The Effect of Students' Academic Motivation on Their Self-Perceived Digital and Sustainability Competencies in Wood Science and Technology Education

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The wood and furniture sector faces challenges in adopting digital and sustainability practices, mainly due to a lack of competencies for effective implementation. While current educational reforms in Slovenia emphasize the development of digital and sustainability competencies at all levels of wood science and technology education, the role of motivation, one of the key drivers of learning, in shaping these competencies has not been sufficiently explored. This study investigated how academic motivation affects students, self-perceived digital and sustainability competencies. A survey was conducted among 453 final-year students in wood science and technology education programs, including secondary vocational and technical, short-cycle higher vocational, and higher education institutions. The Academic Motivation Scale was used along with instruments derived from established European digital and sustainability competence frameworks. Structural equation modeling revealed that students' academic motivation positively predicted their self-perceived generic digital, generic sustainability, and professional digital and sustainability competencies, and explained between 22 and 29% of the variance. Intrinsic and extrinsic motivation were not shown to be distinct dimensions, but formed a unidimensional construct, suggesting that both internal interests and external incentives jointly support the perception of these competencies. Students' academic motivation is a decisive factor for their self-perceived digital and sustainability competencies in wood science and technology education.

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INTRODUCTION

While manufacturing companies are still actively advancing their transition to Industry 4.0 (Longo *et al.* 2020) and the discourse on Industry 5.0 is already in full swing (Breque *et al.* 2021), the wood and furniture sector is still lagging behind. Some believe that it is still operating at a level more akin to Industry 2.0 (Červený *et al.* 2022). In the wood and furniture sector, the realization of this twin transition, both digital and sustainable, is hindered not only by financial constraints, but also by deficits in the knowledge and skills required for effective implementation (Kropivšek 2018; Kropivšek and Grošelj 2020; Muench *et al.* 2022; Goropečnik *et al.* 2024, 2025).

This situation can be addressed in the context of formal education, which plays an important role in ensuring that graduates are sufficiently competent in these areas, as it is the cornerstone of societal progress (Ozturk 2008). Recognizing this, the European Green Deal has created a policy framework that has already triggered educational reforms in Slovenia at all levels of education, including vocational education (Ahačič *et al.* 2024; Skubic Ermenc *et al.* 2024), higher vocational education (Mali *et al.* 2025) and higher education (Vlada Republike Slovenije 2022), with sustainability and digital literacy among the priorities. These reforms will also determine the future trajectory of education in the field of wood science and technology. In this area, students at lower levels of education are prepared for careers as carpenters and wood technicians, while at higher levels they are trained as wood engineers.

In line with the principles of competence-based education, on which the current reforms are also based, two European reference frameworks serve as guidelines for the integration of digital and sustainability competencies into curricula. The Digital Competence Framework for Citizens (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). The European Sustainability Competence Framework (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 competencies that are essential for the twin transition.

Even in the context of competence-based education, the integration of competencies should not be approached as a mere checklist or wish list to be fulfilled, but as part of a coherent pedagogical process (Makovec Radovan 2025). The presence of competencies in the curriculum is not in itself a guarantee that they will develop in students; their acquisition depends on how learning is designed, experienced, and internalized, and it is important to consider various factors that influence learning and its outcomes (Chaudhary and Singh 2022).

Among the factors that influence this process, academic motivation is of particular importance. Whether it is driven by intrinsic curiosity and personal growth or extrinsic factors such as grades or rewards, it shapes the way students approach, evaluate, and persevere in their educational journey (Vallerand *et al.* 1992). Motivation is a psychological factor that influences human behavior (Din *et al.* 2024). Over time, a variety of theories have contributed to today's understanding of motivation. Behaviorists such as Skinner (1953) view motivation as a response to external stimuli that is shaped by rewards and punishments, while the psychoanalytic perspective of Freud (1961) views motivation as driven by unconscious needs and instinctual drives. In contrast, humanistic psychologists such as Maslow (1943) and Rogers (1959) argue that neither approach fully explains human motivation and claim that individuals' actions are driven and guided by intrinsic forces. Cognitive psychologists such as McClelland *et al.* (1953) link achievement motivation to goals, expectations, and perceptions of success. Building on this, Weiner's (1985) attribution theory explains how the interpretation of success and failure influences motivation. Bandura's (1986) socio-cognitive view adds social factors and shows how personal characteristics, behavior and environment interact to influence motivation. According to Glasser's (1985) control theory, behavior is driven by internal psychological needs. This theory was later extended by Glasser's (1998) choice theory, which emphasizes choice over control of outcomes. The understanding of motivation has been further deepened in recent decades by the development of self-determination theory (Deci and Ryan 1985), which emphasizes the importance of three basic psychological needs: autonomy, competence, and relatedness.

These views suggest that motivation is anything but a unitary concept. People's motivation differs not only in the degree to which they are motivated, but also in their orientation of motivation (Ryan and Deci 2000). Resolving the dilemma and relationship between intrinsic motivation, which refers to doing something because it is inherently interesting or enjoyable, and extrinsic motivation, which refers to doing something because it leads to a definable outcome, is paramount to understanding and fostering motivation to learn (Marentič Požarnik 2021). This distinction is used by Deci and Ryan's (1985) Self-Determination Theory (SDT), in which motivation is categorized according to the reasons for actions. More specifically, SDT focuses on the way in which individual motives are integrated into the self and regulated. This can be achieved through effective regulatory processes characterized by autonomous forms of motivation that serve to increase the autonomy and functionality of the self (Utvær and Haugan 2016). The approach also emphasizes how ideas, values, and goals become self-internalized within various social influences (Deci and Ryan 2012). In SDT, the concept of internalization has evolved from the simple distinction between intrinsic and extrinsic motivation to the distinction between autonomous and controlled motivation. Autonomous motivation means that one acts of one's own free will, whereas controlled motivation means that one feels pressured by external demands to achieve certain outcomes (Deci and Ryan 2008).

Academic motivation, whether driven by intrinsic curiosity and personal growth or extrinsic factors such as grades or rewards, shapes the way students approach, evaluate, and persevere in their educational journey (Vallerand *et al.* 1992). The Academic Motivation Scale (AMS) developed by Vallerand *et al.* (1992) is based on the principles of SDT and provides a structured approach to assessing the different types of motivation and comprises seven subscales of motivation. It is one of the most commonly used instruments to measure students' willingness to study (Zeng and Yao 2023) and was also used in the present study, which investigates the effects of academic motivation on students' self-perceived digital and sustainability competencies.

The Relationship between Motivation and Sustainability Competencies

Motivation plays a decisive role in learning for sustainability. It influences both the learning process and the learning outcome itself (Hansmann 2010). Previous research has identified several pathways linking motivation to sustainability-related outcomes. For example, self-efficacy appears to mediate the relationship between motivation and sustainable behavior, with environmental education programs improving both constructs (Mullenbach and Green 2018). Other studies emphasize the role of intrinsic factors such as autonomy, reflection, interpersonal relationships, and self-actualization in sustaining student engagement in education for sustainable development (Mulder *et al.* 2015).

Emotional and cognitive factors also play an important role. Emotional intelligence increases students' motivation to learn about sustainability (Nogueira *et al.* 2023). In addition, perceptions of environmental impact, convenience, and self-efficacy have a strong influence on sustainable behavior (Perrault and Clark 2018). Furthermore, declarative knowledge increases competence in sustainability management and aversion to sustainability can hinder it, while motivation to act sustainably and interest do not always show a significant effect (Michaelis *et al.* 2020). Finally, Núñez *et al.* (2024) have shown that motivation, together with attitude, knowledge and commitment, is strongly associated with the development of sustainability competencies, with motivation being the most influential factor.

However, maintaining motivation remains a challenge. Scharenberg *et al.* (2021) observed that although students' knowledge about sustainability increased over the course of a school year, their affective-motivational beliefs and attitudes towards sustainability decreased. Approaches such as gamification have been shown to increase motivation and promote pro-environmental attitudes as well as greater awareness and sensitivity to environmental conflicts (Santos-Villalba *et al.* 2020). Gam and Banning (2011) have also shown that problem-based learning improves critical thinking, motivation, and commitment to sustainable practices. Similarly, Wang *et al.* (2022) have shown that universal pedagogical approaches positively influence students' attitudes and actions towards sustainability, further supporting the role of innovative teaching methods in sustaining motivation.

The Relationship between Motivation and Digital Competencies

Some studies demonstrate the reciprocal relationship between motivation and digital competencies. Supervía and Vega (2024) found a positive correlation between intrinsic motivation and students' digital competence. Yünkül and Güneş (2022) reported a positive but low correlation between digital literacy and academic motivation, while Lee *et al.* (2023) and Rusli *et al.* (2023) confirmed a strong correlation, which is consistent with Anthonysamy's (2022) findings that motivational beliefs such as task value, goal orientation, and self-efficacy correlate significantly with digital literacy. On the other hand, Montilla *et al.* (2023) have shown that teachers' pedagogical digital competence positively correlates with students' academic motivation and performance. Interventions to optimize students' digital competence also show a positive correlation between their digital competence and psychoeducational factors such as motivation and satisfaction (Díaz-Burgos *et al.* 2023).

Studies have also investigated how motivation influences digital competencies. Tian and Park (2022) found that self-determined motivation, especially autonomy and relatedness, played an important role in promoting students' digital literacy, while the influence of competence was relatively insignificant. A positive attitude towards technology improves data literacy, digital skills (Chu *et al.* 2023) and engagement in learning processes (Pala 2023). Academic motivation drives engagement with digital tools and improves digital competence, while amotivation has a negative effect on engagement (Novikova *et al.* 2022). Similarly, self-efficacy and mastery orientation are important predictors of digital competence (Hatlevik *et al.* 2015a,b).

Conversely, digital competence also influences academic motivation. Digital literacy has been shown to positively influence motivation to learn (Wahyuni *et al.* 2023). Students' perceptions of digital literacy predict their attitudes towards online learning and their academic aspirations, with attitude acting as a mediator (Akman 2021). Informal digital learning improves performance, increases motivation, and enhances knowledge (Jin *et al.* 2019), which in turn promotes academic engagement and digital competence (Heidari *et al.* 2021). Posekany *et al.* (2023) found that participation in the "Digital Transformation" course improved intrinsic motivation, competence and relatedness in the use of digital technologies.

Research Model and Hypotheses Development

While numerous studies have investigated the relationship between motivational factors and digital or sustainability competencies and emphasized the important role of motivation in their development, there is still a lack of integrated research that addresses both areas simultaneously. This is particularly important given the principles of competence-based education, in which the individual competencies are not developed in isolation but simultaneously and in interaction, and the current educational reforms in Slovenia that focus on both areas. This research gap is even more evident in the field of wood science and technology education, an area of particular interest to the authors due to their connection to this field. Here, previous research has not yet sufficiently investigated how motivational factors influence these competencies in students.

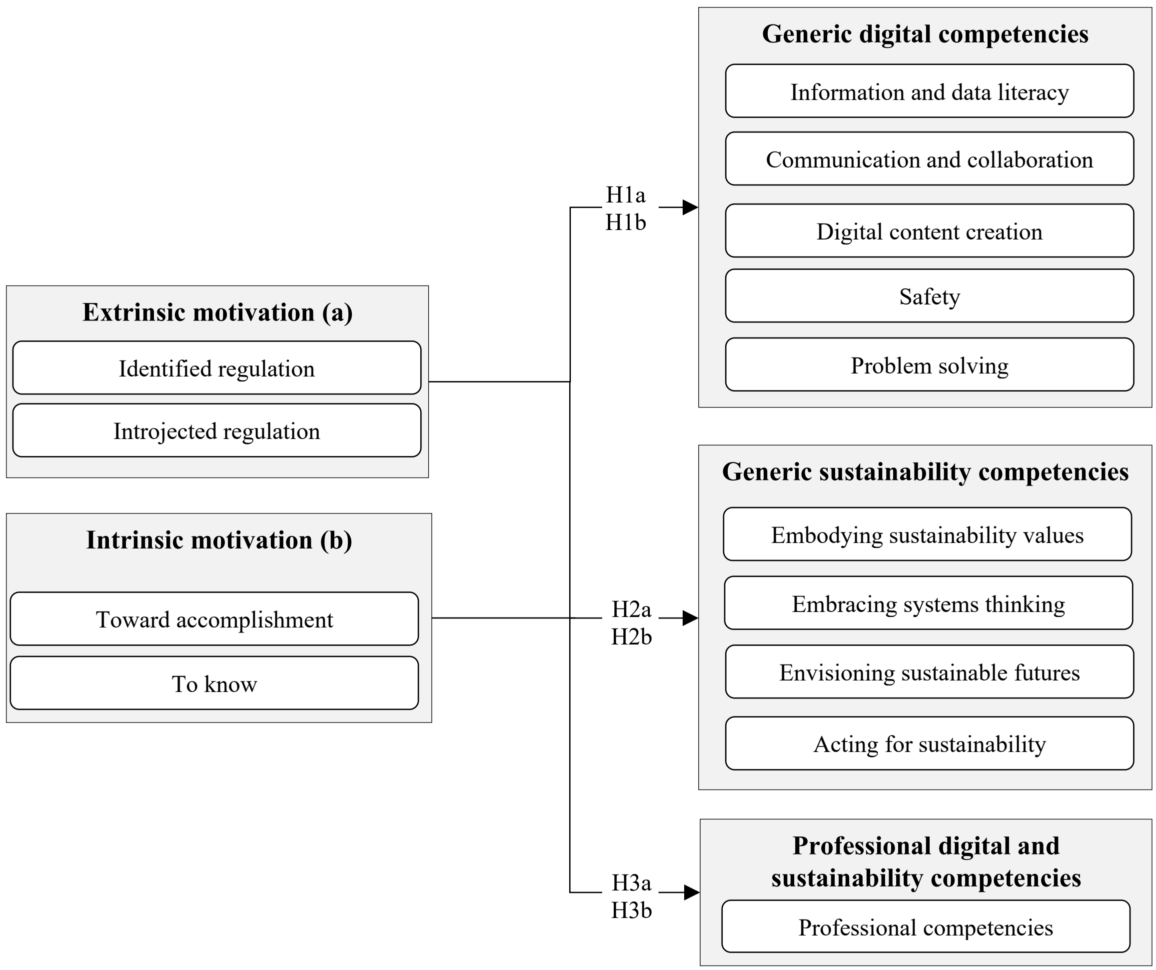

Fig. 1. Conceptual model

The aim of this study was to determine whether the motivation of students in wood science and technology education affects their self-perceived digital and sustainability competencies, which were categorized into three groups, namely generic digital competencies, generic sustainability competencies, and professional digital and sustainability competencies. Understanding this relationship could help to develop effective interventions to support the development of these competencies in students enrolled in wood science and technology education programs. The research question was:

What types of academic motivation (intrinsic and extrinsic) do students have and to what extent do they affect their self-perceived generic digital, generic sustainability, and professional digital and sustainability competencies?

Based on this research question, the following hypotheses were developed, as illustrated in Fig. 1:

- **H1: Academic motivation affects the generic digital competencies of wood science and technology students.**

H1a: Extrinsic motivation has an effect on generic digital competencies.
H1b: Intrinsic motivation has an effect on generic digital competencies.

- **H2: Academic motivation affects the generic sustainability competencies of wood science and technology students.**

H2a: Extrinsic motivation has an effect on generic sustainability competencies.
H2b: Intrinsic motivation has an effect on generic sustainability competencies.

- **H3: Academic motivation affects the professional digital and sustainability competencies of wood science and technology students.**

H3a: Extrinsic motivation has an effect on professional digital and sustainability competencies.
H3b: Intrinsic motivation has an effect on professional digital and sustainability competencies.

EXPERIMENTAL

Data Collection and Processing

The study focused on students enrolled in wood science and technology education programs in Slovenia. The questionnaire was developed based on a literature review and underwent a pilot phase to ensure the clarity and validity of the questionnaire items. Feedback from experts and students was incorporated into subsequent revisions, which focused primarily on item wording and clarity. The revised questionnaire was distributed using a non-probability sampling method, namely purposive sampling, which is best suited for studying a particular group (Tongco 2007).

The data was collected from March to May 2024. During this period, all educational institutions in Slovenia that offer the educational programs examined in this study were visited. These included Šolski center (ŠC) Ljubljana, Srednja lesarska šola; ŠC Škofja Loka, Srednja šola za lesarstvo; ŠC Novo mesto, Srednja gradbena, lesarska in vzgojiteljska šola; ŠC Nova Gorica, Srednja prometna in lesarska šola; ŠC Slovenj Gradec, Srednja šola Slovenj Gradec in Muta; Srednja gozdarska in lesarska šola Postojna; Srednja poklicna in tehniška šola Murska Sobota; Lesarska šola Maribor; Gimnazija in srednja šola Kočevje; Srednja šola Sevnica; Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za lesarstvo. This corresponded to 35 final- year classes of students within the wood science and technology education programs. The survey was administered in a supervised classroom environment, where students completed the online questionnaire individually on the school's computers. This made it possible to give them precise instructions and ensure that all respondents received the same guidance throughout the survey.

According to Slovenian regulations, formal ethical approval was not required for survey-based educational research at the time of the survey. However, this study was conducted in strict compliance with ethical guidelines and the principles of informed participation. As part of standard practice in Slovenian upper secondary schools and universities, students (or parents/ guardians in the case of minors) give their general written consent to participate in the study upon enrollment. In addition, the participants were informed about the objectives of the study before the survey began, they were assured anonymity and voluntariness, and their verbal consent was obtained before participation.

Descriptive statistics were used to analyze the data to examine the distribution of the observed variables. The internal consistency of the measurement scales was assessed using Cronbach's alpha, calculated in IBM SPSS Statistics 29. The construct validity of the measurement model was examined by Confirmatory Factor Analysis (CFA), which was performed in AMOS 29. Subsequently, Structural Equation Modeling (SEM) was used to assess the hypothesized relationships within the proposed conceptual framework.

Measures

The questionnaire consisted of three content sections and a demographic section. In the first content section, students rated the level of their own digital and sustainability competencies. In the second and third sections, various aspects were examined, including the students' academic motivation, which is the subject of this study. A previously validated multidimensional instrument was used to assess students' academic motivation and self-perceived generic digital and generic sustainability competencies, while for professional digital and sustainability competencies, a list of competencies related to the wood and furniture industry were developed (see below).

Assessment of digital and sustainability competencies

For the assessment of students' competencies, 21 digital competencies were used from all five domains of DigComp, namely Information and Data Literacy, Communication and Collaboration, Digital Content Creation, Safety, and Problem Solving in Digital Environments (Vuorikari *et al.* 2022), as well as 12 sustainability competencies from all four domains of GreenComp, namely Embodying Sustainability Values, Embracing Complexity, Envisioning a Sustainable Future and Acting for Sustainability (Bianchi *et al.* 2022).

As many of these competencies are generic in nature, an additional set of 24 profession-specific competencies focusing on digitalization and sustainability in the wood and furniture sector were additionally included. The development of these competencies took place in a multi-stage process. First, the authors relied on the *Implementation Document for the Development of the Slovenian Wood Industry until 2030* (Ministry of Economic Development and Technology & Wood Industry Directorate, 2022), which highlights essential competencies for future wood science and technology graduates. These include areas such as design, construction, architecture, heritage conservation, mechanical processing of wood, practical training, public relations, and selected areas of social sciences. On this basis, 12 experts from different professional backgrounds identified the most important competencies in their respective fields, with a particular focus on digitalization and sustainability. Each expert also provided a description of the scope and content of their proposed competencies. Overlapping items were then combined into a harmonized list, which was then evaluated by the same group of experts in an extended panel, using a four-point Likert scale to assess their importance for wood science and technology graduates. Based on this, the final set of 24 professional competencies was developed and used for students' self-assessment. These competencies included: sustainable design; computer-aided design; smart furniture; restorative environmental and ergonomic design; energy-efficient and smart houses; wooden constructions; mechanical stress simulations; cultural heritage; wood pests and protection; use of wood residues; wood recycling; sustainable consumption and production; autonomous and adaptive production; human–robot collaboration; renewable resources and sustainable energy; biomass-based alternative products; environmental impact of products; circular business models; sustainability of supply chains; industrial symbiosis; legal framework for sustainability; digital business operations; digital promotion; and digital monitoring of consumer behavior.

Students self-assessed their competencies based on 8 proficiency levels defined in DigComp 2.1 (Carretero *et al.* 2017), which describe increasing levels of competence in terms of task complexity and autonomy. When assessing the competencies, students were provided with the name and full description of each competence. For the established frameworks (DigComp and GreenComp), the official Slovenian translations of the questionnaires were used.

Table 1. Rating Scale for the Proficiency Level of Competencies (Carretero *et al.* 2017)

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

Assessment of student's academic motivation

To assess students' academic motivation, the Academic Motivation Scale (AMS) (Vallerand *et al.* 1989) was used. It is available in two versions, one for VET students and one for HE students. The Slovenian translation of the HE version by Puklek Levpušček and Podlesek (2017) was used, with the necessary adaptations for the VET context. AMS measures 3 constructs of Intrinsic Motivation (to know, toward accomplishment, to experience simulation), 3 constructs of Extrinsic Motivation (identified, introjected, external regulation), and one construct of Amotivation, which together contain 28 items. Students were asked to indicate on a 7-point Likert scale from '1 - Does not correspond at all' to '7 - Corresponds exactly', the extent to which each of the statements currently corresponds to one of the reasons why they go to school/university.

The complete AMS scale was initially included in the measurement model. In refining the model, the modification indices and model fit diagnostics indicated that certain dimensions were less relevant for capturing learning-oriented motivation, which is central to the aims of this study. To obtain a parsimonious and well-fitting model while maintaining the conceptual integrity of the AMS framework, four dimensions were included in the final analysis, two intrinsic (to know and toward accomplishment) and two extrinsic (identified regulation and introjected regulation).

Participants

The population of this study consists of students in their final year of study in Slovenian wood science and technology education programs at different levels of education. There were 453 final year students included in the study, which is about 82% of the total population. The sample was predominantly male (97.0%), reflecting the current demographics in the sector. Students of upper secondary vocational education (3-year, ISCED 353) for "Carpenters (46.1%)", upper secondary technical vocational education (4-year, ISCED 354) for "Technicians" (16.6%), 2-year vocational technical education (2-year , ISCED 354), that enable graduates of a upper secondary VET program to obtain an upper secondary technical level of education (22.3%), short cycle higher vocational education (2-year, ISCED 554) for "Engineers" (5.5%), vocational and academic bachelor's degree programs (3-year, ISCED 645 and 655) for "Bachelors of Wood Engineering" (7.1%), and master's degree program (2-year, ISCED 767) for "Masters of Wood Science and Technology" (2.4%) were included in the survey. However, students enrolled in short upper secondary vocational program and doctoral studies were excluded from the study due to the specific structure and nature of their competency acquisition, which are not directly comparable to those of the other educational programs included in the analysis.

Measurement Model

Because the latent constructs theoretically proposed in the conceptual model (see Fig. 1) could not be empirically confirmed, an Exploratory Factor Analysis (EFA) was conducted to investigate the underlying structure of the competency-related items. The EFA revealed an ambiguous factor structure among the items, which was characterized by systematic cross-loadings between theoretically distinct groups of competencies. However, the structure was not coherent enough to justify combining all competencies into a single latent construct. Therefore, based on the content classification of competencies – generic digital competencies, generic sustainability competencies and professional digital and sustainability competencies – and supported by the approximate (albeit unclear) factor structure, the predefined thematic grouping of items was retained, with awareness of the potential issues related to multicollinearity.

The next step was to develop a measurement model containing the following latent constructs: DigC1 represents fundamental generic digital competencies such as information literacy, communication, and collaboration; DigC2 represents digital safety and online behavioral generic competencies, that include digital safety, copyright and licensing, and online etiquette; and DigC3 captures more complex generic digital competencies such as digital content creation and problem solving. The generic sustainability competencies were found to be a one-dimensional construct (SusC). Professional digital and sustainability competencies were modeled as a two-dimensional construct: The first dimension (ProfC1) primarily reflected technical professional digital and sustainability competencies, while the second dimension (ProfC2) primarily represented professional digital and sustainability competencies for business operations. Motivation was also identified as a unidimensional construct containing items that reflect both intrinsic and extrinsic motivation. Each item measuring students' self-assessed competencies and academic motivation was treated as an individual observed indicator in the measurement model.

RESULTS AND DISCUSSION

The reliability and validity of the measurement model was assessed using the established guidelines for reflective models (Bagozzi and Yi 1988). The reliability of the items was assessed using the standardized factor loadings, which were all above the recommended minimum of 0.50, with the lowest loading being 0.565. Internal consistency (see Table 2) was assessed using both Cronbach's alpha (α) and composite reliability (CR). The results indicate strong internal consistency for all latent constructs, with the lowest Cronbach's alpha value being 0.856 and the lowest CR being 0.866. These values are above the conventional threshold value of 0.70 and thereby confirm the internal reliability of the measurement model. Convergent validity was assessed using the average variance extracted (AVE). All latent constructs measuring the competencies met or exceeded the generally accepted threshold of 0.50, indicating that a moderate proportion of the variance in the associated items was explained by the respective latent constructs. The AVE value for the construct Motivation was below the generally accepted threshold of 0.50. However, as the construct showed satisfactory internal consistency, it was retained in the model for further analysis. Discriminant validity was assessed using the Fornell–Larcker criterion (Fornell and Larcker 1981), which compares the square root of the average variance extracted (AVE) for each latent construct with its correlations with other constructs. As shown in Table 2, several cases were identified for which the square roots of the AVE values (diagonal elements in bold) were lower than the inter-construct correlations. This was particularly evident within the subject areas of the same competence group: The three dimensions of generic digital competencies showed weak discriminant validity among themselves, as did the two dimensions of professional digital and sustainability competencies.

Table 2. Descriptive Statistics, Internal Consistency and Validity Estimates for Latent Factors, Including Inter-factor Correlations

		1	2	3	4	5	6	7
1	Generic Digital Competencies 1 (DigC1)	**.733**						
2	Generic Digital Competencies 2 (DigC2)	.803	**.707**					
3	Generic Digital Competencies 3 (DigC3)	.824	.816	**.723**				
4	Generic Sustainability Competencies (SusC)	.734	.773	.788	**.710**			
5	Professional Digital and Sustainability Competencies 1 (ProfC1)	.632	.644	.708	.772	**.726**		
6	Professional Digital and Sustainability Competencies 2 (ProfC2)	.572	.576	.718	.695	.864	**.719**	
7	Motivation	.218	.220	.217	.283	.292	.251	**.657**
	M	4.77	4.88	4.37	4.67	4.56	4.04	4.35
	SD	1.236	1.389	1.348	1.273	1.277	1.290	1.142
	α	.885	.873	.856	.917	.935	.902	.884
	CR	.890	.874	.866	.918	.935	.914	.883
	AVE	.537	.499	.522	.505	.527	.517	.432

Note. M = Mean; SD = Standard Deviation; α = Cronbach's Alpha; CR = Composite Reliability; AVE = Average Variance Extracted. The lower triangle presents correlations among latent factors. Diagonal values in bold represent the square root of the AVE.

In addition, the generic sustainability competencies showed strong correlations with all other competency dimensions, suggesting considerable conceptual and statistical overlaps between the constructs. While the high inter-construct correlations reflect the theoretically expected relationships discussed in the Discussion section, they also urge caution in interpreting the results.

Structural Model

The evaluation of the model fit statistics indicated a mostly acceptable fit of the structural model to the data. The χ2 statistic ($\chi2(1946) = 5936.8$, $p < .001$) was statistically significant, which is to be expected given the large sample size. However, the normed χ2 value (CMIN/DF = 3.05) indicated a good fit. The Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) were both below the conventional threshold of 0.90 with values of 0.769 and 0.753 respectively, indicating a moderate fit. The Root Mean Square Error of Approximation (RMSEA) was 0.067 (90% CI = 0.065 to 0.069).

Hypothesis 1 proposed that academic motivation has an effect on the generic digital competencies of wood science and technology students. As shown in Fig. 2, the results support this hypothesis.

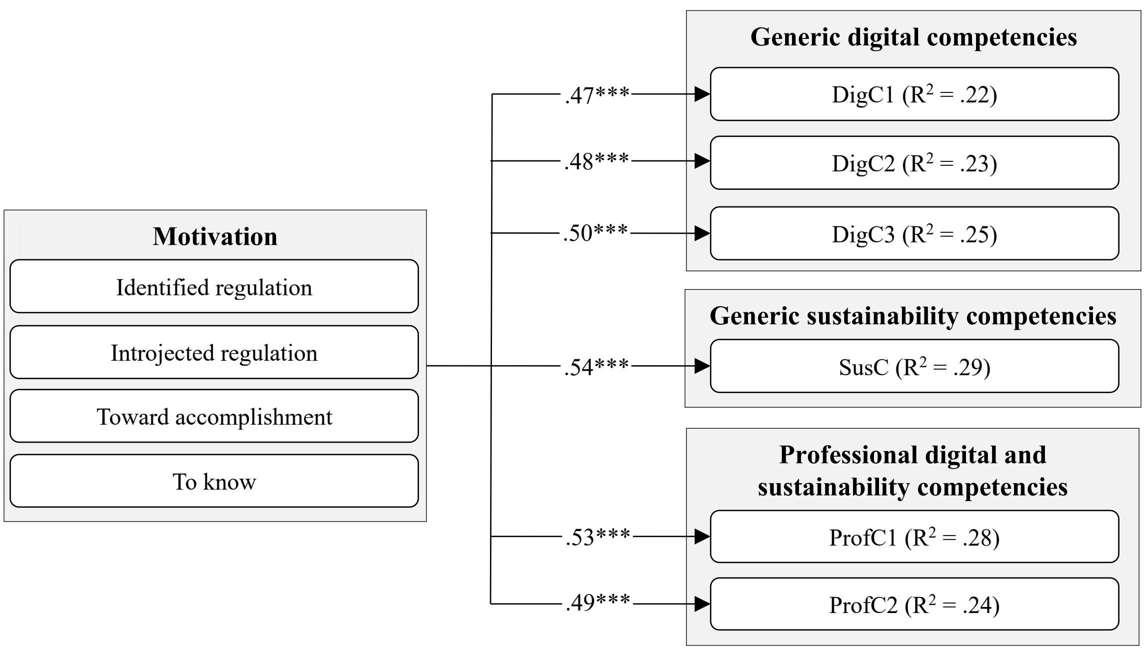

Fig. 2. Structural model. *** indicates that p < 0.001

Academic motivation showed a statistically significant positive effect on all three dimensions of generic digital competencies: fundamental generic digital competencies ($\beta = 0.47$), digital safety and online behavioral generic digital competencies ($\beta = 0.48$), and more complex generic digital competencies ($\beta = 0.50$). Higher academic motivation of wood science and technology students corresponds with higher self-perceived generic digital competencies. The academic motivation of wood science and technology students explained 22.4% of the variance in fundamental generic digital competencies, 23.4% in digital safety and online behavioral, and 24.9% in advanced generic digital competencies. It was also hypothesized (H2) that academic motivation has an effect on the generic sustainability competencies of wood science and technology students. Hypothesis 2 was also supported by the results, as academic motivation had a positive and moderate effect ($\beta = 0.54$) on the generic sustainability competencies of wood science and technology students and explained 29.3% of the variance in generic sustainability competencies. Hypothesis 3 proposed that academic motivation has an effect on the professional digital and sustainability competencies of wood science and technology students. The hypothesis was supported by the results as academic motivation has a statistically significant positive effect on both – technical professional digital and sustainability competencies ($\beta = 0.53$) and business operations digital and sustainability competencies ($\beta = 0.49$). The academic motivation of wood science and technology students explained 28.4% of the variance in technical professional digital and sustainability competencies and 24.2% in business operations digital and sustainability competencies.

Discussion

The results of this study supported the hypothesis that academic motivation has a significant effect on students' self-perceived digital and sustainability competencies. In line with Hypothesis 1, academic motivation was found to significantly and positively predict all three dimensions of generic digital competencies, namely fundamental, digital safety-related, and more complex, among wood science and technology students in this study. Although the explained variance (R^2 = 22–25%) suggests that academic motivation is not the only factor contributing to the development of these competencies, it still represents a meaningful portion of the variance and emphasizes the importance of motivational factors in promoting digital literacy. Similarly, Hypothesis 2 was also confirmed, showing that students' academic motivation also contributes significantly to their generic sustainability competencies, explaining nearly 30% of the variance. Finally, the results also support Hypothesis 3, which states that academic motivation has a positive effect on both technical professional digital and sustainability competencies, as well as business operations digital and sustainability competencies related to the wood and furniture sector, which explain 24–28% of the variance. The amount of explained variance in the models is in line with expectations in social science research, where student outcomes are influenced by many factors and the focus is less on high predictive power and more on identifying statistically significant predictors, with R^2 values above 10% generally considered acceptable (Ozili 2022).

In summary, students who are more academically motivated are more likely to perceive themselves as having higher digital and sustainability competencies in all three competency groups in this study, *i.e.* generic digital competencies, generic sustainability competencies, and professional digital and sustainability competencies. The results thus suggest that fostering academic motivation can be an important lever to promote a broad range of perceived digital and sustainability competencies among wood science and technology graduates. This is consistent with findings from other contexts, including for digital competencies (Tian and Park 2022) and for sustainability competencies (Núñez *et al.* 2024).

The results showed that within the population of wood science and technology students, intrinsic and extrinsic motivation did not emerge as distinct constructs but are best represented as a unidimensional construct. While many studies and theories support the distinction between intrinsic and extrinsic motivation (Diseth *et al.* 2020; Lepper *et al.* 2005; Vallerand *et al.* 1992), there is also ample evidence that these constructs may overlap, interact, or exist on a continuum. Self-Determination Theory (SDT) distinguishes between intrinsic and extrinsic motivation, but it conceptualizes them as being part of a continuum of self-determination, ranging from amotivation, to increasingly self-determined forms of extrinsic motivation, to intrinsic motivation (Deci and Ryan 2000). Furthermore, Reiss (2012) argues that the strict dualism between intrinsic and extrinsic motivation lacks construct validity because human motives are genetically diverse and cannot be reduced to just two categories. These explanations emphasize that there is no sharp boundary between intrinsic and extrinsic motivation and that the distinction can become blurred, which is one explanation for why they did not emerge as distinct constructs in this study.

Additionally, this pattern could also reflect the fact that internal interests and external incentives can act synergistically rather than competitively. For example, Amabile (1993) argued that extrinsic motivators can enhance performance when intrinsic motivation is already high, and Vansteenkiste *et al.* (2004) showed in college students that intrinsic goals lead to greater learning and persistence when supported by autonomy-enhancing external contexts. However, other studies show a more complex dynamic, *i.e.*, Cerasoli *et al.* (2014) found that intrinsic motivation predicts quality of performance, while external rewards can drive quantity and sometimes undermine quality, and Lin *et al.* (2003) reported that students with high intrinsic and moderate extrinsic motivation performed the best, while very high extrinsic motivation was detrimental. This suggests that while extrinsic incentives can sometimes complement intrinsic motivation, caution should be exercised in efforts to increase extrinsic motivation, as poorly designed or excessive incentives may weaken rather than support students' learning outcomes.

When interpreting the results, it is also important to address the issue of discriminant validity. As noted in the assessment of the measurement model, several latent constructs, particularly within the same thematic groups, did not meet the Fornell–Larcker criterion for discriminant validity. This was particularly evident in the three dimensions of generic digital competencies and the two dimensions of professional digital and sustainability competencies. In addition, the generic sustainability competencies showed strong correlations with all other groups of competencies. From a statistical point of view, such high inter-construct correlations could be considered problematic as they indicate possible multicollinearity and conceptual overlap. In this case, the lack of strict discriminant validity provides meaningful insights rather than undermining the value of the model. Namely, the observed overlaps between the constructs reflect the inherent interconnectedness of generic digital, generic sustainability, and professional digital and sustainability competencies in the context of wood science and technology education. The fact that the competencies are not entirely distinct but mutually reinforcing, aligns well with the development of students' competencies in formal education, where students develop different competencies simultaneously, especially in the context of competence-based education, which requires integration across subjects and modules and promotes learning approaches that enable holistic development of competencies (Makovec Radovan 2025). In other words, students who are digitally competent are also likely to be better equipped in terms of sustainability practices and professional readiness, and vice versa. This correlation between competencies represents a meaningful characteristic of competencies that are strongly interrelated and thus explains how students develop these different competencies. Despite statistical concerns about discriminant validity, the theoretically and contextually meaningful constructs were retained for the analysis. The primary goal was not to develop a model with high predictive power or strict statistical parsimony, but rather to explore and explain how academic motivation is related to multiple dimensions of students' self-perceived competencies. Ultimately, the moderate to strong relationships observed between all competency domains suggest that efforts to promote student motivation can simultaneously improve a broad range of digital and sustainability competencies, suggesting that pedagogical approaches should take an integrated approach to competency development rather than focusing solely on isolated dimensions.

The study has other limitations. First, the use of self-assessments may lead to biases. Although they provide valuable insights into learners' perceptions, they only capture one perspective. Future research should therefore include triangulation methods, such as teacher evaluations, curriculum analyses, or performance-based assessments (*e.g.*, practical tasks or exams). Second, because the data reflects observations from a single point in time, this cross-sectional design limits causal inference between motivation and competencies. However, the results still reveal meaningful relationships between these variables, highlighting the need for longitudinal or experimental approaches to establish causality. Third, as the study focused on a single educational field, the findings should be interpreted within this specific context. Nevertheless, the use of validated frameworks (DigComp, GreenComp, AMS) supports the broader relevance and potential transferability of the theoretical model, methodological approach, and findings, while acknowledging that the gender imbalance in the sample (97% male) may have influenced the results. Future studies could replicate this research across different disciplines, in diverse national contexts, and with more balanced samples.

CONCLUSIONS

1. Academic motivation showed a statistically significant and positive effect on students' self-perceived digital and sustainability competencies in all areas studied, *i.e.*, generic digital competencies, generic sustainability competencies and professional digital and sustainability competencies.
2. Academic motivation explained a meaningful proportion of the variance in competencies, ranging from approximately 22% to 29%, confirming its great importance for students' self-perceived competencies in wood science and technology education.
3. Academic motivation had a positive effect on all three sub-dimensions of generic digital competencies, namely fundamental, digital safety and online behavior, and more complex digital competencies, indicating that motivated students perceive themselves more competent in all aspects of digital competence.
4. Students' academic motivation contributed with the strongest effect to their generic sustainability competencies, suggesting that motivation is an important factor in students' self-perceptions of their sustainability-oriented competencies.
5. Profession-specific digital and sustainability competencies were also positively affected by students' academic motivation in their two sub-dimensions, *i.e.* technical and business operations oriented, showing that motivation not only promotes generic but also profession-specific digital and sustainability competencies related to the wood and furniture sector.
6. In this study, of the population of wood science and technology students, intrinsic and extrinsic motivation were not demonstrated to be distinct constructs, but rather a

unidimensional construct, suggesting that internal interests and external incentives jointly shape students' self-perceptions of digital and sustainability competencies.

7. The strong correlations between the three groups of competencies, namely digital competencies, sustainability competencies, and professional digital and sustainability competencies, indicate that these areas are interrelated and mutually reinforcing, reflecting the integrated nature of competency-based education in wood science and technology.

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