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Efficiency of European Wood Science and Technology Educational Programmes in Including Green and Digital Topics

Učinkovitost europskih obrazovnih programa o znanosti o drvu i drvnoj tehnologiji u uključivanju zelenih i digitalnih tema

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ABSTRACT • *The integration of sustainable and digital competences in educational programmes is vital for shaping a promising future. Through interviews and analysis, we assessed the inclusion of green and digital (industry 4.0 and ambient assisted living) topics in wood science and technology educational programmes across different European countries. Our research revealed disparities in vertical alignment within countries and deviations among similar programs across countries. With the help of fuzzy logic and by using Data Envelopment Analysis, we evaluated the technical efficiency of programs in incorporating these topics in teaching, considering multiple factors. Results show varying performance levels, with some programs achieving optimal efficiency, while others lagging behind. To improve underperforming programs, prioritizing topic integration is crucial. National coordination and alignment across educational levels are necessary to establish a cohesive system. Equipping individuals with these competences enable them to contribute to sustainable development, leverage digital technologies, and meet societal demands.*

KEYWORDS: *wood science and technology; education; green; digital; DEA*

SAŽETAK • *U izgradnji obećavajuće budućnosti ključnu ulogu ima integracija kompetencija za održivi razvoj i digitalnih kompetencija u obrazovne programe. Putem intervjua i analiza procijenili smo učinkovitost uključivanja zelenih i digitalnih tema (ambijentalno potpomognut život i industrija 4.0) u obrazovne programe o znanosti o drvu i drvnoj tehnologiji u različitim europskim zemljama. Naše istraživanje otkrilo je razlike u vertikalnom usklađivanju unutar zemalja i odstupanja među sličnim programima u različitim zemljama. Uz pomoć neizrazite logike i primjenom analize omeđivanja podataka procijenili smo tehničku učinkovitost programa u uključivanju tih tema u nastavu s obzirom na više čimbenika. Rezultati su pokazali različite razine izvedbi, pri čemu se uvođenjem nekih programa postiže optimalna učinkovitost, a drugi zaostaju za njima. Kako bi se poboljšali programi s lošom*

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izvedbom, najvažnije je dati prioritet integraciji tema. Za uspostavu kohezivnog sustava nužni su nacionalna koordinacija i usklađivanje među obrazovnim razinama. Osposobljavanje pojedinaca za te kompetencije omogućuje im da pridonose održivom razvoju, iskoriste digitalne tehnologije i zadovolje društvene zahtjeve.

KLJUČNE RIJEČI: *znanost o drvu i drvna tehnologija; obrazovanje; zeleno; digitalno; DEA*

1 INTRODUCTION
1. UVOD

The increasing environmental and other challenges have raised significant concerns (European Commision *et al.*, 2016; Campbell-Johnston *et al.*, 2020; Pędzik *et al.*, 2021) prompting countries to develop a range of policies, strategies, and actions, such as the Sustainable Development Goals (SDGs) (Baeyens and Goffin, 2015). In line with these efforts, the European Commission (EC) has identified its primary priorities for the period of 2019-2024, among which it is also the European Green Deal (von der Leyen, 2019). The bioeconomy plays a crucial role in the attainment of the goals set forth by the European Green Deal by sustainable utilization of biomass (European Commission, 2012). The wood-based industry is one of the conventional bioeconomy industries strongly connected to forestry-based industries and can help address many environmental challenges. (MGRT, 2021). It is a very important EU economic sector and covers a range of forestry downstream activities (Scarlat *et al.*, 2015). Efficient utilization of wood to meet the growing demands for wooden products and wood-based composites is a central tenet of the circular economy (Janiszewska *et al.*, 2016; Antov *et al.*, 2021). Companies can further advance this principle by embracing digitalization to optimize processes, enhance the responsible use of raw materials, improve waste management practices, and contribute to sustainable, environmentally friendly development (Watanabe *et al.*, 2019). However, the successful implementation of the digital and green transition hinges on the knowledge and skills of employees within organizations. Without the appropriate expertise, organizations may encounter difficulties in adopting and integrating sustainable and digital practices (Kropivšek and Zupančič, 2016; Koch *et al.*, 2022). Therefore, it is imperative for the education system to adapt by enriching curricula, which can also affect teaching formats and methods. As part of the preparation and planning of educational programmes, an important step involves examining the current state (Ličen, 2015). However, when analyzing and comparing the current state of educational programmes from different countries, one must consider that education, training, and qualification systems vary across them due to their intricate dynamics between the states, the labour market, and employers (Mikulec and Ermenc, 2016), and recognize that education development is interconnected with the broader economy (Mingat and Tan, 1988).

European Qualifications Framework (EQF) is a European instrument designed to enable the comparability of qualifications in European countries and is intended for all types and categories of qualifications, from general and vocational qualifications to higher education qualifications, and also qualifications obtained in a non-formal or informal context (Mikulec and Ermenc, 2022), and thus a comparison between countries that have adopted the EQF is possible. To consider multiple factors, e.g. when studying outputs of education, data envelopment analysis (DEA) can be used for frontier-efficiency analysis.

The concept of frontier-efficiency, which explores the connection between inputs and outputs initially introduced by Farrell (1957) gained substantial recognition following the seminal work of Charnes, and Rhodes (1978). Since then numerous studies have been conducted to measure the efficiency using DEA, including those focusing on educational institutions, where DEA has emerged as the most widely used technique (Zuluaga-Ortiz *et al.*, 2022), because of the ability to offer a mathematical solution for calculating efficiency, particularly in situations where organizations contend with multiple inputs and outputs (Moore, 2021). However, assessing the efficiency of educational institutions and determining the value of numerous inputs and outputs can be challenging. Moreover, there is no definitive study providing clear guidance on the selection of inputs and outputs for evaluating the efficiency of education (Joumady and Ris, 2005). This complexity underscores the need for careful consideration and contextual understanding when applying methods like DEA to measure the efficiency of education. Different authors study the relative efficiency of education from various angles. For instance, many studies have relied on the outcomes of standardized tests as indicators, with a majority utilizing the results from the Programme for International Student Assessment (PISA) (Henriques *et al.*, 2022) conducted by the Organization for Economic Co-operation and Development (OECD). Giambona *et al*. (2011) employed the results of PISA 2006 as outputs to examine the efficiency of educational systems in EU countries, considering the educational resources accessible at home and students' family background. Similarly, Henriques *et al*. (2022) studied the efficiency of secondary schools using PISA data. Some other studies have employed the results from standardized tests typically administered at the conclusion of students' studies (Zuluaga-Ortiz *et al.*, 2022). This implies that there are various factors, or perspectives related to efficiency of education, which indicates and confirms that the efficiency of education is not consistent or uniform across all contexts or situations.

As education plays a vital role in shaping individuals and preparing them for the challenges of the future, our research endeavours to investigate the extent to which green and digital topics are integrated into wood science and technology educational programmes across various European countries. Through interviews and rigorous analysis, our aim is to assess the inclusion of these topics at different educational levels, considering the macroeconomic and institutional context as well as other factors in the countries under study. Through our examination of the relative efficiency of these programs, our aim is to gain a comprehensive understanding of the current educational landscape. By identifying areas for improvement, we hope to contribute to informed decision-making and the advancement of educational practices in this field.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

The methodology chapter of our study is divided into three parts. In the first part, the data collection process is described, detailing how the data was gathered. The second part focuses on the data processing procedures, explaining the steps taken to organize and prepare the data for analysis. Lastly, in the third part, the DEA method is introduced, employed to assess the efficiency of various educational programmes.

2.1 Data collection
2.1. Prikupljanje podataka

To evaluate the inclusion of specific green and digital topics in wood science and technology educational programmes, remote interviews were conducted with teachers and relevant individuals from educational institutions, which have a holistic view of the studied educational program. The interviews gathered data on the level of inclusion of content in teaching, focusing on green and digital topics, where digital topics were further divided into industry 4.0 (I4.0) and ambient and assisted living (AAL) subtopics (Table 1). The interviews were conducted over six months in years 2021 and 2022, as part of the ALLVIEW project, spanning various educational levels, including upper national diploma (EQF 4), higher national diploma (EQF 5), bachelor's degree (EQF 6), and master's degree (EQF 7), in seven European countries. It is important to note that the presented results reflect the situation in a single institution within each country, although the same or similar programs are offered in multiple locations within the same country.

2.2 Data processing
2.2. Obrada podataka

Based on the findings from the conducted interviews, we were able to determine the level of inclusion

Table 1 List of topics by areas
Tablica 1. Popis tema prema područjima

Green topics *Zelene teme*	**Industry 4.0 topics** *Teme o industriji 4.0*	**Ambient and assisted living topics** *Teme o ambijentu i potpomognutom životu*
Eco Design / *ekodizajn* Cascading use / *kaskadna uporaba* Natural resource management *upravljanje prirodnim resursima* Renewable energy sources *obnovljivi izvori energije* Sustainable production / *održiva proizvodnja* Environmental effects / *ekološki učinci* Circular business models / *kružni poslovni modeli* Industrial symbiosis / *industrijska simbioza* Biotechnology / *biotehnologija* Systemic thinking / *sistemsko razmišljanje* Wood residues to energy / *drvni ostatci i energija* Biorefinery / *biorafinerija* Green chemicals / *zelene kemikalije* Bioeconomy / *bioekonomija* Functional materials / *funkcionalni materijali* LCA analysis / *LCA analiza* Collection and recycling / *prikupljanje i recikliranje* Transparency in supply chains / *transparentnost u opskrbnim lancima* Hazardous chemicals / *opasne kemikalije* Green public procurement / *zelena javna nabava* Nano technology / *nanotehnologija*	Cross Reality *križna stvarnost* Cloud computing *računalni oblak* Online security *online sigurnost* Internet of Things *internet stvari* Simulations / *simulacije* Autonomous robots *autonomni roboti* Big data *velike baze podataka* Additive production *aditivna proizvodnja* Artificial intelligence *umjetna inteligencija*	Smart buildings / *pametne zgrade* Smart furniture / *pametni namještaj* Ergonomic interior design *ergonomski dizajn interijera* Sensors / *senzori* Fire and other safety *protupožarna i druga zaštita*

of individual topics within each respective educational program across different countries. These results allowed us to calculate the average representation of fully included, partially included, and not included topics within Green, I4.0 and AAL areas.

2.2.1 Fuzzy logic model
2.2.1. Model neizrazite logike

To optimize the data for DEA analysis, a 10-point fuzzy scale was devised to classify the three areas (green, I4.0 and AAL) of the individual educational programmes under study, using fuzzy set theory, introduced by Zadeh (1965). Fuzzy logic can deal with imprecise information as an element x can only partially belong to a fuzzy set A. The degree of membership of x in A is determined by the value of a membership function $u_A(x)$, which ranges from 0 to 1. For our model, linear membership functions were chosen with triangular and trapezoidal shapes because they are well suited and easy to implement (Carbajal-Hernández *et al*., 2012).

The objective of the fuzzy logic model was to aggregate the proportions of not included, partially included, and fully included aspects of individual areas and educational programmes into a unified score. The construction of the fuzzy logic model involved four phases. First, the fuzzy logic inference system (FIS) (Carbajal-Hernández *et al*., 2012; Jamshidi *et al*., 2013) was constructed. The membership functions for

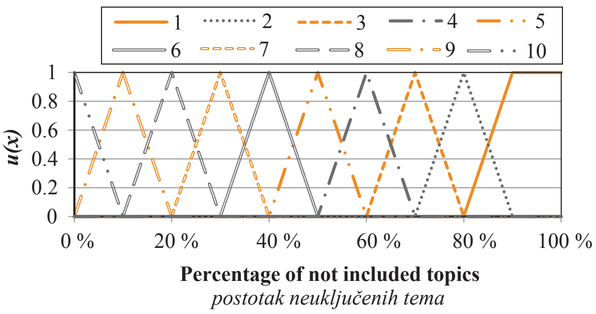

Figure 1 Membership functions for percentage of not included topics
Slika 1. Funkcije članstva za postotak neuključenih tema

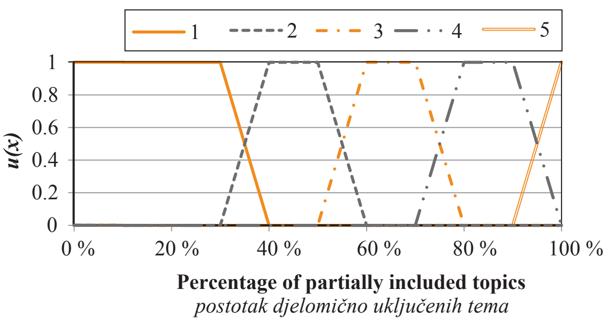

Figure 2 Membership functions for percentage of partially included topics
Slika 2. Funkcije članstva za postotak djelomično uključenih tema

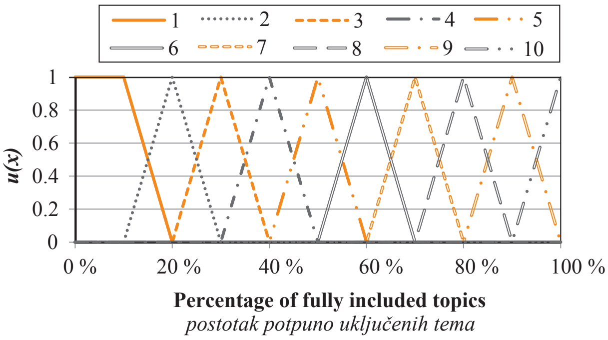

Figure 3 Membership functions for percentage of fully included topics
Slika 3. Funkcije članstva za postotak potpuno uključenih tema

not included, partially and fully included topics were determined and are shown in Figures 1-3.

To reduce the negative interference between the parameters of the partially and fully included areas, the FIS was divided into two separate parts. Part *a* aggregates not included and partially included areas, while part *b* aggregates not included and fully included areas. The Mamdani-type inference system (Mamdani and Assilian, 1975) with intuitive rules and imitation of human reasoning (Che Osmi *et al*., 2016; Kovac *et al*., 2012) was selected. Then, the membership functions were defined for all three areas. In the following phase, IF-THEN decision rules were established. The basic fuzzy operations employed were intersection (AND) $u_{A\cap B}(x) = \min(u_A(x), u_B(x))$ and union (OR) $u_{A\cup B}(x) = \max(u_A(x), u_B(x))$. The areas were aggregated using the max-min composition of membership functions:

$$u_c(z) = \max(\min(u_A(x), u_B(y))) \tag{1}$$

Where u_C, u_A, and u_B are membership functions of the output z and inputs x and y, respectively. Table 2 presents the possible combinations of IF-THEN rules, e.g., IF topics are absent in the given area at most 20 % and are at least 80 % fully included, THEN, the resulting fuzzy score is 8.

The third phase encompassed the defuzzification process to convert the aggregated fuzzy sets into crisp values. The centre of maximum was chosen as one of the most commonly used defuzzification methods (Pathak *et al*., 2005; Ross, 2004), which calculates the weighted mean of the centres of areas x_k and the membership functions $k=1,..., n$ (Eq. 2):

$$x^* = \frac{\sum_{k=1}^{n} x_k u_{Ck}(x)}{\sum_{k=1}^{n} u_{Ck}(x)} = \frac{1\,u_1(x) + 2\,u_2(x) + \cdots + 10\,u_{10}(x)}{u_1(x) + u_2(x) + \cdots + u_{10}(x)} \tag{2}$$

Both parts *a* and *b* were analysed independently in all phases until a crisp value x^*_a and x^*_b were obtained. In phase 4, the individual scores were combined using equation 3, resulting in a final classification represented by x^*_{ab} on a 10-point scale. The final scores represent the outputs in our DEA model, as shown in Table 3.

$$x^*_{ab} = (x^*_a + x^*_b) - 1, \tag{3}$$

Table 2 IF-THEN rules of fuzzy inference system *a* and *b*
Tablica 2. IF-THEN pravila neizrazitih sustava zaključivanja *a* i *b*

10-point fuzzy scale *Neizrazita skala od deset točaka*	**FIS *a***		**FIS *b***	
	Not included *Nije uključeno*	**Partially included** *Djelomično uključeno*	**Not included** *Nije uključeno*	**Partially included** *Djelomično uključeno*
10	0 %	/	0 %	100 %
9	10 %	/	10 %	90 %
8	20 %	/	20 %	80 %
7	30 %	/	30 %	70 %
6	40 %	/	40 %	60 %
5	50 %	100 %	50 %	50 %
4	60 %	80-90 %	60 %	40 %
3	70 %	60-70 %	70 %	30 %
2	80 %	40-50 %	80 %	20 %
1	90-100 %	0-30 %	90-100 %	0-10 %

2.3 Data envelopment analysis (DEA)
2.3. Analiza omeđivanja podataka (DEA)

DEA involves using linear programming for measuring the efficiency of decision making units (DMUs), which convert multiple inputs into multiple outputs (Coelli *et al*., 2005). The DEA method is based on the concept of Pareto efficiency, which states that the full efficiency of a DMU is achieved when the value of none of the inputs or outputs can be improved without reducing the value of any other input or output.

The model chosen for this study is based on constant returns to scale (CRS) with output orientation that focuses on maximizing outputs while holding inputs constant, following the notation adopted by Johnes (2004). The choice of orientation is not as crucial in education as it is in econometric estimations (Coelli and Perelman, 1999). In the context of our study, where the efficiency of topics inclusion in teaching is examined based on inputs over which educational institutions have less control, an output orientation is more appropriate. Each of n DMUs requires m different inputs to produce s different outputs. Specifically, DMU k requires x_{ik} units of input i and produces y_{rk} units of output r. Here, it is assumed that each DMU has at least one positive input and one positive output. In output-oriented DEA model, the linear program has a multiplicative form and aims to maximize the weighted sum of outputs (Eq. 4), while keeping the values of the inputs constant (Eq. 6). The technical efficiency of DMU k is denoted by θ_k, and the linear program has $n+1$ constraints (Eqs. 5, 6).

$$\max\ \theta_k = \sum\nolimits_{r=1}^{s} u_r y_{rk} \tag{4}$$

Subject to:

$$\sum\nolimits_{i=1}^{m} v_i x_{ij} - \sum\nolimits_{r=1}^{s} u_r y_{rk} \geq 0 \qquad j = 1,\ldots,n \tag{5}$$

$$\sum\nolimits_{i=1}^{m} v_r x_{ik} = 1 \tag{6}$$

$$u_r, v_i, x_{ik}, y_{rk} \geq 0 \qquad \forall_r = 1,\ldots,s; \qquad i = 1,\ldots,m \tag{7}$$

2.3.1 Inputs and outputs for DEA analysis
2.3.1. Ulazi i izlazi za DEA analizu

As previously mentioned, the outputs consist of inclusion level for individual content areas (green, I4.0, AAL) within various educational programmes across different EU countries. These levels were determined through the fuzzification of interview results, mentioned above.

Since education development does not occur in isolation from the rest of the economy, our inputs were based on macroeconomic and other indicators related to our outputs, that reflect unique characteristics of each country. Therefore, the inputs used in this study include (1) country's GDP per capita (European Commission, 2022b), as countries with higher economic development often invest in improving educational standards and curriculum, (2) annual expenditure per student on educational institutions (OECD, 2021), as increased funding also contributes to offering a comprehensive and enriching learning experience, (3) digitalization level of the country (European Commission, 2022a), as the impact of digitalization on education mirrors the digital progress in the country, (4) index for digital lifelong learning readiness (Centre for European Policy Studies, 2019), as aging population in the EU is steadily increasing, (5) value added per employee in C16 (wood processing – except furniture) + C31 (manufacture of furniture) (Ronzon *et al*., 2022), as it can have a positive effect by providing opportunities for investments in developing business and educational infrastructure and technology, (6) country's greenhouse gas emissions per capita (European Environment Agency, 2022), as inclusion of green topics in the curriculum becomes more important as emissions rise, and lastly, (7) the level of topic inclusion in the lower educational programmes is considered, as inclusion level should increase along the educational vertical.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Table 3 highlights disparities in topic inclusion among countries, even within the same educational level, pointing to inconsistencies in educational verticals within each country. However, it is important to note that our findings are based on a single institution per program in each country, and educational programmes may have unique objectives. While the importance of including these topics may vary, EU guidelines emphasize the significance of sustainable and digital competences for future students. As a result, all educational programmes will need to adapt at some point, although the extent of this adaptation remains uncertain.

Table 3 shows significant variations in input values among countries. Poland has the lowest GDP per capita, while the Netherlands has the highest. Annual expenditure per student is lower in vocational education compared to higher education across all countries, with Poland and Slovenia having the lowest. The Netherlands has the highest annual spending per student in higher education and ranks highest in digital lifelong learning readiness and digitization levels. Germany has the lowest score in digital lifelong learning readiness, and Italy has the lowest digitization level. Belgium has the highest value added per employee in the C16 and C31 sectors, while Poland has the lowest. Poland also has the highest greenhouse gas (GHG) emissions per capita, while Spain has significantly lower GHG emissions per capita.

When determining the average inclusion level from a lower EQF level, two assumptions were made. First, it was assumed that students in each country at a specific EQF level possess prior knowledge from a lower level, as studied in this research. Second, it was assumed that students have no prior knowledge before entering EQF 4.

Figure 4 illustrates the technical efficiency of individual DMUs using DEA. Among the 23 DMUs in our study, 10 are identified as fully efficient in including green, I4.0 and AAL topics in teaching, based on given inputs. These include EQF 6 and 7 in Slovenia, EQF 4 in Belgium, Germany, and Spain, EQF 6 in Ger-

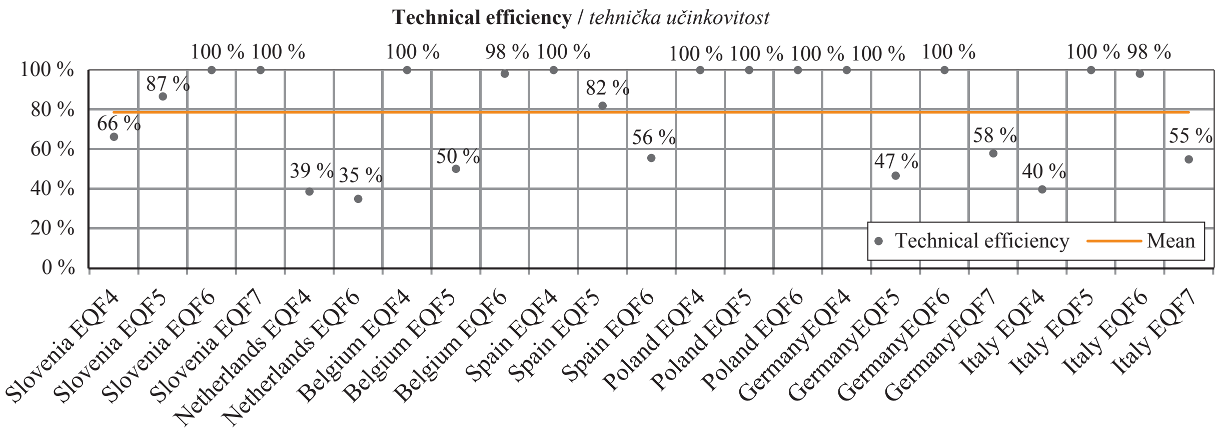

Figure 4 Efficiency of different educational programmes across various institutes in studied countries
Slika 4. Učinkovitost različitih obrazovnih programa u različitim institucijama promatranih zemalja

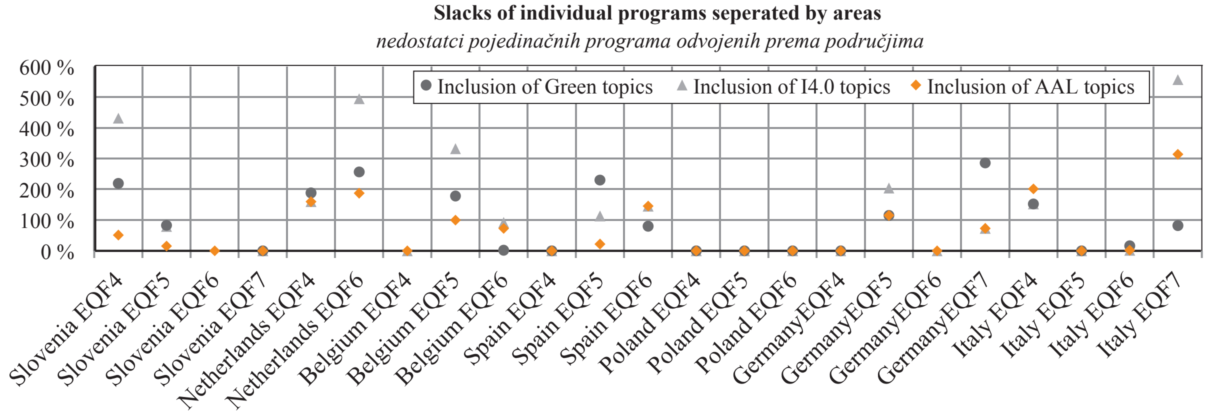

Figure 5 Slacks of areas in individual DMUs, to reach full efficiency
Slika 5. Nedostatci područja u pojedinačnim DMU-ovima kako bi se postigla potpuna učinkovitost

Table 3 Level of inclusion of different topics in wood science and technology educational programmes across different countries, used as representation of outputs and values of the inputs for DEA
Tablica 3. Razina uključenosti različitih tema u obrazovne programe za znanost o drvu i drvnu tehnologiju u različitim zemljama koja služi kao prikaz izlaznih rezultata i ulaznih vrijednosti za DEA

DMUs		**Outputs** / *Izlazi*			**Inputs** / *Ulazi*						
Country *Država*	Level of education *Razina obrazovanja*	Inclusion level of green topics *Razina uključenosti zelenih tema*	Inclusion level of Industry 4.0 topics *Razina uključenosti tema industrije 4.0*	Inclusion level of ambient and assisted living topics *Razina uključenosti tema o ambijentu i uzdržavanju*	Country's GDP per capita, € *BDP zemalja po stanovniku, €*	Annual expenditure per student on educational institutions, $ *Godišnji izdatci po učeniku u obrazovnim institucijama, $*	Score for digital lifelong learning readiness, Index *Ocjena spremnosti za digitalno cjeloživotno učenje, indeks*	Digitalization level, Index *Stupanj digitalizacije, indeks*	Value added per employee in C16 + C31, € *Dodana vrijednost po zaposleniku u C16 + C31, €*	Greenhouse gas emissions per capita *Emisije stakleničkih plinova po stanovniku*	Average inclusion of all 3 topics from lower EQF level *Prosječna uključenost svih triju tema s niže EQF razine*
Slovenia	EQF 4	2.00	1.54	4.00	21260	9772	0.60	53.5	29471	7.6	1.00
	EQF 5	2.69	2.70	6.00	21260	9772	0.60	53.5	29471	7.6	2.51
	EQF 6	7.14	7.00	10.00	21260	14060	0.60	53.5	29471	7.6	3.80
	EQF 7	9.05	7.78	10.00	21260	14060	0.60	53.5	29471	7.6	8.05
Netherlands	EQF 4	2.24	3.13	3.00	41860	14726	0.68	67.3	65798	9.8	1.00
	EQF 6	2.24	1.33	4.00	41860	20898	0.68	67.3	65798	9.8	2.79
Belgium	EQF 4	6.63	6.67	10.00	35850	14758	0.57	50.4	77448	9.5	1.00
	EQF 5	2.38	1.54	5.00	35850	14758	0.57	50.4	77448	9.5	7.77
	EQF 6	7.21	4.44	4.00	35850	20471	0.57	50.4	77448	9.5	2.97
Spain	EQF 4	6.67	7.00	7.00	23510	10290	0.63	60.7	38212	5.9	1.00
	EQF 5	2.00	2.66	6.00	23510	10290	0.63	60.7	38212	5.9	6.89
	EQF 6	3.80	2.66	3.00	23510	13800	0.63	60.7	38212	5.9	3.55
Poland	EQF 4	6.24	10.00	5.00	13580	8220	0.57	40.5	19445	10.0	1.00
	EQF 6	7.00	6.00	8.00	13580	11192	0.57	40.5	19445	10.0	7.08
	EQF 7	7.00	6.00	8.00	13580	11192	0.57	40.5	19445	10.0	7.00
Germany	EQF 4	6.24	2.70	5.00	35480	13926	0.50	52.9	55036	8.9	1.00
	EQF 5	3.00	2.00	4.00	35480	13926	0.50	52.9	55036	8.9	4.65
	EQF 6	7.14	6.67	7.00	35480	19324	0.50	52.9	55036	8.9	3.00
	EQF 7	1.76	4.22	4.00	35480	19324	0.50	52.9	55036	8.9	6.94
Italy	EQF 4	2.24	2.56	2.00	26700	11962	0.51	49.2	43598	6.5	1.00
	EQF 5	6.05	7.78	3.00	26700	12305	0.51	49.2	43598	6.5	2.26
	EQF 6	6.00	7.00	6.00	26700	12305	0.51	49.2	43598	6.5	5.61
	EQF 7	4.14	1.00	2.00	26700	12305	0.51	49.2	43598	6.5	6.33

Table 4 Ranks of DMUs by level of inclusion (before DEA) and by efficiency ranks (after DEA)
Tablica 4. Poredak DMU-ova prema razini uključenosti (prije DEA) i rangu učinkovitosti (nakon DEA)

DMUs		**SUM level of inclusion** *SUM razina uključenosti*	**Rank by SUM** *Poredak prema SUM razini*	**DEA efficiency** *DEA učinkovitost*	**Rank by DEA efficiency** *Poredak prema DEA učinkovitosti*
Country *Država*	**Level of education** *Razina obrazovanja*				
Slovenia	EQF 4	27	1	66 %	5
	EQF 5	24	2	87 %	3
	EQF 6	23	3	100 %	1
	EQF 7	21	4	100 %	1
Netherlands	EQF 4	21	4	39 %	12
	EQF 6	21	4	35 %	13
Belgium	EQF 4	21	4	100 %	1
	EQF 5	16	7	50 %	9
	EQF 6	21	4	98 %	2
Spain	EQF 4	19	5	100 %	1
	EQF 5	17	6	82 %	4
	EQF 6	14	8	56 %	7
Poland	EQF 4	11	9	100 %	1
	EQF 6	9	11	100 %	1
	EQF 7	11	9	100 %	1
Germany	EQF 4	10	10	100 %	1
	EQF 5	9	11	47 %	10
	EQF 6	8	13	100 %	1
	EQF 7	8	13	58 %	6
Italy	EQF 4	7	14	40 %	11
	EQF 5	8	13	100 %	1
	EQF 6	7	14	98 %	2
	EQF 7	9	12	55 %	8

many, EQF 5 in Italy, and all studied EQFs (4, 5, and 6) in Poland. The average efficiency across all DMUs is 79 %, and in addition to the fully efficient units, 4 other units perform above the average. However, there are nine educational programmes from various countries that demonstrate below-average performance levels. Some of these programs exhibit an efficiency of 40 % or even lower. To enhance their efficiency, the institutions where these programs were studied should significantly increase the inclusion of these topics. For example, educational institution, where the data for the EQF 4 and 5 were obtained in the Netherlands, should increase inclusion of these topics by 61 % in EQF 4 and by 65 % in EQF 5. These two EQFs were identified as the least efficient in our study.

Figure 5 provides a visual representation of the slacks for individual areas within studied DMUs. By incorporating topics from these areas more extensively in teaching, DMUs have the potential to enhance their performance and approach the efficiency frontier. It is notable that less efficient DMUs (Figure 4) tend to exhibit more significant slacks (Figure 5). It becomes apparent that the largest slacks are commonly observed in domain of industry 4.0.

Table 4 shows that the ranking changes when additional conditions are also included in the DEA as inputs. For example, EQF level 4 in Slovenia landed in first place based on content inclusion, but after the DEA analysis, when additional conditions were considered, it only showed 66 % efficiency and dropped significantly in the ranking. It was different with EQF 5 and 6 in Italy. After considering content inclusion alone, these two programs achieved last and second-to-last position in the ranking. However, after applying DEA analysis, they achieved exceptional efficiency and moved up to the 1st (EQF 5) and 2nd (EQF 6) position. This highlights the significance of considering multiple conditions, particularly in cross-country comparisons, during research of this nature.

4 CONCLUSIONS
4. ZAKLJUČAK

The increasing importance of sustainable and digital competences is playing a pivotal role in shaping a promising future. To realize this vision, it is vital to integrate these subjects into educational curricula, equipping future students with the necessary knowledge and skills. As an initial stride in exploring this domain, the inclusion of specific content in wood science and technology educational programmes has been assessed in various EU countries. As education systems in different countries vary in terms of conditions and opportunities for improving educational standards and curriculum, the efficiency of individual educational programmes in incorporating green and digital topics into teaching were further analysed, considering other relevant factors in the countries under study. Taking into account multiple factors has demonstrated its significance, particularly when conducting cross-country comparisons.

In conclusion, the findings of our research reveal significant disparities in the inclusion of green, industry 4.0, and ambient assisted living topics within wood science and technology educational programmes across different countries and educational levels. Moreover, the application of Data Envelopment Analysis (DEA) in assessing technical efficiency highlights notable disparities among programs in effectively incorporating these topics into teaching. While some programs have attained full efficiency, demonstrating optimal performance based on our selected inputs, others exhibit suboptimal levels of performance. To improve the efficiency of underperforming programs, it is crucial for the responsible institutions to prioritize the incorporation of these topics in teaching. Additionally, the calculation of slacks offers valuable insights into specific areas where certain educational programmes fall behind in the inclusion of individual topics. This analysis provides a detailed understanding of the deviations in comparison to other programs examined in our research.

In summary, our research highlights the imperative for comprehensive inclusion of green, I4.0, and AAL topics in educational programs. It is crucial to coordinate this effort at the national level, ensuring alignment across all levels of education. By doing so, a cohesive and well-rounded educational system can be fostered that effectively addresses these important topics. By equipping individuals with these essential competences, they are empowered to contribute to sustainable development and effectively leverage digital technologies to drive innovation and progress. This serves as a catalyst for building a resilient and adaptable workforce, equipped with the necessary skills to tackle the evolving demands of our society.

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