Engineering Excellence for the Mobility Value Chain

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Abstract. Based on the project "Engineering Excellence for the Mobility Value Chain" (EE4M), this paper addresses the increasing need for training, re-, and upskilling of engineers in manufacturing enterprises in the mobility value chain. Recently, the European mobility value chain is influenced by a multitude of hyper-dynamic factors, like changing consumer behavior, disruptive technologies, etc., which leads to the fact that a continuous realignment of engineering education is indispensable. The focus is placed on operations management (OM) which is changing due to the two policy-driven and pre-dominant drivers "Industry 4.0" and "Sustainability". The implementation of smart and sustainable concepts in OM in the mobility value chain entails both a transformation of production processes and a change in the working and learning processes of the employees. Companies are increasingly required to design, manage, and integrate learning processes and learning environments to provide a lifelong learning ecosystem and to prepare employees for changes in work and tasks. Moreover, educational institutions are challenged to successfully address those demands. Therefore, this paper introduces the European research project EE4M which focuses on the professional development of smart and sustainability competences of engineers in the mobility value chain through innovative educational modules supported by a transnational platform between the main drivers of the European mobility value chain. The innovation of the project can be explained by the fact that OM serves as the basis for empirically based realignment of engineering education to create requirement-orientated competence profiles.

Keywords: Engineering Excellence, Competence profiles, Vocational Education and Training

1 Introduction

In recent years, European manufacturing companies have constantly faced a multitude of complex challenges which are mainly triggered by exogenous influencing factors, like enhanced global competition, a tremendous change in customer behavior, the volatility and vulnerability of global supply networks, a continuous demographic change, a shifting attitude regarding the role of labor in the entire society, and an ongoing need for professionalized employability processes [1–9].

In this context, "Industry 4.0" research focuses on the usage of modern technologies which should ultimately enable manufacturing companies to develop new and better products, continuously improve their internal and external processes. Besides those developments, the research highlighted, that the transformation towards smart operations management in manufacturing companies is not possible without considering the future role of the human being and his realigned tasks in the modern socio-technical manufacturing systems. Future work will be significantly different from today´s tasks and, therefore, the skills, competences, and qualifications of the engineers of tomorrow need to be realigned by using empirical-based evidence [1, 10–14].

In this transformative society, the teaching of relevant and up-to-date skills is indispensable and thus represents a central element of the European Pillar of Social Rights [14–16]. Hence, high-quality education should be made available to all people, enabling them to make significant contributions actively and self-confidently as citizens to drive further developments and ongoing innovation [4, 17–19]. According to Tietgens (1992), the expectations, needs, or wishes of key stakeholders involved in the learning process in their respective disciplines can be emphasized as an essential success factor. Only in this way it is possible to respond to current trends and challenges in practice and to equip future engineers with the necessary knowledge, qualifications, and competences [20]. In turn, these stakeholders' demands must then be fed back to guarantee professional methodological-didactic training programs [14, 21].

Furthermore, sustainable development (SD) addresses the biggest challenges facing humanity in the 21st century [22, 23]. Currently, the largest challenge is the fact that emissions of GHG have increased in constant increments since 1970, and according to the high growth scenario of the Intergovernmental Panel for Climate Change (IPCC), the present impacts could almost double by 2030 [24, 25]. Therefore, European manufacturing companies must also find new ways to respond to novel regulations regarding green and transparent operational processes to meet macro-economic targets as defined in initiatives such as the 2030 Agenda for SD and its 17 Sustainable Development Goals (SDGs), the European Green Deal or the Paris Agreement. In this context, only a handful of studies are focusing on the transition towards sustainable operations management in manufacturing companies to operate in a resource-saving and low-emission-orientated manner. According to the three pillars of sustainability (economic, social, and environmental) [26], environmental goals must be in line with economic goals and the respective impact on people and the wellbeing of society as well. Thereby, the systematic transition towards a sustainable value chain, aligned exemplary with the principles of the circular economy [27], demands a variety of complex and transdisciplinary adaptations in engineering education based on evidence-based competence profiles to

contribute to the safety, health, and welfare of the public [2, 3, 28]. In this context, the Council Recommendation of 24 November 2020 on vocational education and training (VET) for sustainable competitiveness, social fairness, and resilience [29] and the Commission Communication on "An SME Strategy for a sustainable and digital Europe" further highlight that availability of skilled staff or experienced managers is the most important obstacle to new investment across the EU. Furthermore, the beforementioned Council Recommendation defines VET as a driver for innovation and growth which equips for the digital and green transitions and occupations in high demand, consequently contributing to the achievement of the SDGs. In this context, numerous studies highlight an increased need for sustainable development education [28, 30–36]. In this context, generally, valid competences must be manifested for the entire field of engineering education to guarantee quality assurance, systematic development, competitiveness, and employability for the engineers of tomorrow [36]. Furthermore, Pacher et al. (2020) investigated the educational needs in the extractive sector based on an extensive study within the framework of an EU project and concluded that the focus of higher education should lie on the training of transversal competences such as soft skills, decision-making skills, or digital competences [14, 37]. In addition, practical testing of the technical competences acquired during studies is essential for future careers, as it can be done in learning factory labs and innovation labs, exemplarily implemented for practice-oriented teaching by beneficiaries to foster VET engineering education [37].

The transformative educational processes triggered by the challenges mentioned above are influencing all societal sectors, institutions, as well as, age groups, and therefore require the long-term inclusion of new knowledge, qualifications, and competences over the entire lifespan. In this context, he pedagogical focus must not only be set on the design of suitable learning environments but also the creation of suitable institutional framework conditions [14]. With the establishment of VET platforms for a sustainable and long-term incorporation of innovative teaching and learning concepts into educational institutions throughout Europe, the EE4M project bridges this gap by combining the two components.

This research paper introduces the research project "Engineering Excellence for the Mobility Value Chain" (EE4M) which is co-funded by the European ERASMUS-EDU-2022-PEX-COVE programme under the grant agreement No. 101104549 (www.ee4m.eu). The project is focusing on the realignment and, therefore, the professionalization of engineering education in the respective focus areas of operations management in European manufacturing companies forced by the two predominant and policy-driven drivers "Industry 4.0" (smart operations management) and "Sustainability" (sustainable operations management). This transformation is further challenged by continuous demographic change, a shifting attitude regarding the role of labor in the entire society, and an ongoing need for professionalized employability and structured lifelong learning approaches [1, 4, 5, 7, 9]. The project will establish a dialogue with public and private stakeholders to (1) elaborate the needs and expectations of the industry, (2) establish a constant knowledge exchange within the knowledge triangle to foster skills ecosystems, and (3) and ensure the co-creation of educational materials, tools, and concepts. Streamlining direct stakeholder dialogue on all three sides of the knowledge triangle, with a strong focus on targeting the inclusion of female students in

the training and/or workshops, underrepresentation of gender equality has the opportunity of declining. Furthermore, interdisciplinary best practices are addressed through the unique project team composition, giving access to the latest developments in educational training [16].

1.1 Needs Analysis

Today, our economy and society are subject to a permanent and hyper-dynamic change as outlined in the previous section of this research proposal. To withstand this change, it requires transformational solutions that go beyond incremental innovation strategies. Therefore, business sectors need to adopt new mindsets for "breakthrough innovations" [38, 39]. Engineers play a critical role in finding innovative solutions that balance economic competitiveness, environmental protection, and social acceptance. To do so, they will need more than a strong scientific and technical background. They will need to learn to think out-of-the-box, understand how social, cultural, and economic aspects influence their work, and vice versa link science and engineering to the needs of society, collaborate in interdisciplinary teams, develop entrepreneurial systems thinking [40], propose creative and innovative solutions, and learn how to communicate the proposed solutions to the general public [41, 42]. Recent studies report a tremendous need for qualified engineers in smart and sustainable operations management. In Austria, 51 % of the manufacturing enterprises expect a significant increase in the shortage of skilled workers in their sector over the next three years [43, 44], whereby, 85% of the survey responses report a tendentially strong increase of skilled worker shortage within the next five years [45]. These results are in line with the study of the recent research findings of the IW (Institute of the Germany Economy), reporting an increasing need for at least 48.300 engineers and 68.800 STEM academics per year within the timeframe 2023-2028 [44, 46, 47]. According to 42% of the companies surveyed, a (possible) shortage of suitable top specialists leads to at least minor or, according to 11% of the companies surveyed, considerable turnover losses or unrealized turnover potential for their company [47]. The predicted need for additional education in engineering is spread across all levels of education and training. Studies show the following distribution: 8% basic vocational education, 30% secondary education, 37% more tertiary education, and 25% more lifelong learning [48]. Furthermore, the implementation of smart and sustainable technologies and concepts both a transformation of production processes and the changed work and learning processes for employees as the work of the future will be more flexible, more mobile, and more digitally networked. [10, 49, 50]. In this regard, Dengler and Matthes (2015) forecast that the current number of 40% of all employees in jobs with low substitutable potential will decrease to a maximum of 30% through automation. The human workforce will continue to be regarded as an essential component in global value chains. It seems to be obvious that an ongoing specialization requires adapted operational or organizational learning processes. However, these processes cannot be viewed in isolation, but they must be considered as part of organizational development [10, 51, 52]. Organizations need to transform learning organizations and employees to acquire lifelong knowledge and educational institutions are now challenged to successfully implement the demands and thus to ensure the

ability to work, the understanding of the role of engineers [14, 53]. This transformation requires a new conceptualization or adaptation in a holistic way, i.e. both on the institutional level and concerning transdisciplinary cooperation with industry, as well as, a push towards national and international cooperation [10, 14, 54]. In this context, flexibility, adaptability, resilience, and competences in smart and sustainable operations management are further regarded as essential success factors [14]. As can be derived from the challenges mentioned above, educational reforms are urgently required as of now to extend the education system and cover educational needs throughout the entire lifespan. In this context, professionally sound, competency-based, transparent, and modularized teaching and learning concepts can help to make the transition from reactive education to the proactive, future-oriented design of educational measures considering future needs for smart and sustainable operations management in manufacturing companies [55].

2 Research Method

The research project follows an explorative research approach. A method triangulation will be used, which includes secondary literature analyses as well as quantitative and qualitative research methods. First, the exploration of generic (competence-based) requirements for smart and sustainable operations management in the mobility chain will be investigated using a systematic literature review [56–58], extensive online questionnaires, and qualitative focus groups with experts from academia, research, and business. The same research design will be applied for the investigation of the three focus areas logistics and supply management, product development and manufacturing, and entrepreneurship and industrial marketing management. The educational services´ novelty lies in the topicality of the educational content and formats conveyed. Accordingly, new educational content is to be generated based on current challenges in the economy, society, and education and addressed to specific target groups. Among other things, three essential maxims of education and educational science are to be applied - participant orientation, practical relevance, and life-world orientation - through the application of information-theoretical learning theory. The methodological approach encompasses competence-based education and training based on a modularized program architecture and supported by digital teaching and learning formats in the field of smart and sustainable operations management. These modules, based on a multi-phase teaching and learning arrangement, can be combined depending on the target group and individually adapted to their needs, as well as on the regional-specific smart specialization strategies. Thus, for the respective participants, the CoVE offers both, shorter units (Microcredentials), such as a module with a scope of 5 ECTS workshops, seminars, or trainings, as well as longer further education measures such as train-the-trainer/teacher formats, university courses (15 ECTS), up to further education master programs with 90 to 120 ECTS. These modules are methodically-didactically structured according to new findings, e.g., accelerated learning of educational research to enable holistic learning. Thus, in addition to self-learning units utilizing MOOCs [59], literature research, and online learning materials, the self-learning competence of participants is to be

promoted and combined with already existing knowledge and experience. This new educational content is to be deepened, expanded, and supplemented in discussion with the stakeholders or within a group of participants to be able to guarantee the acquisition of knowledge in the long term. Finally, the consolidation of knowledge and the transfer of knowledge into practice should be ensured through case studies or best practices from the field. The modules can be offered adapted for the secondary, tertiary, and VET education levels since EE4M unites the experts on the European Qualification Framework (EQF) levels 4-8.

3 Impact

Overall, the development of professional and transversal skills is targeted. The innovative methodological-didactical approach of EE4M is used as a guiding principle for the development of a skill ecosystem on a regional and a European level [60]. VET teachers/trainers, practitioners, and students from all European countries within EQF levels 4-8 will be enabled to acquire (new) (inter)disciplinary skills in the fields of operations management, sustainability, digitalization, etc. through innovative teaching and learning environments to create awareness for the handling in and with the digital and sustainable world. EE4M is intended to generate added value for the European Education Area due to the multidisciplinary consortium by amalgamating various perspectives, experiences, and research results. This will ensure the exchange of experience, materials, and best practices across geographical borders and will enhance the innovative strength of all participating countries. During the four-year duration of the project, a foundation for a digital and sustainable inclusive, borderless, and integrated European VET education is to be laid to produce competent and well-trained VET students, graduates, and teachers. This will make a significant and innovative contribution to the current European social, economic, and ecological challenges. Furthermore, the project promotes the principle of lifelong learning and equal and excellent education according to SDG number 4 “Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all” [60]. The education system in Europe is not agile enough to adequately respond to the permanently changing needs of the labor market and societal challenges such as climate change, digitalization, etc. in the field of operations management. For this reason, EE4M represents a key action and thus a bottom-up approach to implement the facets of Operations Management digitally and sustainably in schools, higher education institutions, companies, and consequently also in society with the help of target group-specific innovative teaching and learning concepts. EE4M also enables transnational exchange with and within European member states and their populations. In addition to the professional and transversal competences, the cultural understanding (citizenship competence and cultural competence) shall be expanded, and the multilingual competence shall be promoted by providing teaching and learning concepts in the consortium languages German, Italian, Spanish, Greek, and English. Based on this, the following target groups can be identified: students (upper secondary level), students at HEIs, practitioners, professionals, and employees in operations management [61], teachers at upper secondary and tertiary level, trainers in the

continuing education sector, and the broaer public.The modularized teaching and learning concepts developed will be uploaded to the European/international EE4M platform as an open-access resource to raise awareness and societal acceptance of Operations Management related topics. Thus, the developed concepts can be easily disseminated across Europe and internationally to educate current (prospective) engineers and prepare the next generations, so-called engineers of tomorrow, for the future of work. Accordingly, EE4M project partners manifest the long-term impact of the produced project results and outputs.

EE4M aims not only to promote STEM subjects and student numbers in the technical field but above all to educate the next generations transregionally with innovative, creative, and future-oriented competence profiles and mindsets. In addition, a successful regional, as well as international, skills ecosystem should be provided to increase European competitiveness, professionalize the European VET engineering education culture and increase employability and resilience.

The active dialogue and exchange partnership established within the EE4M project between all essential stakeholders from the knowledge triangle will allow to work together with a shared vision and objectives towards a more sustainable and digital operations management sector and society subsequently [60].

4 Conclusions and Implications

The EE4M project is based on the transparent and empirical-based investigation of future educational needs and necessary transversal key competences for the engineers of tomorrow in the smart and sustainable operations management in the mobility value chain. To ensure European competitiveness as well as the employability of European citizens, it contributes to the establishment of a culture of professional lifelong learning in the field of engineering education by focusing on the the following objectives:

- Development of European Vocational Education Training (VET) platforms for the (trans)national realignment of engineering education.
- Empowering the transition towards smart and sustainable operations management by fostering the skills of the engineers of tomorrow.
- Competence-based teaching and learning concepts for IVET and CVET learners and teachers to contribute to economic, ecologic, and social wellbeing.
- Fostering (trans)regional skills ecosystems through knowledge exchange within the knowledge triangle on the established VET platforms throughout Europe.
- Establishment and continuous development of professional teaching and learning environments for VET engineering education on EQF levels 4-8.

Through the interconnectivity within the project, educational permeability and the interlinkage between the VET educational levels on the secondary, tertiary, and continuing education levels can be generated. The educational services´ novelty lies in the topicality of the educational content and formats conveyed. Accordingly, new educational content is to be generated based on current challenges in the economy, society, and education and addressed to specific target groups. During the four-year duration of

EE4M, more than 1,000 VET teachers/trainers, practitioners, and students from all over Europe within EQF levels 4-8 will be enabled to acquire transdisciplinary skills in the field of smart and sustainable operations management through innovative teaching and learning environments. A foundation for a smart and sustainable inclusive and borderless European VET education is to be laid to produce competent and well-trained VET students, graduates/professionals, and teachers. Boosting (inter)national skills ecosystems will successfully increase European competitiveness and employability, professionalize the European VET engineering education, and contribute to economic, ecologic, and social wellbeing.

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