustainability competencies highest, followed by digital and then profession-specific competencies. For tertiary graduates, stakeholders have the highest expectations for generic digital competencies, followed by sustainability and profession-specific competencies. Although the differences in mean scores between competence groups are not large, the pattern shifts between secondary and tertiary education levels in both students' self-assessments and stakeholders' expectations.

A closer look at the individual competencies reveals several areas in which the discrepancy between the students' self-assessments and the expectations of industry stakeholders is particularly pronounced. At the Short VET level, students consistently rated themselves higher than the expectations of stakeholders, by more than 1.5 proficiency levels for more than half of the competencies assessed. As the students' self-assessment at this level is higher than the expectations of industry stakeholders, these competencies do not appear to be problematic, so in this case it makes more sense to focus on the competencies with the smallest gaps. Within generic digital competencies, these were found for areas related to digital security and wellbeing, while in sustainability the smallest discrepancies appeared in more individual and values-based competencies, such as "Supporting fairness", "Promoting nature" and "Individual initiative". In contrast, all profession-specific competencies showed statistically significant gaps. Moreover, more than a third of stakeholders considered several profession-specific competencies, as well as "Programming", "Integrating and re-elaborating digital content", and "Political agency", as not necessary for Short VET graduates. This suggests that these competencies may not need to be prioritized at this level of education. Other competencies for which students rated themselves significantly higher than stakeholder expectations also raise the question of whether further integration into the Short VET curriculum is necessary—at least from the industry's perspective.

At the level of Technical VET, students' self-assessed competencies largely aligned with the expectations of industry stakeholders, with only a few statistically significant differences, all of which were relatively small. A significant proportion of stakeholders considered some competencies at this level to be unnecessary. As many as a third of them hold this opinion for "Programming", "Digitisation of consumer behaviour monitoring", "Legal frameworks for sustainability", "Industrial symbiosis" and "Alternative products based on biomass". Based solely on the current needs of the industry and without taking broader educational considerations into account, these may not need to be prioritized in curriculum development. Since students at this level often continue their education in

Higher VET and Bachelor's degree programmes, integration could be considered for other competencies, even if their alignment is currently satisfactory at the Technical VET level. It would therefore make sense to consider the most critical competence gaps identified at two higher levels and address them already in Technical VET. In this way, the current educational reforms targeting digital and sustainability competencies would not only address the needs of industry, but also ensure greater alignment across the education vertical, which requires coordinated efforts at both secondary and tertiary levels.

At the Higher VET level, which is part of tertiary education, a clear shift can be observed compared to the lower VET levels, since all competence gaps are positive, indicating that students rate themselves lower than the levels expected by industry stakeholders. While many of these gaps are not statistically significant, the most pronounced gaps in generic digital competencies are observed for "Engaging citizenship through digital technologies" and "Protecting devices". For generic sustainability competencies, there are notable gaps in "Valuing sustainability" and "Problem framing". Among profession-specific competencies, related to digitalization and sustainability, the largest gaps are for "Digital technology and operations", "Industrial symbiosis", "Sustainability of supply chains", "Sustainable consumption and production", and "Renewable resources and sustainable energy". Unlike at the lower levels, not many stakeholders considered specific competencies at this level to be unnecessary. Given the scope and relevance of the gaps identified, future curriculum development at this level of education should, from the perspective of the industry, mostly prioritize strengthening the competencies from the generic digital and the profession-specific domains, while most of the generic sustainability competencies could be comparatively de-emphasized.

In both the Bachelor's and Master's degree programmes, students consistently rated their competencies lower than industry expectations in all three competency areas. At Bachelor's level, there were considerable gaps for many competencies, often amounting to more than two proficiency levels. These differences were even more pronounced at Master's level, where differences of more than three proficiency levels were observed for several competencies. These findings underline the importance of integrating all three competence areas, i.e., generic digital competencies, generic sustainability competencies and profession-specific competencies related to digitalization and sustainability, into the curriculum at both levels. Generic sustainability competencies seem to be slightly less prioritized at Bachelor's level compared to the other areas, but are still important as there remain significant gaps. At Master's level, there is a clear need for a stronger and more balanced integration of all three groups of competencies into the educational programme.

In general, our analysis of student self-assessments may suggest that digital and sustainability competencies may not currently be developed systematically and progressively across the entire vertical pathway in wood science and technology education. This is completely understandable, as most of these competencies have not yet been formally integrated into current curricula, although some topics are still covered, likely due to the initiative and voluntary efforts of individual teachers. However, we must not overlook the fact that these were the student's self-assessments, which may not fully reflect their actual competence in these areas, and that this should be considered in the interpretation of the results.

One explanation for why students rated their competence similarly across educational levels could be the Dunning-Kruger effect. In our case, this explanation may be even more pertinent when comparing self-assessed competencies within each qualification level across competence groups, as on average, students across all levels rated their profession-specific digital and sustainability competencies lower than their generic competencies, possibly indicating a clearer awareness of their limitations in more technical or specialized areas

closer to them and their profession. Similarly, Araújo, et al. [42] found that graduates of an interdisciplinary bachelor's degree programme in marine sciences rated their generic competencies higher than profession-related competencies such as applying knowledge in practice and understanding basic disciplinary content—both formally classified as generic but described by the authors as more vocational in nature.

A second possible explanation for the similar competency assessments across educational levels is that students are realistic about their competencies, but in relation to the tasks associated with the occupations that match the educational level they are currently pursuing. Although the rating scale for assessing competencies used in this study defined levels of task complexity and autonomy, the specific tasks associated with each competency at each proficiency level were not specified, leaving room for individual interpretation based on students' career expectations. This thesis is supported by situated learning theory [43], which emphasizes that learning is contextual and shaped by participation in real or simulated environments. However, if current educational programmes do not simulate the types of tasks students will encounter in the workplace, it may be difficult for them to assess their readiness in relation to actual job requirements. One way to promote a realistic understanding of students' actual competencies is to take a broader view of the subject area and then narrow the focus to more specific topics, especially at the lower levels of education. This approach could help students to understand the broader context while gaining depth in key areas. It can also have practical implications, such as in the selection of elective courses or in guiding students towards further education and training.

Nevertheless, despite the limitations of self-assessment, students' perceptions of their own competencies are important and should not be overlooked. Self-perception influences the development of self-efficacy, the belief in one's ability to successfully apply knowledge and skills to future tasks [44], which plays an important role in shaping motivation, engagement, learning outcomes and the ultimate acquisition of skills [45,46]. As Bandura [45] explains, individuals with strong self-efficacy are more likely to view difficult tasks as challenges to be overcome rather than threats to be avoided.

Furthermore, it is important to note that stakeholders in this study assessed competencies specifically in the context of the digital and sustainable transition within the wood and furniture industry. As such, their responses may reflect the current needs of the industry rather than broadening societal expectations or long-term development goals that education systems must also strive to fulfil. Since students in vocational secondary programmes often continue into tertiary education through vertical pathways within the same field, it is essential that competencies with higher levels of cognitive demand, including both generic and profession-specific digital and sustainability competencies, are systematically developed at the secondary level. This approach not only supports smooth academic progression, but also ensures that students are well-prepared to engage in a dynamic, knowledge-based society. This aligns with the general orientation of the White Paper on Education in the Republic of Slovenia (2011), which emphasizes the systematic development of generic competencies across all levels of education and their meaningful integration with subject-specific content. Although the document does not explicitly address digitalization or sustainability, understandably given its age, it underscores the importance of preparing students for active participation in society, and for lifelong learning as a foundation for both personal and professional development. However, both digitalization and sustainability are recognized as key areas in documents dealing with ongoing curriculum reforms at all levels of education [11–13]. Our study contributes to this by identifying specific areas that need to be prioritized in these two areas, distinguishing between generic and profession-specific competencies in wood science and technology education.

Limitations and Future Research

First limitation that should be considered, and that we have already pointed out is that the use of self-assessments can lead to bias. Nevertheless, while the self-perception of competencies is important, the rating scale in future research could provide accurate descriptions of what each competence level means for each individual competence, as is already the case in DigComp2.1 [38], or even more precisely in DigComp2.2 [17] and GreenComp [18], where each competence is separately described in terms of knowledge, skills and attitudes. However, this would require the participants to invest much more time and cognitive effort when completing the survey. In addition to a more detailed description of the rating scale for each competency, or as an alternative, further research could also consider the inclusion of multiple data sources to validate the self-assessed data, e.g., teacher ratings, analyses of curriculum content and examinations. It is currently unknown to what extent the competencies assessed are explicitly addressed in the formal curricula at the different levels of education. Therefore, it remains unclear whether the observed gaps in competencies are due to curriculum deficiencies, inconsistencies in implementation or merely gaps in perception. Longitudinal studies could examine how perceived and actual competencies develop over time, particularly in the transition from VET to higher education and employment.

Although we complemented the well-established DigComp and GreenComp frameworks with a third framework of profession-specific competencies related to digitalization and sustainability, tailored to the wood and furniture sector, these have not been formally validated. However, given the exploratory and comparative nature of this study, this was not strictly necessary to achieve its objectives. Nevertheless, it is important to recognize that our list of competencies may not fully cover all the specific needs of the wood and furniture sector and all educational goals. Future research could therefore focus on the development and validation of sector-specific frameworks that more fully reflect the needs of this sector.

The generalizability of the results is also limited. The study focused exclusively on Slovenian students and industry stakeholders in one sector, which might limit the transferability of the conclusions to other national contexts or industries. In addition, while the gender imbalance in the student sample (97% male) reflects the current demographics of the field, it also limits generalizability.

As our study focuses exclusively on the needs of industry and not on the broader societal expectations or long-term development goals that education systems must also fulfil, future research should consider these additional perspectives by including a broader spectrum of social partnership in education.

5. Conclusions

As the wood and furniture industry moves towards the vision of Industry 5.0, one of its most pressing challenges remains the lack of competencies needed to support the transition to a digital and sustainable industry. This study confirms that industry stakeholders attach great importance to the digital and sustainability competencies needed to manage this transition. At secondary educational level, the focus should be on developing a solid foundation of generic digital and sustainability competencies that meet the current needs of the industry and provide the necessary prerequisites for the acquisition of more profession-specific digital and sustainability competencies in tertiary education—where such competencies are becoming increasingly important.

However, our findings reveal notable gaps between students' self-perceived competencies and the expectations of industry stakeholders, as well as patterns that can inform ongoing educational reform. Specifically, while students' self-assessment increases only

slightly with increasing educational level, the expectations of industry stakeholders increase significantly more. This suggests that current educational programmes may not yet effectively support the progressive development of students' competencies, or their perception of them, in alignment with industry requirements across educational levels.

To address these gaps, ongoing educational reforms in Slovenia targeting digitalization and sustainability competencies should not only respond to industry needs, the primary focus of this study, but also acknowledge that effective curriculum development requires input from a broader range of stakeholders, in line with Slovenia's evolving model of social partnership in education. However, the role of industry in this partnership is particularly important, and this is the aspect our study specifically addresses. Its active involvement helps ensure that the competencies developed at each educational level are well-aligned with labour market demands, thereby contributing to a more coherent and responsive education system. Bridging the mismatches identified in our study will better prepare graduates to contribute meaningfully to the digital and sustainable transformation of the wood and furniture sector.

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