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Determining Learning Outcomes Relevant for Logistics Higher Education on Sustainability and Industry 4.0

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Abstract: The ambitious goals of the European Union require companies to transform themselves into sustainable and smart. To do so, for example, in the logistics field, employees who will know how to implement green transport and logistics and how to establish smart systems based on a higher level of digital maturity are needed. This article lists 51 essential topics from Sustainability, Industry 4.0, Logistics 4.0, and Digitalisation areas, further supported by 127 unique learning outcomes gathered through a multi-stage international Delphi study including practitioners and academics. Experts from 6 countries participating in the study first identified the most important topics from the field and the connected learning outcomes in the following rounds, and consequently achieved consensus on the most important learning outcomes that the future workforce in the logistics sector should have. Supporting the logistics sector with a workforce educated based on this framework should help it reach the European Union's strategic goals.

Keywords: digitalisation; higher education; Industry 4.0; learning outcomes; logistics; sustainability

1 INTRODUCTION

Among the six defined priorities for 2019-2024 of the European Commission are a European Green Deal, digital transformation, and empowering people with the skills necessary for a new generation of technologies [1]. The goal of the European Commission is also to assist all industrial sectors in harnessing emerging technologies and facilitating the shift towards an intelligent Industry 4.0 industrial system [2]. In order to achieve the European Union's stated mission, companies will need to focus on sustainability, digitalisation, and Industry 4.0. The growing need to develop these areas is also reflected in the scientific literature, as briefly summarised below.

The heightened awareness of economic, environmental, and social issues has brought sustainability into the spotlight. As a result, customer purchasing behaviours have shifted towards sustainable products from companies that prioritise eco-friendliness, social welfare, and financial prosperity. This shift has motivated supply chains to prioritise sustainability initiatives and Industry 4.0 technologies [3,4].

Sustainable development refers to creating solutions that satisfy society's current needs without compromising future generations' ability to meet their own needs [5]. The three sustainability dimensions, environmental, economic, and social, are frequently discussed in the literature [6,7]. Achieving balance in these processes is crucial for businesses to be sustainable and prosperous. However, due to these dimensions' intricate nature and interdependence, attaining this balance and success can be challenging [8].

Industry 4.0 was frequently mentioned after 2010 as essential to Germany's Action Plan High-tech Strategy 2020 [9] and represents the 4th Industrial Revolution. Although Industry 4.0 has substantially impacted the industry since its emergence, especially in the manufacturing sector, the current priorities are focused on the digital transformation of the economy. In practice, companies have a low level of digital maturity, which is a prerequisite for their active participation in Industry 4.0.

Hermann et al. [10] defined Industry 4.0 as a set of technologies and ideas related to organising the value chain that emerged during the fourth industrial revolution. The core components of Industry 4.0, according to the authors, are Cyber-physical systems (CPSs), Internet of Things (IoT), Internet of Services (IoS), and Smart Factory, along with design principles such as interoperability, virtualisation, decentralisation, real-time capability, service orientation, and modularity. The fundamental goal of the Industry 4.0 movement is to provide factories and businesses with strategic tools for offering new types of services and business models, revolutionising the concept of the production chain, and progressively transforming traditional factories into smart factories [11,12]. Although only some companies are mature enough to implement Industry 4.0, there is already talk of Industry 5.0. Industry 5.0 is a new concept that aims to combine the strengths of machines and human experts to improve the manufacturing industry. It is expected to bring back the human touch to manufacturing by combining the critical thinking of humans with the high speed and accuracy of machines. Industry 5.0 will enable mass personalisation, increase manufacturing efficiency and improve production quality. Collaboration between people and machines will lead to high-speed production, where repetitive tasks are assigned to machines, and critical thinking tasks are assigned to people [13].

All concepts mentioned above are also relevant to logistics, which is the focus of this article. Sustainable logistics is a vital sub-component of the Green Supply Chain Management (GSCM) process, a popular topic in recent decades due to globalisation, market competition, customers' demands, and the exploration of new markets [14]. On the other side, the advancements in Industry 4.0 technologies have brought about benefits in logistics operations, resulting in the emergence of Logistics 4.0. This leads to improved efficiency in logistics activities, such as transportation, inventory management, and material handling [15].

To effectively implement sustainability, Industry 4.0, and digitalisation concepts in reality, competent employees are needed. Logistics students and other logistics participants need to understand and be able to implement sustainability, Industry 4.0 technologies and digitalisation to meet future challenges in logistics.

Logistics students or employees in the logistics sector often overlook sustainable development issues because they primarily focus more on the engineering aspects of logistics. However, this is not following modern development of the logistics field and Logistics 4.0 initiatives [16]. In order to get a sufficient number of logistics graduates that will be well-versed future sustainability leaders, HEIs need to improve learning experiences [17] and monitor the needs of the economy and adapt the curricula and learning outcomes that students need to acquire.

Recognising the significance of integrating sustainability subjects into education, including higher education, has been extensive [18]. As Leich and co-authors [19] claim, education is the starting point for helping students to engage with sustainability-related issues and become change-makers. Teaching only from an economic perspective or promoting only economic growth can potentially lead to unsustainable consumption patterns. Sustainability needs to be integrated into the educational process horizontally, especially content aimed toward systemic and holistic thinking based on the principles and approaches of sustainable development [20].

Besides understanding sustainability, it is important for logisticians to continually enhance their knowledge and stay up-to-date with recent innovations [21] and with concepts of Industry 4.0. From this point of view, it is necessary to update educational content with sustainability, Industry 4.0, and digitalisation content, and establish lifelong education [22]. Short educational programs accessible to logistics students and logistics sector employees would also be welcome.

However, an analysis of the literature on Industry 4.0 education and institutional innovation suggests that there are limited studies that systematically examine the crucial institutional factors required for an Industry 4.0 response toward educational innovation, change, or reform [23]. Boston Consulting Group [24] summarises the nine pillars of Industry 4.0 that need to be addressed in educational programs: advanced robotics, additive manufacturing, augmented reality, simulation, horizontal/vertical integration, industrial internet, cloud, cybersecurity, big data, and analytics. Romero-Gazquez and co-authors [22] developed a specific module for teaching the basic concepts of Industry 4.0, which includes the following thematic fields: autonomous robots, simulation, system integration, internet of things, cybersecurity, cloud computing, additive manufacturing, augmented reality, and big data. Some managerial and technological implications that present themselves when sustainability and circular economy are at the forefront were defined by Khan and co-authors [25] as digital platforms, e-learning solutions, artificial intelligence, and machine vision. Various models have been suggested for sustainability competencies, and the framework proposed by Wiek and co-authors [26] for key competencies in sustainability is one of the most frequently cited. Burndiers and co-authors [27] did a Delphi study to provide insights into a consensus statement on critical sustainability competencies. The research aimed to promote sustainability and related programs at higher education institutions across the United States.

Two critical questions should be addressed when deciding on a curriculum position or focus, independent of the field of study. The first is, "What are the main takeaways for students regarding knowledge and understanding from this course? What content counts, then?" The second question is, "How should it be taught?" [28]. Considering the first question and the definition of learning outcomes described below, it is essential to focus on learning outcomes that are important for sustainable logistics and Industry 4.0. Learning outcomes are statements about what the student should know, understand and be able to demonstrate after completing the learning process. Learning outcomes focus on the student's achievements and not only on learning content [29].

A scientific literature review was expected to not sufficiently describe which learning outcomes are relevant in connecting logistics with sustainability, Industry 4.0, and green, which was confirmed by the presented literature overview. This presents a research gap that needs to be overcome if educational efforts are to be designed to cater to the industry's needs and identified research highlights. The most significant contribution of the study is that it reveals learning outcomes that have been shown in practice to be necessary for working in Logistics 4.0 concerning sustainability. To the best of the authors' knowledge, this is the first time anyone has explored relevant learning outcomes in this area with a methodology that combines researchers, academics, and practitioners in a single study on an international level.

In order to find out which learning outcomes are essential for logistics students to cope successfully with future logistics challenges, a Delphi study was designed and undertaken with the final goal of identifying the topics and contributing learning outcomes referring to teaching sustainable logistics and Industry 4.0.

In the following chapters, the paper briefly summarises the main features of the Delphi studies that were followed in preparing the present study. A detailed description of the steps of the study itself follows. In the Results, we present which topics in logistics, sustainability, green, and Industry 4.0 experts consider important for students to listen to during their studies. The learning outcomes that emerged from the study as the most important are also presented. The paper concludes with findings and a conclusion.

2 METHODS AND METHODOLOGY

A Delphi study was designed to determine key and essential learning outcomes for logistics higher education on sustainability and Industry 4.0. The Delphi methodology is a valuable tool for researching the future of education as it can help to explore the underlying assumptions that lead to different judgments [30]. The Delphi method systematically combines opinions by a group of experts to reach a consensus on a complex problem [31] in an asynchronous way [32]. Structured anonymous communication among individuals is highlighted in the Delphi method [33]. It is valuable for scenarios where individual opinions must be gathered and consolidated to tackle a lack of consensus or an incomplete understanding of a subject [34].

The Delphi method is a group technique in which a researcher or research team brings together a panel of experts, presents questions, consolidates feedback, and guides the group toward a consensus. Unlike traditional survey methods that aim to determine means and generalise results across a population through online, in-person, or mail surveys, the Delphi method involves an iterative process similar to a long series of focus groups [35]. The outcome of a Delphi study is usually evidenced by the agreement among experts in a specific area where there was previously none [36].

The typical procedure involved in the Delphi process is as follows [32]: (1) identifying and defining the problem or topic to be addressed in the process, (2) designing the process from an operational perspective, (3) selecting experts to participate in the process, (4) creating a questionnaire that initially allows for open-ended responses but becomes progressively more restricted in subsequent rounds, (5) conducting at least two rounds of the process, evaluating the results after each round, and adapting the questionnaire in between rounds, (6) using the results to achieve a consensus on the topic.

A different variation of the Delphi method involves creating a questionnaire that permits respondents to provide comments alongside their answers. The questionnaire remains constant throughout all rounds of the Delphi process, but each subsequent round incorporates a summary of the experts' comments and reasoning for their responses. This allows experts to review and revise their opinions based on new arguments presented in the succeeding rounds of the Delphi process. Typically, this variation is carried out over two rounds [37].

The Delphi panel's makeup should not rely on random sampling or statistical sampling methods. Instead, it should be a deliberate choice based on the research question and consist of experts who are knowledgeable and reputable in the field of Delphi [38]. Furthermore, the panel's composition should be kept confidential from the participating expert panelists, and direct communication between them should be avoided. Panelists and their views should be fully anonymised [37]. After the first round of the Delphi process, which typically includes open-ended questions, the responses should be analysed using content analysis to consolidate them. Aggregation and synthesis can then be employed to generate input for the second round [38]. Despite being mainly qualitative, the Delphi method can also incorporate some quantification, particularly in the second and subsequent rounds. This can be achieved by using 5-point or 7-point Likert scales to gauge experts' opinions on statements derived from the initial open-ended questions [32].

2.1 Delphi Implementation to Elaborate Learning Outcomes Relevant for Logistics Higher Education on Sustainability and Industry 4.0

The study presented in this article was implemented as a part of the Erasmus+ project: Sustainable Logistics4.0: Digital and green skills for boosting innovation and sustainability of the logistics sector. It includes four universities: Politechnika Poznanska (Poland), Gaziantep Universitesi (Turkey), Universidade de Aveiro (Portugal), and University of Maribor (Slovenia), and three companies Valuedo srl (Italy), ECQA (Austria) and Zerynth srl (Italy).

Based on the research aims, a multi-round Delphi study was designed that began with open ended questions and progressed to more concrete outcomes in subsequent rounds. It had a national and an international level. Hence, two rounds on each level were sufficient for the desired level of consensus among the included experts. The first step for each round was selecting potential experts, followed by the questionnaire design. After the questionnaire design was finished and confirmed by all project partners, the round of Delphi was conducted. After individual rounds that included open-type questions, the researchers read and analysed the open-ended responses independently. The research team then discussed the responses to modify and consolidate each contribution. When using the Likert scale, the results were analysed with the use of descriptive statistics. The objectives of a particular Delphi round are presented in Fig. 1. Objectives and detailed implementation of the study are described in more detail below.

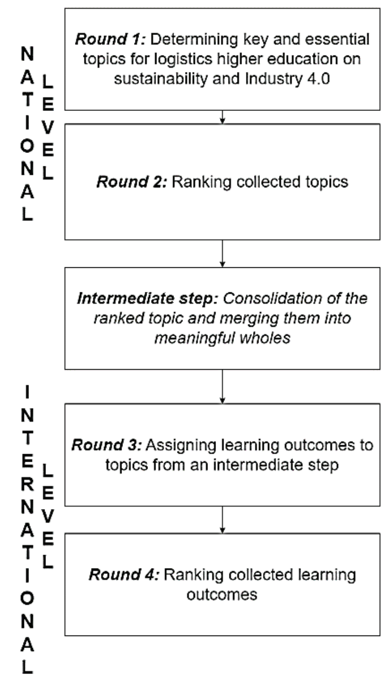

Figure 1 Delphi study process

2.2.1 Expert Panel

During the preparation phase, an international group of experts was gathered. The expert panellists were selected from academic and company representatives to ensure a broad consensus on the final results. Briedenhann and Butts [39] argue that including both professional and academic experts is essential for achieving a balance between different perspectives on knowledge and bridging the gap between research and professional communities in terms of knowledge sharing, communication, priorities, etc. The Delphi method does not require the expert panel to be representative regarding statistical sampling. Rather than the number of experts, the quality of the panel members determines their representativeness [35]. In addition, having a geographically diverse panel of experts was crucial for capturing a wide range of perspectives on the discussed topic.

Inclusion criteria mandated for the academics or teachers were that they had published at least two papers on logistics and/or sustainability in the last five (5) years or have taught a course from this field at least a high school level in the last five (5) years. Practitioners from companies were included in the case that they work for a company that provides logistics services or from companies that have logistically complex processes (e.g., a large production company). In all four rounds of the Delphi method, we included a sufficient number of experts (Table 1). In all four rounds, we included more practitioners than academics. Practitioners provided valuable insights into the needs of the economy. Participation in the Delphi study was completely anonymous.

Table 1 Number of experts included in expert panels

		Academics	Practitioners	Sum
National level	First round	32	36	68
	Second round	25	31	56
International level	First round	9	19	28
	Second round	7	9	16

2.2.2 Delphi Implementation

The research employed an online Delphi approach. The appeal of using the internet for communications and data collection was due to the time and cost savings it provided, which were particularly beneficial given the global nature of the study and the conventional constraints imposed on the Delphi methodology [40]. The Delphi approach used quantitative and qualitative questions, which have been demonstrated to improve research rigor [41].

2.2.3 National Level of the Delphi Study

Researchers from four universities individually performed the national level of the Delphi study. In this part, four expert panels were held in parallel: in Poland, Portugal, Slovenia, and Turkey. The process and questions for the panellists were the same for all panels to get quality input into the international round of the Delphi study. The questionnaires prepared were translated into the national languages. The recommendation given to all researchers was to prepare both an online and a Word version of the questionnaire and send both versions to participants to increase the chances of getting a response since some people prefer the modality of answering a questionnaire. The national-level expert panels have been implemented at different times - depending on the capacity to recruit panellists. Implementations occurred between 8th December 2022 and 15th January 2023.

The main idea behind the first round at the national level was to determine key and essential topics for logistics, sustainability, and Industry 4.0 and which will have to be taught in the future. Therefore, experts were asked open-ended questions. The analysis of the individual results was qualitative to extract all the topics of interest in a manner of potential teaching topics. In the second national round, the collected topics were ranked. Experts evaluated topics based on the importance of educating future logisticians. A 10-point Likert-type scale (not important at all – 1 score, essential – 10 score) was used to assess the participant's level of agreement. Each research group did a basic analysis of the results. Means and standard deviation were calculated for each topic regarding the importance ratings from the panellists. This presented the final conclusion of the national-level Delphi study.

All four inputs of the identified learning topics or course contents from the national level of Delphi were consolidated into a final list of proposed topics for the international round of Delphi. The consolidated topics were then input into the third round of Delphi, held at the international level of Delphi.

2.2.4 International Level of the Delphi Study

An international group of researchers performed the international round of the Delphi study. Panelists were experts from Slovenia, Poland, Portugal, Turkey, India, and Mexico. In Delphi round 3 (held between 3rd and 20th of February 2023), the experts were asked to propose the learning outcomes that students should achieve learning about a specific topic, where the input topics were the highest-rated topics from Delphi round 2 on the national level. Proposed learning outcomes by panelists were then consolidated and presented back to the panelists in the Delphi round 4 (held between 20th and 31st of March 2023). The panelists rated learning outcomes in Delphi round 4 according to the importance of learning outcomes. A 10-point Likert-type scale (not at all important – 1 score, very important/crucial – 10 score) was used to assess the participant's level of agreement. Means and standard deviation were calculated for each learning outcome regarding the importance ratings from the panellists. The final result of the Delphi on the international level is thus the list of essential learning outcomes for future logisticians.

3 RESULTS

The results are presented in two subsections, following the described Delphi methodology. First, the national study results are presented, and then the international study results present essential learning outcomes relevant to logistics higher education.

3.1 National Level of the Delphi Study

The consolidated list of topics from all four expert panels in national Delphi studies had 147 topics. Tab. 2 presents only consolidated and merged 19 topics that were found to be most relevant. The decision to present only the highest-rated topics was made because the list of topics was too extensive. As seen in the table, topics were divided according to the study areas of this article: digitalisation, Industry 4.0, and Sustainability. A specific topic for "green" was added because this is where most of the effort in the sustainability area is currently being invested. Another addition was the area of "basic knowledge" to see if the experts also proposed any topics related to the basic knowledge of logisticians. The most significant number of topics is from the field of digitalisation (7), followed by green (5). Three topics each have been identified in the teaching areas of Sustainability and Industry 4.0.

Table 2 Topics in the areas of logistics, sustainability, and Industry 4.0 that experts consider the most relevant

Topic	M	SD	Teaching Area
Human-Centric Digital Transformation	9.5	2.07	I4.0
SAP system	9.5	1.08	D
Information management. Construction of information models. Data analysis.	9.5	1.56	B
Reverse and green logistics	9.47	1.07	G
Green packaging/packaging	9.37	0.95	G
Digitalisation of document flows and transition to paperless logistics operation	9.33	1.18	D
Collection and processing of large amounts of data and analytics, knowledge of databases, advanced use of data editing and analysis programs (e.g., Excel)	9.33	0.85	D
Digitalisation of business operations, ERP, programs and applications to support logistics activities	9.33	0.94	D
Green storage	9.31	1	G
Green transport	9.31	1	G
Circular economy and waste management	9.26	0.99	S
Autonomous warehouse equipment	9.26	0.99	I4.0
Optimisation in logistics (process optimisation, routes, supply chains) to achieve sustainability goals, optimisation tools	9.08	1.26	S
Green purchasing	9.05	0.97	G
Autonomous solutions in logistics (storage, transport). Autonomous vehicles and means of internal transport	9	1.48	I4.0
Digitalisation of logistics processes	9	1.78	D
Database	9	1.56	D
Big data in order to, for example, profile the image of the customer or predictive analyses to examine the supply chain in order to minimise threats	9	2.08	D
Quality control	9	1.56	B
Disruptions, Risk Analysis & Mitigation Strategies	9	1.74	B
Environmental Impact of Logistics Operations Tools	9	2.01	S

*B – basic logistics knowledge, D – topics related to the Digitalisation, G – topics related to Green, I4.O – topics related to the Industry 4.0, S – topics related to Sustainability

Other relevant topics (evaluated with a mean value between 8.0 and 8.99) were topics about environmental ethics (S), emission calculation methods (S), product lifecycle analysis (S), 17 sustainable development goals (S), circular economy and waste management (S), sustainable warehousing and logistics (S), sustainable operations management (S), internet of things (D), virtual and augmented reality (I4.0), cybersecurity (D), digitalisation of communication (D), electronic documentation systems (D), data management (D), machine learning (I4.0), automation and robotics (I4.0), IoT Technologies (I4.0), connected information systems and collaborative platforms (D), route optimisation (B), simulation tools and procedures for simulation of logistics processes (B), logistics planning (B), production planning (B), logistic centres (B), reverse logistics (B), modelling of business processes (B), legal regulations (B), goods tracking systems (RFID systems) (D), management of storage devices (I4.0), resource management (B), dark warehouse (I4.0), smart logistics (I4.0), work-life balance (S), labour law and respect for employee rights (S). Other identified topics (86) were evaluated with a mean value between 5 and 8. Among all identified topics, only one was considered insignificant with a score lower than 5 (M: 4.5, SD: 2.84): Cultural, economic, and political forces influencing environmental attitudes and decision-making based on understanding science and technology.

All defined topics were analysed and consolidated since some were listed several times from different textual records. The result was a shortened list of topics that were entered into the third round of the Delphi study performed on an international level. A final list included 51 topics that were considered essential for future logisticians. Topics were then divided into seven different thematic chapters (Tab. 3): (1) Industry 4.0 and Logistics 4.0 concepts, (2) Digitalization and Logistics 4.0 maturity models, (3) Sustainability in Logistics 4.0, (4) Economic sustainability in Logistics 4.0, (5) Social sustainability in Logistics 4.0, (6) Environmental sustainability in Logistics 4.0 and (7) Industrial Internet of things for green logistics.

Table 3 Final list of topics essential for future logistician

Thematic chapters	Addressed topics
Industry 4.0 and Logistics 4.0 concepts	• Industry 4.0 definition and potential for implementation as Logistics 4.0 • Autonomous warehouse equipment • Autonomous vehicles and mobile robots • Robots and cobots in logistics • Automatic truck unloading systems • Artificial intelligence and machine learning in logistics • Drone applications • Virtual and augmented reality
Digitalization and Logistics 4.0 maturity models	• Digital economy concept • Human-Centric Digital Transformation • Connected Information Systems and Collaborative Platforms (ERP and MES in logistics) • Digitalisation of logistics processes • Digital maturity • IT security and cybersecurity, blockchain • Digitalisation of document flows and electronic data interchange • Multi-criteria support for decision-making processes in logistics (e.g. route optimisation) • Goods tracking and tracing systems on the basis of different identification approaches • Data management • Digital twin technology
Sustainability in logistics 4.0	• 17 sustainable development goals • Circular economy • Regulatory and policy frameworks for sustainable logistics • Integration of social, environmental, and economic sustainability issues in logistics • Environmental ethics • Sustainable tangible fixed assets in logistics (land, buildings, equipment and spare parts, small inventory)
Economic sustainability in logistics 4.0	• Economic analysis of sustainable interventions in logistics • Low-carbon economy and climate-neutral economy/logistics • Triple Bottom Line

Table 3 Final list of topics essential for future logistician (continuation)

Thematic chapters	Addressed topics
Social sustainability in Logistics 4.0	• Social aspects of sustainability in logistics • Work-life balance • Corporate social responsibility in logistics
Environmental sustainability in Logistics 4.0	• Reverse logistics • Green and sustainable packaging • Green and sustainable transport • Green and sustainable storage and warehousing • Green and sustainable intralogistics • Emission and carbon footprint calculation methods • Life cycle analysis • Renewable energy sources in logistics • Waste management and recycling systems in logistics • Energy saving in logistics processes • Green and sustainable purchasing • Sustainable Operations Management • Green and sustainable city logistics
Industrial Internet of things for green logistics	• (Industrial) Internet of Things (IoT) and technologies (e.g., cloud computing) • Adopting IIoT in the logistics sector • Designing intelligent logistics systems • Simulation tools and procedures for logistics processes • Optimisation tools and procedures for logistics processes • Project management • Teamwork

3.2 International Level of the Delphi Study

Based on the final list of topics from the national level Delphi study, the panelists were asked to propose essential learning outcomes that future logisticians will need to achieve under each topic on the list to cope with a green and smart future. As is seen in Tab. 4, panelists determined 607 learning outcomes in Delphi round 3. Most learning outcomes were suggested for the thematic chapter Industry 4.0 and Logistics 4.0 concepts. The fewest were defined for the chapter Economic sustainability in logistics 4.0. After combining the same learning outcomes propositions, a list of 127 unique learning outcomes was defined and used in the Delphi round 4 on the international level. The list of learning outcomes was shortened to 79.08% reporting essential learning outcomes for future logisticians.

Table 4 Number of learning outcomes across different thematic chapters

Thematic chapter	Number of learning outcomes determined in Delphi round 3	Number of learning outcomes after consolidation
Industry 4.0 and Logistics 4.0 concepts	160	25
Digitalization and Logistics 4.0 maturity models	123	28
Sustainability in Logistics 4.0	62	13
Economic sustainability in Logistics 4.0	26	8
Social sustainability in Logistics 4.0	37	8
Environmental sustainability in Logistics 4.0	125	32
Industrial Internet of things for green logistics	74	13
Sum	607	127

Table 5 Average importance of learning outcomes devided between course modules

Course modules	Number of learning outcomes	M	SD
Logistics 4.0 in the smart society	21	7.79	1.41
Sustainability in Logistics 4.0.	61	8.06	1.34
IIoT: adopting 4.0 for green logistics	39	7.7	1.51
Green challenge and practical applications	6	8.3	1.5

Table 6 Higher-ranked learning outcomes per course module

Learning outcomes	M	SD
Logistics 4.0 in the smart society		
Is able to identify 4.0 technologies and their applicability to the Logistics 4.0 cases.	8.3	0.99
Can assess the maturity of a logistics department/company for Industry 4.0 using the Industry 4.0 maturity model.	8.2	1.25
Has knowledge of the requirements and infrastructure necessary for the implementation of different autonomous warehouse equipment	8.2	1.42
Can identify the benefits and risks of usage of different types of autonomous warehouse equipment in a warehouse and describe their functions.	8.2	1.09
Is able to describe the need for tracking and traceability along the supply chain and outline implementation alternatives.	8.2	1.2
Sustainability in Logistics 4.0.		
Can critically judge transport modes in sense of green and sustainable goals.	8.7	1.4
Can plan green and sustainable transport based on the comparison of alternatives.	8.7	1.49
Can locate and measure waste in a supply chain and establish its reuse/recycling.	8.6	1.11
Can learn and follow national/international legislations for sustainable logistics.	8.6	0.87
Can plan green and sustainable storage and warehousing by following a methodology.	8.6	0.94
IIoT: adopting 4.0 for green logistics		
Can plan digital technology (digital platforms, software, and other technologies) to automate and optimise the various logistics processes such as transportation planning, inventory management, and order fulfilment.	8.3	1.26
Can plan, collect, receive, organise, control and use data with the support of appropriate tools.	8.3	1.36
Can define what artificial intelligence and machine learning are and describe how they can be applied to improve logistics operation.	8.2	1.48
Can identify potential and possibilities of artificial intelligence and machine learning applications in logistics processes.	8.2	1.51
Is able to identify logistics processes that can benefit from digitalisation.	8.2	1.51
Is able to find solution providers and choose the most suitable one among them.	8.2	1.47
Green challenge and practical applications		
Implements teamworking.	8.9	1.22
Can manage human relations.	8.7	1.1
Can prepare a project plan (cost, time, resources, risk, changes management, quality, WBS, list of activities).	8.4	1.54
Can monitor and direct project implementation.	8.2	1.44
Knows multi criteria decision making tools and can apply at least one.	7.9	1.78

After consolidation, the learning outcomes were divided into four (4) course modules (Tab. 5). All 127 learning outcomes were retained. In Delphi round 4 on the international level, each learning outcome was rated on a scale from 1 (not at all important) to 10 (very important).

After the panel finished, the average learning outcomes' importance rating was calculated for all modules (Tab. 5). On average, all learning outcomes scored as important. The result confirms that the determined learning outcomes are important for future logisticians and that appropriate consensus was reached among all of the Delphi panellists.

Tab. 6 lists five higher-ranked learning outcomes per course module. The lowest average score (6.8) received the learning outcome "can describe the structure of a digital twin for a specific logistics system" from course module IIoT: adopting 4.0 for green logistics.

4 CONCLUSIONS

The ambitious goals of the European Union require companies to transform themselves into sustainable and smart companies. Regarding sustainability, the highest goals are set in the area of greenness. Smart companies, however, will be based on digital maturity and implemented elements of Industry 4.0. The mentioned drivers have been particularly strengthening since 2010. During this time, however, not much has changed in higher education. We are witnessing pilot applications of topics from sustainability, greenness, and Industry 4.0 and exceptional practices. However, we cannot claim that the spirit of transition has already comprehensively encompassed the entire academic space.

There are few attempts to involve international groups of experts from different scientific disciplines in a focused thinking about adding sustainability and Industry 4.0 content to HE courses. This research has succeeded in doing so for the field of logistics.

In the scientific literature, there is much talk about which knowledge and competencies are necessary but almost nothing about learning outcomes, which define what the participant in education knows at the end of the educational process. In this regard, we view the study as original.

This article lists 51 essential topics from Sustainability, Industry 4.0, Logistics 4.0, and Digitalisation areas, further supported by 127 unique learning outcomes. Experts from 6 countries believe that the future workforce in the logistics sector should be able to use them in practice. Supporting the logistics sector with a workforce educated based on this framework should help it to reach the strategic goals of the European Union. However, simply adding these learning objectives to regular study programs will not be enough. The research also supports efforts to establish lifelong learning for logistics professionals who have acquired their education in past eras.

There are several limitations of this research. The number of participating experts decreased over the Delphi rounds. The main obstacle was the length of the questionnaires. Furthermore, we allow the possibility that we have omitted a topic or learning outcome. If more experts were included, it would very likely further improve the research results.

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