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EREMI: An Innovative Interdisciplinary Approach for Higher Education in Resource Efficient Manufacturing Environments

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Abstract: This paper presents an overview of EREMI, a two-year project funded under ERASMUS+ KA203, and its results. The project team's main objective was to develop and validate an advanced interdisciplinary higher education curriculum, which includes lifelong learning components. The curriculum focuses on enhancing resource efficiency in the manufacturing industry and optimising poorly or non-digitised industrial physical infrastructure systems. The paper also discusses the results of the project, highlighting the successful achievement of its goals. EREMI effectively supports the transition to Industry 5.0 by preparing a common European pool of future experts. Through comprehensive research and collaboration, the project team has designed a curriculum that equips students with the necessary skills and knowledge to thrive in the evolving manufacturing landscape. Furthermore, the paper explores the significance of EREMI's contributions to the field, emphasising the importance of resource efficiency and system optimisation in industrial settings. By addressing the challenges posed by under-digitised infrastructure, the project aims to drive sustainable and innovative practices in manufacturing. All five project partner organisations have been actively engaged in offering relevant educational content and framework for decentralised sustainable economic development in regional and national contexts through capacity building at a local level. A crucial element of the added value is the new channel for obtaining feedback from students. The survey results, which are outlined in the paper, offer valuable insights gathered from students, contributing to the continuous improvement of the project.

Keywords: higher education; resource efficiency; manufacturing industries; unique interdisciplinary international higher education approach; lifelong learning; quality feedback survey and results assessment

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1. Introduction

The following study is a collective effort of the entire EREMI project team, and presents its interdisciplinary approach to elaborating a cutting-edge educational concept and curriculum in order to prepare a common European pool of experts for the future that is able to manage all challenges arising on the path to achieving the goals of Industry 5.0 in terms of resource efficiency and integrity, and the integration of the latter at full scale. Additionally, the project's novel knowledge transfer concept, including an innovative

quality management approach based on a proactive learners' quality feedback channel, is described.

A core element of the project's continuous success and sustainability is the quality feedback survey, which focuses on the involved learners at the partner educational organisations, enabling the project team to constantly improve the learning materials.

Empirical study on the statistical results of this quality feedback survey among over 100 students in total from all involved partner organisations with regard to the EREMI learning content and the different aspects and parameters of its quality was performed, and the results are presented here in detail. This step is crucial for understanding the effects and impact of the EREMI project in the long-term perspective.

1.1. EREMI in a Nutshell

First, an extended description of the EREMI project context should be made to better understand the goals and objectives that the project team is pursuing, as follows.

Over the last few years, it has become clear that the digitisation of industry, the benefits of the Internet of Things (IoT), and the integration of Artificial Intelligence (AI) and Big Data into it are a natural evolution towards a more efficient and sustainable way of manufacturing and building systems, as well as a faster and more seamless transition to Industry 5.0 [1]. This creates a need for new skills in almost every area of industry, due to the numerous emerging sectors. This new era of rapid development requires the implementation of lifelong learning strategies for engineering professionals to have a sufficiently skilled workforce to meet the challenges of the future.

Nowadays, Bulgaria, North Macedonia and Romania, the three project partner countries, are precisely countries whose industries are experiencing extensive development and the relevant required expertise profile for engineers needs to be designed and built in a sustainable way—by offering a relevant interdisciplinary higher education programme. However, these countries are facing serious challenges in higher and adult education and retraining, which are crucial for success in the current re-industrialisation situations.

Industries in Bulgaria, in particular in the industrial region of Plovdiv and its surroundings, as well as in the large metropolitan areas of Romania, face this challenge in a very intense manner, and therefore would benefit from receiving qualified support from a suitably experienced partner from the highly developed region of Southwest Germany—HSO. The main objective was to develop a higher education programme aimed at optimising resource utilisation, and in particular energy efficiency, in industrial production environments, by integrating Big Data handling while using AI as a tool for virtualisation, along with the respective optimisation of physical production facilities, as well as certainty regarding the processes taking place within them. This issue is also of great importance for the environment and the energy transition.

Moreover, in recent years, North Macedonia has experienced an intense wave of production facility establishment by many OEMs, and has the chance, in the sense of this trend and in the course of becoming an EU member state, to prepare its education system to meet the challenges of the intensive processes of re-industrialisation.

Moreover, Bulgaria is facing a noticeable shortage of specialists in the computer and engineering sciences, both of which are strongly needed for the necessary industrial transition towards higher resource efficiency in producing industries. The reasons for the former include the rapid development of the sector, as well as the slower pace of the education system development in providing candidates with the necessary skills due to outdated curricula, but also the need for new teaching methodologies. The reasons for the latter include the increased demand for highly skilled professionals resulting from the number of emerging sectors, a decrease in supply due to students' lack of motivation to pursue technical careers, and a lack of orientation of teachers and universities towards job-specific skills.

In all three Eastern European countries, consumption of resources, in particular energy for industrial production, remains at a higher level than all other socio-economic sectors.

In order to counter and reverse this trend, the EREMI team collaboratively developed and validated an advanced higher education program, along with a lifelong learning component. This programme focuses on the interdisciplinary subject of resource efficiency in manufacturing industries, as well as the comprehensive optimisation of under-digitised physical infrastructure through the utilisation of IoT technologies. The aim is to equip professionals in the field with the knowledge and skills necessary to effectively address these challenges. The initiative is supported by the experienced German partner HSO, operating in a country and region that experienced this stage of industrial development in its recent past. Higher education content, and in particular curricula for Bachelors, Masters and PhD students in this field, will be vetted and/or supported by all five participating project partners. The programme will be based on an interdisciplinary approach of academic and professional (also from relevant companies in the regions of the participating universities) trainers, as well as on an internal education system involving students from the three academic educational stages mentioned above.

Having developed and validated the online-based learning content and platform, based on these, all participating project partners considered a curriculum for a joint higher education programme on the EREMI theme aimed at the target group of postgraduate students. Its accreditation at each of the participating universities will take place at the end of the project, due to the specificities of the time planning involved, which are different in the different countries involved.

Throughout the project, a free online interactive teaching/learning platform was developed. The Moodle platform was designed to address the specific educational requirements of university students and postgraduate professionals. It serves as a valuable resource for universities, students, and companies seeking efficient and rapid professional training in this crucial field. The platform's importance is particularly notable for industries experiencing transformation, such as those in the Plovdiv region of Bulgaria. Rapid industrialisation trends in this region, coupled with a shortage of adequately educated engineers, make the platform an essential tool for effectively addressing these challenges. The creation, refinement, validation, and revision of this product were ongoing processes carried out throughout the project's duration. By continuously improving and adapting the platform, it ensures the delivery of high-quality educational content that meets the evolving needs of its target audience.

The content of the EREMI education programme is based on open-source rules and is publicly available online to all stakeholders and citizens of Europe via the EREMI website. It is regularly promoted through relevant events, social and public media posts, and especially through the participating voluntary partners from the policy development, research and development fields and definitely through all relevant platforms of ERASMUS+, the EC and platforms such as LinkedIn.

The main added value of the project is the developed quality feedback survey system, which successfully aims to (a) establish a permanent channel for learner–teacher feedback as well as (b) allowing the participating teachers to optimise the learning content. The project team developed a questionnaire that has been successfully disseminated to participating learners in all project countries, and the results show how positively the idea and the results of the project are perceived by the learners. With more than 100 responses in the short time after the completion of the training materials, with most of them giving positive and/or strongly positive feedback, EREMI has clearly achieved its objectives.

1.2. Literature Review: Relevant Landscape—Resource Efficiency, Manufacturing, Higher Education and Beyond

In the recent period, the efficient use of resources and knowledge has become increasingly important, and many educational institutions, companies and researchers have made significant efforts to identify more efficient and innovative techniques to develop advanced and more attractive methods and technologies for teaching and education purposes for different types of industries. There are learning environments oriented towards the require-

ments of Industry 4.0, with a focus on standards and protocols developed for this type of industry, cloud computing and data storage, process automation and distributed computing, virtual reality and digital twin simulation, and interconnection with neighbouring IoT systems [2]. The described model was tested on a set of 20 students enrolled in the Master's programme "Automation and control of production processes in the pharmaceutical industry" and some statistical results are presented in the paper. The different factors influencing the implementation of the training and the problems faced by higher education actors to implement training programmes on this topic are discussed in [3]. In addition to this comes the development of a SWOT analysis, which is based on the views of staff and students, and, in combination with the analytic hierarchy process (AHP), can offer several recommendations for the further development of such training programmes. Industrial development requires new skills and achievements; therefore, it is imperative to develop new higher education programmes that address the latest technological trends and develop new knowledge and skills to cope with the rapid changes that industry and the corporate sector are facing [4], as well as the identified extensive and comprehensive state of the art in terms of needs when it comes to skills and training of future professionals in Industry 4.0, which includes a wide range of fields from autonomous robots to machines, managing complex manufacturing systems of systems etc.

The authors of [5] explored how manufacturing firms can carry out smart and resilient transformation through the application of digital services. They used data from more than 100 manufacturing firms and concluded that the networks of manufacturing firms were most significantly impacted in the case of those manufacturing companies using an appropriate mix of services and digital technologies. Their findings also demonstrated that utilising digital technologies, such as Big Data analytics, digital twins, 3D printing, etc., increased the gross yearly turnover of manufacturing companies during the COVID-19 pandemic. Companies must familiarise themselves with some of the key digital technologies, such as Big Data, cloud computing, the Internet of Things, etc., as well as understanding which technologies they need to adopt, to develop a sustainable smart transformation of their manufacturing organisation. Industry 4.0 offers manufacturing companies the ability to quickly respond to environmental changes in accordance with the demands caused by quick changes in the market, with COVID-19 testing the resilience of manufacturing systems [5]. With the help of considerable technical breakthroughs, Industry 4.0's primary objective is to satisfy individual needs by changing the industrial paradigm from mass production to personalised production [6]. The authors found that product-related services, like repairs, maintenance, and training, were the most important nodes from a service perspective, and that from the standpoint of digital technologies, cyber security, Big Data analytics, the Internet of Things, cloud computing and digital twins are the most significant nodes. Through the use of the new technologies commonly included in Industry 4.0, the authors of [7] claim that operational flexibility can be increased. The most common definition of operational flexibility is that it is the ability of a system to respond to changing conditions [8], and is often described as a mixture of various forms of flexibility and as having different types of sources. The authors describe the ways in which different technologies can help manufacturing businesses in the final stages of assembly [7,8]. For example, 3D printing (additive manufacturing) can help print parts that are too complicated for conventional manufacturing procedures, Industrial Internet of Things (IIoT) enables the remote monitoring and management of physical objects like machines and can monitor and improve assembly processes, Big Data aids in the effective management and control of manufacturing processes [9], machine learning facilitates the creation of digital twins and enables the detection of anomalies and patterns in data [9,10], etc.

The authors of [11] presented the concept of a tool that would allow employers to easily visualise knowledge gaps among their employees, with the aim of promoting employee retention with the help of specialised training. They claimed that the human factor is central to the industrial digital upgrade, and that in order to maintain organisational knowledge, businesses must be able to provide a more dynamic allocation of workers to tasks and

ensure staff retention. It was found that it is possible that, as Industry 4.0 develops, soft skills will become more and more crucial, and also that teaching them is far more difficult and time consuming. The difference between the proposed tool and existing tools is that it includes the opportunity to express preferences regarding the abilities to be utilised and improved [12,13].

In [14], the authors analyse the impact of the development of Industry 4.0 on the education sector, recognising that students from different regions have different backgrounds and technical skills, and that more effective and friendly teaching strategies need to be developed to facilitate the learning process. The authors of [15] explore the effect of the COVID-19 pandemic on the industrial and education sectors and highlight the benefits that could be obtained on the basis of this experience. In [16], the authors show the effectiveness of combining new, revolutionary educational tools with modern teaching methods to develop effective Education 4.0 strategies, from competencies to ICT-based teaching methods and infrastructure. Several recent studies have already focused on climate change and the importance of education in reducing its impact on the environment. In [17], the authors attempt to develop a common framework to help introduce the concept of climate change at different levels of the educational chain, to develop a comprehensive model for the management of climate education, and to offer scientists, educators and policy makers the perspective to change our concept and adapt it to local conditions. With the same agenda, the authors of [18] propose several techniques, practices and models to improve sustainability education in university curricula, in terms of both the research they performed and their administrative entrepreneurship. In [19], the authors analyse and present the capabilities and competencies needed for sustainability and, based on a comprehensive study, conclude that there is a requirement for sustainability capabilities among managers in different positions in companies, but there is also a need to have professionals with sustainability skills in the research departments of companies. In 2021–2023, a special issue on "Education for Sustainability in Higher Education" [20] was organised, gathering 25 papers on topics related to these keywords from different perspectives and from different parts of the world.

The discussion of sustainable development and how knowledge (human capital) is related to it is a vital one to have. The authors of [21] seek to introduce a comprehensive theory in development studies by utilising Mill's stage theory. The theory places a strong emphasis on how knowledge, innovation, and nature interact to generate economic change. The need for historical depth in economic analysis to comprehend current events and the significance of interdisciplinary approaches that integrate different factors shaping economic development, such as economics, sociology, politics, and psychology, are emerging as two imperatives for economic science and development studies. The authors claim that Mill's theory could clarify the ways in which cultures and their economic systems have changed historically, as well as how knowledge, innovation, nature, and culture have shaped modern economies [21].

In [22], the author explains how macroeconomic history and analysis can take nature into account as a capital asset. This approach, according to the author, demonstrates the unsustainability of economic growth around the globe, particularly in areas where population growth has outpaced the growth of other types of capital, as is the case in areas like South Asia and sub-Saharan Africa. The author also argues that population growth in South Asia, sub-Saharan Africa, and potentially even in the UK and the US has resulted in a failure to compensate for the decline of natural capital, suggesting, though, that China could be an exception to this. The author of the text makes the case that each generation should leave behind a productive base that is at least as substantial as the one it inherited from the generation before it. The productive base, which is where the author suggests a society's well-being comes from, is made up not only of its capital assets (knowledge, human capital, natural capital, etc.), but also its institutions and culture [22].

Some relevant papers on the implementation of active learning platforms have also been presented in the literature [23–25], where three case studies are reported on their implementation in higher education related to transport issues, a smart making lab and

a test centre for biodesign. In [26], a comprehensive state of affairs is presented related to the educational issues that have arisen as a result of industrial evolution towards I4.0, emphasising the required capabilities with respect to both management and specific skills, and also the technical areas related to this evolution (such as ICT, software skills, algorithms, data analysis and processing, security, etc.). Ref [27] is a comprehensive book that discusses the importance of higher education programmes in promoting new and challenging fields and economic issues. In [28], the authors present some preliminary available results regarding this project.

Online learning in higher education appears to be effective and is perceived positively by the majority of students, as evidenced by [29].

Below are compiled a series of projects that have served as valuable sources of information for the EREMI project:

ICARUS

The aim of the ICARUS project is to provide an open digital toolkit for HEI (higher education institution) educators to use in introducing Industry 4.0 technologies to both current and former HEI students. This open digital learning toolkit will result in a more capable digital transformation workforce, increasing the competitiveness of the sector in which they work [30].

One of the outcomes of the project is the ICARUS pedagogical framework, which aims to identify and guide innovative pedagogical approaches to explore and address the needs of HE teachers and students, and provide guidance through the potential design space for upcoming development and adaptation to effectively address the skills gap in Industry 4.0. The project also produced a compendium on Industry 4.0 and Digital Manufacturing, which provided a wealth of information on advanced manufacturing technologies, additive manufacturing, virtual and augmented reality, industrial IoT, cybersecurity, Big Data, and other topics [31].

EUGPUT

The aim of the project was to develop a one-week educational programme to increase learners' understanding of and familiarity with upcoming green public transportation systems in future smart cities. The target groups were: students, stakeholders, universities and entrepreneurs. The programme consisted of seven learning modules and one support module: Smart Mobility, Energy Smart Grids, Green Vehicles and Designing a Green Public Transport Network, as well as others related to intermodal public transport planning, economics, and entrepreneurship opportunities. The outputs of the project included the syllabi for the modules, a Lecture Notes handbook to serve as a document for supplementary reading before joining the programme, and a Teaching Guide that can be used by lecturers who will teach the same programmes in their universities. Posters, e-bulletins and Q&A videos were prepared for all modules and made available through the project website. A research book was also published [32].

DIGITAL INNOVATION

The context of this project was the fact that digital technologies offer unprecedented opportunities for innovation, but there is a significant technology gap between SMEs and large firms in the EU, highlighting the need for universities to train and support SMEs in the uptake of digital innovation tools. To improve the way service innovation is taught, the Digital Innovation project aimed to better understand how small service firms currently approach new product development. In order to produce skilled graduates that would benefit the service sector and support the competitiveness of EU businesses in the global market, the aim was to equip educators with the ability to incorporate digital tools into their curricula [33,34]. The outputs of the project consist of practical and reusable resources for practitioners, research materials that represent a step forward in the thinking in the sector, and community building tools [33]. In addition, the project website features a benchmarking tool, which is an innovative and interactive online platform designed for

SMEs to determine where their innovation development process stands in terms of using available digital tools [35].

1.3. Structure of the Paper

Following the introduction presented above, the current paper is constructed in the following manner. Section 2 provides extensive information on the materials and methods applied in the project. It elaborates on the challenges faced by the EREMI team, how the tasks and responsibilities are distributed among the relevant partners, what the contents of the educational package are, and what the desired impacts of the project are.

A crucial element of the project described here, is the quality feedback survey, designed and performed by the project team in an online environment, which has strongly supported the constant improvement of the EREMI contents. Its results were evidently positive, which itself shows the highly positive effect of the EREMI approach, which was obviously highly anticipated and warmly regarded by learners in all project partner countries. Section 3 provides information on the results achieved so far through the efforts of the EREMI team, and what value has been added to the project to date, focusing on the quality feedback survey results as final evidence of the success of the project approach.

Section 4 consists of a discussion of how COVID-19 has affected the project, policy recommendations, and information on the project's dissemination, including a focus on the quality feedback survey.

Finally, Section 5 presents the conclusions drawn from what as learned in this study, followed by sections, which are dedicated to the acknowledgements and references.

2. Materials and Methods

2.1. Challenges Faced by EREMI

Since mid-2010, the world has been experiencing the Fourth Industrial Revolution, also known as Industry 4.0. Industry 4.0 is a new level of organisation and control over the entire product lifecycle value chain, and the concept involves a range of technologies that are constantly evolving and improving. It is defined by the combination of artificial intelligence, advanced robotics, additive manufacturing (3D printing) and IoT to make manufacturing more efficient. Digitalisation and the application of intelligent methods in manufacturing are necessities of today's industry. Industry 5.0, which we are all moving towards, represents a major step forward in the customisation of manufacturing. The new trends that we are encountering in society and technology in the course of Industry 4.0 come with challenges, but also provide opportunities [36]. Along with the advancement of the new industrial revolution, a transformation is taking place in modern education. There is a need to improve the competencies of the personnel facing the challenges of this new era in industrialisation. Staff must be adequately technically trained and possess appropriate technical and social competences related to the field of Industry 4.0. For this reason, it is necessary to transform modern education into the Education 4.0 system and changes in traditional educational methods and approaches. Education 4.0 is a new educational system that is oriented towards the application of digital technologies through personalised education [37]. The EREMI project addresses the obvious and intense need for engineering professionals with an adequate interdisciplinary education in the field of resource efficiency in manufacturing industries as a highly relevant, and economically, politically and technically key topic.

Led by UHT, the EREMI consortium is dedicated to developing innovative interdisciplinary programmes for postgraduate students, while also catering to undergraduate engineering students. The project team has achieved this by adopting a holistic perspective on resource-efficient manufacturing, viewing it as a complex system comprising various interconnected subsystems. These subsystems encompass aspects such as energy efficiency in pneumatic and hydraulic systems, digitisation of physical infrastructures, IoT integration, Big Data analytics, predictive maintenance, and entrepreneurship, among others. The team's primary focus is the creation of highly innovative and comprehensive inter-

disciplinary teaching materials. Building upon this foundation, they have developed new subjects, courses, and programmes for higher engineering education in partner institutions across Bulgaria (UHT), Romania (UPB, BEIA), North Macedonia (UKLO), and Germany (HSO). By offering an advanced interdisciplinary higher education program, the EREMI team aims to support higher education organisations, industries, and regional economies in addressing the challenges posed by ever-evolving technologies and the increasing demand for engineers with interdisciplinary knowledge. Modern, resource-efficient, and sustainable industry and the transition to a circular economy, as elements related to the future of industry, require new generations of students to be trained in these innovative fields by updating existing and developing new curricula to be adopted in line with the requirements of the new technological era.

To address the urgent threat of climate change and tackle the complex challenges in the energy sector, countries globally are investing in low-carbon-energy solutions. This includes initiatives in renewable energy, energy storage, smart grids, and energy efficiency, which are pivotal for achieving significant reductions in carbon emissions on a large scale. However, it is essential to acknowledge that overcoming these challenges requires more than just technological advancements alone; knowledge-based innovation stemming from energy education and research is paramount. To successfully address these challenges, new mechanisms need to be put in place to link higher education institutions with industry and society and to lead to new innovative solutions [36]. EREMI is being implemented and conducted as a living laboratory activity. Its aim is to co-develop innovative learning content and digital platforms for higher education, and this requires the active participation of several stakeholder groups, including students, faculty, industry partners, and policy makers.

On a global scale, the industrial sector is responsible for around one-third of total electricity consumption. In Bulgaria, specifically, the industrial sector accounts for approximately 43% of the country's overall electricity consumption, as reported by the National Statistical Institute in their BG—Total Energy Balance of 2016. Notably, the industrial sector in Bulgaria is primarily characterised by a concentration of a few energy-intensive primary industrial sectors. In certain sectors, such as glass production and highly automated manufacturing facilities, this percentage can even reach as high as 45–50%. UHT carried out a study based on direct measurements in eight manufacturing facilities operating in Bulgaria belonging to different industries. As no other verified data are available for Bulgaria, the results obtained from this UFT study confirm the global trends, and an average of approximately 15% can be considered realistic. The predictive maintenance made possible by the application of IoT and the virtualisation of physical systems (an area where HSO is a leading research and education partner in the EU, and is supported by UFT, UPB and UCLO in the framework of the EREMI project towards the integration of this topic in training) represents an even greater challenge that promises great potential for improvement. The responsibility for addressing resource efficiency in manufacturing is primarily covered by UFT and UKLO, with support from UPB, BEIA, and HSO.

The EREMI project takes place in the specific context of the COVID-19 pandemic, which has dramatically affected all areas of life, including the way higher education works and conducts its activities. Universities and teaching must undergo a significant digital transformation to meet the demands of today's generation and the fully digitised world in which it will live. The COVID-19 pandemic has rapidly and unexpectedly forced higher education institutions and the education system to engage in such change [38]. For many students and faculty, the COVID-19 pandemic was the trigger that brought them into contact with teaching and learning connections that take place entirely online in a virtual classroom. The EREMI consortium is developing innovative interdisciplinary highly online-based content for subjects, courses and programmes that can be taught in any online situation. One of the main advantages of distance learning tools is the ability to easily access classes from the desired location while realising lower costs. In addition, it is possible to share learning content, i.e., learning materials, at any time. The content of the EREMI

learning programme will follow open-source principles and will be publicly available online to all European stakeholders and citizens via the EREMI website.

Distance learning is primarily reflected in the drive to implement and use online learning platforms. Over the last few years, more and more universities have introduced online learning platforms, resulting in a large number of different platforms that are used on a daily basis all over the world. Most platforms support basic teaching processes, such as publishing materials, sending notifications to students, and organising tests. However, they have mostly been developed as general-purpose platforms, and therefore do not include processes that are specific to the domain of a particular educational area. A problem that often arises in the development of such systems is the difficulty of integrating different platforms, reduced adaptability, and reduced overall performance. EREMI's final product will be a free online interactive teaching/learning platform, embedded in Moodle, targeting university students and postgraduate professionals and serving relevant universities and companies for fast and effective professional learning on this key topic for industry across the EU. This product will continue to be created, refined, and validated in the course of the project.

Clearly, in an increasingly digitised society, and with access to new knowledge, engineers cannot be expected to use the knowledge they have acquired over the course of their lives. The abilities and competences required for continuous professional development, advancement, and investment in one's own potential have become extremely important, especially in the case of engineering professionals. Lifelong learning and education is one of the strategic goals of higher education defined at the beginning of the Bologna reform, and it has become particularly relevant in the last decade in the European Higher Education Area [31,39,40]. With the development and improvement of e-learning and distance learning, new opportunities are opening up for the idea of lifelong learning. The set of online courses created within the EREMI project can be seen as a form of lifelong learning and professional development for engineers in the field of resource efficiency in manufacturing industries. However, the implementation of lifelong learning policies requires strong partnerships among authorities, higher education institutions, students, employees, and employers.

Internationalisation in higher education is considered to be one of the main pillars of modern higher education, and is mainly realised through student mobility, the implementation of joint curricula and the mobility of teaching and administrative staff. Twenty years after the implementation of the Bologna Declaration in the territory of the European Higher Education Area, mobility, as one of the forms of internationalisation of higher education and a key element of the Bologna Process, is applied in almost all countries of the area [41]. Additionally, faculty mobility includes several under-researched and under-used positive outcomes for both the institutions from which faculty are sent for exchange and the institutions to which faculty go. Quality education also implies a significant effort by the academic community to explore new directions in engineering and other professions, as well as the internationalisation and broad cooperation of this community in the European educational area, which are topics that should not be neglected. The EREMI project, as an international project funded under the ERASMUS + KA203 programme, involves not only research activities, but also faculty mobility, as well as other collaborative activities among higher education institutions from a number of countries, which has a positive impact on international cooperation and promotes the internationalisation of the project partner institutions.

Overall, the last few years have clearly presented a new set of challenges and opportunities for industry and education. The need for a new approach when it comes to preparing engineering students and future/current professionals for tomorrow has clearly emerged with the rapid integration of modern systems, digitalisation, the Internet of Things in various fields, the rise of artificial intelligence and Big Data as valuable and useful tools, and the need for more efficient and sustainable systems in the face of a changing climate and social issues. With the world evolving faster with each passing decade, there is a need

to create a platform that enables lifelong learning and upskilling of people tasked with solving complex engineering problems, and to do so in an efficient and sustainable way for the future. COVID-19 has also pushed this narrative to the forefront, and over the past few years, various digital platforms have shown their value when it comes to international communications, education and problem solving. Thus, as a reaction to all this, the EREMI platform is emerging, which will provide an international, digital, and interdisciplinary training, upskilling and lifelong learning environment aimed at engineering students and professionals. The following section describes the different partners involved in the EREMI project and the way in which the tasks have been distributed among them.

2.2. The EREMI Project Consortium and Task Allocation

EREMI is being implemented and conducted as a living laboratory activity. It focuses on the collaborative development of innovative learning content and a digital platform for higher education, which requires the active participation of several stakeholder groups: students, faculty, industry partners, policy makers, etc.

The engagement and roles of the partners and participants can be outlined as follows:

UFT coordinates the project. In terms of content, it actively develops and implements the EREMI learning content in the following educational and practical areas:

- Mechanical engineering;
- Electrical engineering;
- Systems engineering;
- Pneumatics;
- Energy efficiency;
- Industrial economics.

Participating students are selected by their professors, who carefully choose the most motivated and well-performing individuals. In the subsequent stage, students have the opportunity to indicate their preferred subject areas and availability as test students, allowing them to actively participate in the selection process.

The HSO is responsible for the overall organisation and launch of the ITP, as well as for the development of the content of the educational areas related to the (Industrial) Internet of Things ((I)IoT):

- Communication systems;
- Sensor systems;
- Edge computing.

HSO has the opportunity to include participants in its adult learning programmes, with the aim of testing EREMI content during their training at its Centre for Lifelong Learning in Offenburg (CeLLO).

UPB takes charge of developing the EREMI learning content package in the domain of Big Data analytics. With the assistance of local BEIA support, UPB will conduct a test deployment and an ITP (Initial Test Period) that encompasses both order and duration.

BEIA is assigned the responsibility of carrying out the test implementation of the professional courses focused on the digitisation of physical systems. As previously mentioned, BEIA will collaborate with UPB to conduct the ITP, primarily during adult education workshops that cater to IT professionals.

The responsibility of developing EREMI content in the field of Resource Efficiency in Manufacturing Systems and Facilities lies with UKLO. Furthermore, UKLO has effectively integrated the EREMI content into modules within a lifelong learning programme designed for adults and retirees. This programme has undergone a substantial phase of development and validation during the project's implementation.

The partners involved and their responsibilities, as well as collaborations among the participants, are shown in Figure 1 and described as follows:

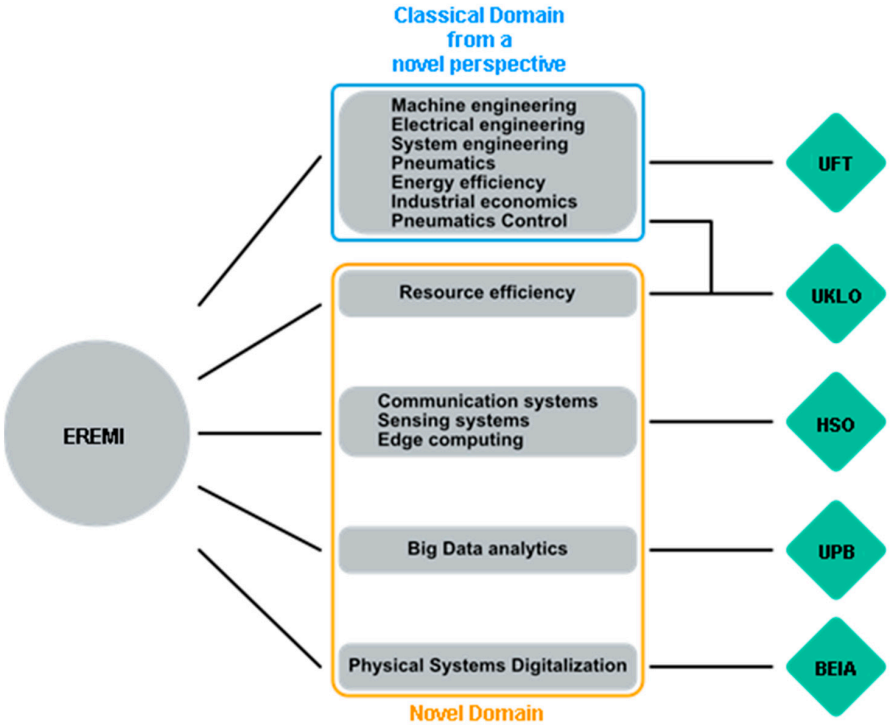


Figure 1. A graphical representation of the main focus domains within the development of the curriculum, and how the particular partners collaborate in them.

2.3. The EREMI Learning Contents Package

UFT led the collective development and delivery of a highly innovative ITP training programme focused on resource efficiency skills in manufacturing systems for undergraduate and postgraduate students (e.g., in mechanical engineering, electrical engineering, pneumatics, etc.), which is currently identified as a serious gap by industry across the EU and Bulgaria in particular, i.e., there is a lack of adequately educated engineers. The programme emphasises the utilisation of IoT-based technologies to enhance efficiency, ensuring that components, machines, systems, and factories are future-proof. In addition to addressing general learning objectives related to IoT and data analysis, the programme delves deep into the topic of energy savings in high-dynamic pneumatics. This serves as a practical use case, allowing students to explore the subject extensively. Moreover, the EREMI programme also covers predictive maintenance, which is a cross-cutting thematic area known for its potential to achieve substantial resource savings.

UPB and BEIA jointly developed the ITP, leveraging their expertise in software, processing and communication for the use and integration of large energy efficiency datasets in manufacturing facilities and buildings, from education, R&D and practice. They have been working together on industrial and scientific projects for a long time, and have established their expertise and experience.

The HSO has actively supported the development of the virtual ILT (ILT) platform, playing a lead role, followed by embodying the ITP in an interactive ILT training toolkit and upgrading/adapting the training content. In addition, HSO has leveraged its expertise in retrofitting IoT-based devices to perform condition and energy monitoring in manufacturing facilities.

UKLO played a significant role in the co-development of EREMI content, leveraging its expertise in the efficient utilisation of industrial resources. As the sole partner of the consortium from North Macedonia, UKLO contributed to the creation of a distinctive lifelong learning module. This module holds great potential for enabling adult learning and facilitating occupational reorientation for valuable members of the workforce in North Macedonia. With the country expecting to experience intensified industrialisation in the

coming years, the module addresses the growing need for skilled labour, aligning with the intensive industrialisation in the country.

UKLO, UPB, and BEIA are actively involved in the implementation of the new platform as a demonstration case, focusing on the collaboration between UFT and the education unit within the industrial zone surrounding the TPP Plovdiv. By leveraging their expertise and experience, the consortium members are dedicated to refining the ITP and virtual toolkit based on valuable insights gained during the test implementation phase.

The final outcome of the project will be a dynamic teaching/learning platform that specifically caters to the needs of university students and postgraduate professionals. This platform serves as a valuable resource for relevant universities, students, and companies seeking rapid and effective professional training in a critically important field for industries across the EU. It holds particular significance for industries undergoing transformation, such as those in the Plovdiv region of Bulgaria, which are experiencing rapid industrialisation trends and facing a shortage of adequately educated engineers in this strategic area of industrial engineering.

The ITP serves as a basis for an international joint Master's programme on the EREMI theme, which will be implemented by the participating partner higher education organisations, which will be accredited following the completion of the EREMI project, due to country-specific accreditation criteria and deadlines.

The ITP and ILT serve as the basis for the establishment of a network of EU universities and a student mobility programme in a follow-up ERASMUS Mundus project.

In the framework of the project, HSO developed and implemented a new format allowing more efficient knowledge transfer. It is based on augmented reality and offers pre-recorded lectures in a suitable industrial environment, combined with static lecture materials that provide a solid foundation for students' learning.

2.4. The Desired Impact of EREMI

EREMI is aimed at one of the most important target groups in education, the much-needed field of multifunctional manufacturing systems engineers, who are expected to cope with the ever-increasing demands for energy efficiency and diminishing resource volumes in every aspect.

EREMI's main unique commercial advantage is its interdisciplinary approach to imparting knowledge originating from several classical engineering fields, combined with the necessary areas for digitalisation and virtualisation of production environments and perfect management of complex systems in terms of optimal resource efficiency with respect to production capacity and raw materials.

By developing and implementing an interdisciplinary core of knowledge and a new learning system through international online teaching and learning combined with virtual and augmented reality, the project team aims to dramatically increase the interest and motivation among active engineers across Europe and beyond to build a better understand and to the ability to develop and manage complex systems approaches in the context of the manufacturing industry.

EREMI aims to lay the foundations for the creation of a new generation of capability in systems engineering throughout Europe, enabling Europe to have a strong interdisciplinary pool of experts capable of working in different environments in terms of culture, different specific manufacturing industries, and legal requirements.

By offering both a broad overview of the core subject areas and an in-depth understanding of each of the professional fields, including the classical engineering disciplines as well as the IoT and Big Data fields, EREMI offers a unique platform for training and knowledge transfer to all stakeholders—industries, universities, learners from a wide range of demographics, and academia—allowing a new generation of interdisciplinary experts capable of working in a highly international context to emerge and continuously develop.

UKLO developed a new learner feedback model that was implemented in the project to produce a summary of the intended lessons learned.

2.5. The Quality Feedback Survey of EREMI: Strategic Approach and High-Added-Value Project Element

The quality feedback survey was developed by the project team during the second half of the project implementation period with the aim of making it a fixed element of the EREMI online learning platform and a mandatory requirement for course completion. The students are expected to understand the need for the EREMI team to receive quality feedback on the provided online learning materials in order to be able to optimise the educational product and thus optimally meet the demands of the European industry and economy, as well as, of course, those of the learners themselves.

The anonymous questionnaire, which also provides important information on the organisation of the students' learning, is structured in five sections—I. General information; II. Course content; III. Learning outcomes; IV. General evaluation; and V. Qualitative, open-ended response—and consists of 20 single-choice questions [37].

The aim of the querent survey was to optimally gather learners' objective and subjective perceptions of EREMI's learning content, taking into account its real-world relevance to the market, the learners' expectations, and the learners' career goals and understanding of industries as complex interdisciplinary and international professional environments.

3. Results

EREMI has resulted in the following three main pillars of knowledge and the generation of their respective added value:

3.1. The EREMI Close-to-Practice Interactive Learning Contents Package Will Be an Answer to the Challenges Faced Today by the Industry in the Context of Upskilling, Lifelong Learning, and Rapid Digitalisation in the Following Directions

In terms of interdisciplinarity, the aim of the project is to provide value and skills to a wide audience of engineering professionals and students, consisting of a broad set of topics aimed at addressing challenges arising from the need for digitisation, efficiency and sustainability. The suite of learning content provides essential and sought-after knowledge, targeted at individual learners and the industry as a whole, in a way that will provide lifetime value and a modern update of the skills coming from classical engineering disciplines. As claimed by the authors of [11], the human component is crucial to industrial digital upgrading, and promoting employee retention with the help of specialised training is a key aspect that companies must bear in mind.

Observing the degree of response to trends identified in labour markets and industry developments in the partner countries and at the European level, it has become clear that the learning platform constitutes a response to the increased demand for and shortage of skilled professionals in the partner countries, as well as in the EU as a whole, in the areas of industry and engineering related to the digitisation of production, the use of artificial intelligence, the Internet of Things and Big Data, as well as the need for greater efficiency. Courses on the platform are drawn from a wide variety of disciplines, including advanced and new ones, with the idea of giving learners a more complete view of this highly interdisciplinary area of the manufacturing industry environment, characterised by complex systems of systems needing a broad perspective in terms of achieving an overall reduction of resource consumption, going into detail regarding different types of resources and energy forms, including raw materials, secondary raw materials, compressed air and process heat. Among the subjects introduced are the following:

Classical Subjects: The platform offers subjects in relevant classical engineering areas, as a solid foundation with a good understanding of the basics is required for learners to easily transfer to new subjects related to the digital world and be able to connect and integrate the classical with the new in an effective manner. The field of classical subjects ranges from mechanical and electrical engineering to industrial economics, and is offered to students in a manner close to what is used in practice.

New Subjects: One of the main reasons to create such a platform is to have a place to learn the new skills required for modern industry. Having new subjects in the curriculum

will help students connect their existing knowledge with the digital skills needed for a new efficient and sustainable environment. The area of new subjects revolves around IoT, communication systems, sensor systems, Edge computing, etc.

Industry Needs: The needs of higher education systems and relevant industrial areas in partner countries are discussed, including the need to create innovative resources to support academics, and the need for innovative teaching methods to motivate students and deepen their knowledge so that they are fully prepared for the job market in the manufacturing industries of the near future.

Learner Capabilities: The target groups are (a) young people, (b) young and older professionals, and (c) all persons interested in learning and becoming involved in the activities and development of industry, in particular the manufacturing industry of the future.

Unique Expertise: The project targets learners from different demographic groups and academic backgrounds, providing the labour market with a wide range of interdisciplinary professionals and experts able to meet the challenges of tomorrow and work in an international environment, while developing continuously.

Continuous Learning Methods: In the context of a rapidly evolving industry and the digitalisation of the work environment, it is necessary to provide engineers with the knowledge required to keep their skills up to date. The courses created for the EREMI platform address the precise need for lifelong learning for engineers in the field of resource efficiency in manufacturing industries.

3.2. The EREMI Learning Platform's Goal Is to Be an Easy-to-Use Place and Means for Interdisciplinary Modern Industrial Knowledge to Be Disseminated among Willing Learners

Moodle: The aim of the project was to create a place where knowledge can be shared freely, and education can be carried out seamlessly. It is for this reason that EREMI chose to use a modern open-source platform called Moodle. The values of this platform are perfectly aligned with the project idea discussed in this document. Its founding principle is to democratise quality online education by making it accessible to all. Moodle has received many awards, is certified as a B Corporation, and is a member of Open Education Global and the UNESCO Global Education Coalition.

Access is granted after registration following first contact through the project website; for each new learner, following registration with the platform, the platform will be unlocked, and a first contact will take place on the basis of an introduction on the project website.

Easy to use: One of the project's goals was to make the acquisition of knowledge and skills, as well as the navigation of the educational platform, as easy a task as possible. This helps immensely in making learning more effective, as well as in getting to where you want to be.

All learning content is available in English. In this way, the project ensures that the knowledge will have the best chance of reaching the widest audience and being universally understood.

Innovative combination of lectures and tasks/exercises: The platform offers a new collection combining lectures and practical tasks/exercises to give the highest possible value to learners when it comes to acquiring new skills in today's digital world.

3.3. The EREMI Platform and the Distribution of Its Quality Feedback Survey and Assessment System as a Standard, Where Its Impact Is Expected to Be That It Allows the Better Evolution of the Project for Each Involved Stakeholder: Survey Results

The first part of this feedback system consists of a learner questionnaire which consists of various questions ranging from general information to learning outcomes and course content. The questions are in a multiple-choice response format. The idea is to integrate the questionnaire directly into Moodle and make it a prerequisite for course completion.

The second part of this system is to create a summary of lessons learned that will help improve and enrich the platform. Each such summary will be created based on feedback

provided by a number of completed questionnaires, as well as those from the previous section.

The decisive result of the EREMI quality feedback survey, with over 100 learners responding among the partner organisations and countries, given the extremely short response time following the completion of the courses and the design of the survey, is highly positive feedback from most learners, meeting and even exceeding their expected level of quality.

Over 50% of them responded with very positive feedback to most questions.

The distribution of responses according to the trainees' alma mater and specific area of core expertise, as well as previous academic or educational experience, is interesting, with the highest number of responses being received from scholars in Romania, followed by North Macedonia, as well as Bulgaria and Germany. This speaks, on the one hand, to the degree of integration of EREMI materials into the daily teaching and learning process, and on the other hand, to the openness of scholars to digital learning and online research.

Statistical data can be presented dynamically in a variety of ways thanks to the flexible questionnaire tool used, which was offered by one of the world's largest data management and processing partners.

A detailed statistical evaluation of the survey results is presented below, as well as a trend analysis of the identified student/student movements.

Improving courses requires significant input from students, and a critical aspect of improving the quality of higher education is the self-assessment of higher education institutions. In the process of self-evaluation, students play a significant role by contributing to the perception and evaluation of the quality of curricula, teaching methods and other learning-related issues.

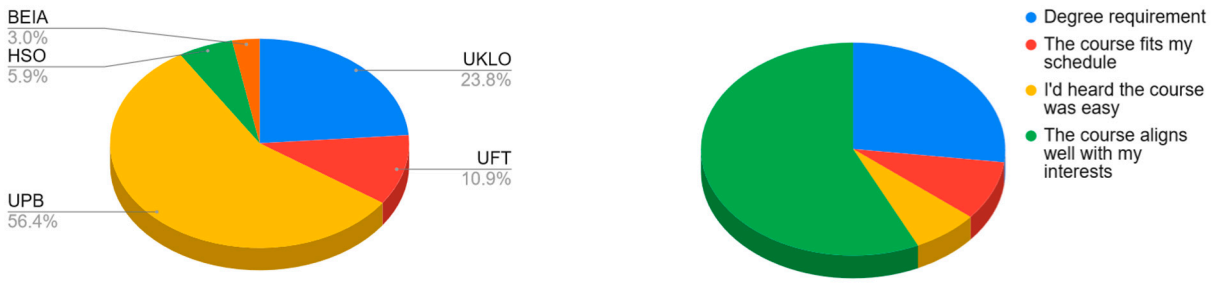
Post-course evaluation is an important step in e-learning design, as it allows course designers to obtain feedback and input from learners, which can then be used to improve future learning materials and courses. Course evaluations not only provide valuable information for course improvement, they also offer learners the opportunity to reflect on their learning and provide feedback. One of the most common indirect methods of course evaluation is through course evaluation surveys, which provide an opportunity to capture learners' perceptions of their learning experiences, expectations, and attitudes toward the learning process. A survey-type questionnaire was prepared as a course evaluation tool to help improve the content of EREMI courses and to further develop online learning materials based on participant feedback.

The designed questionnaire consists of five parts, each with a different focus. The first part asks for general information about the respondents [33]. The second part of the questionnaire contains nine questions that are related to the course content, and the third part of the questionnaire contains four questions that are related to the learning outcomes. The fourth part contains four questions that relate to the overall perception of the course. The last part of the questionnaire has open-ended questions that allow respondents to provide more detailed information and explanations. The questions in Parts II, III and IV are of the five-point Likert scale type, ranging from 'strongly disagree' to 'strongly agree'. Questions of this type are intuitive and universal, providing clean data that are easy to analyse and understand.

An online survey was conducted in April 2023 using the Google Forms platform. All students who had taken relevant courses were invited to participate in the survey, which included open-ended questions that allowed respondents to provide more comprehensive information and explanations. A total of 101 people participated in the survey, and all information revealed by respondents was treated confidentially and analysed anonymously.

By analysing the data collected through the survey questionnaire, it is possible to gain insight into both the strengths and weaknesses of the material published online. The feedback received from the learners during this process can be used to improve various aspects of the online courses and to better understand the needs of the learners, facilitating the continuous development and improvement of the EREMI concept.

Figure 2 presents the participants' institutions and the main reason for choosing the course. As the main reason for choosing a particular course, 57% of participants indicated that the course was a good match for their interests.



(**a**) (**b**)

Figure 2. General information: (**a**) participants' institutions; (**b**) primary reason of choosing the course.

The survey questions are shown in Table 1, along with their corresponding importance ratings, as provided by students on a five-point Likert scale (ranging from 1 = strongly disagree to 5 = strongly agree). Among these questions, the quality of the provided learning materials received exceptionally high importance ratings, ranging from 4.4 to 4.8 on the Likert scale. The term "Mean" represents the average value, whereas "SD" refers to the standard deviation.

Figure 3 illustrates respondents' agreement regarding course content. Improving course content is a focus of the survey, as learners can provide valuable input on course structure, logical flow, materials, and quality of content. Feedback from learners indicates that they agree or strongly agree that the courses are well organised, appropriately presented, professionally developed, relevant, and address existing issues.

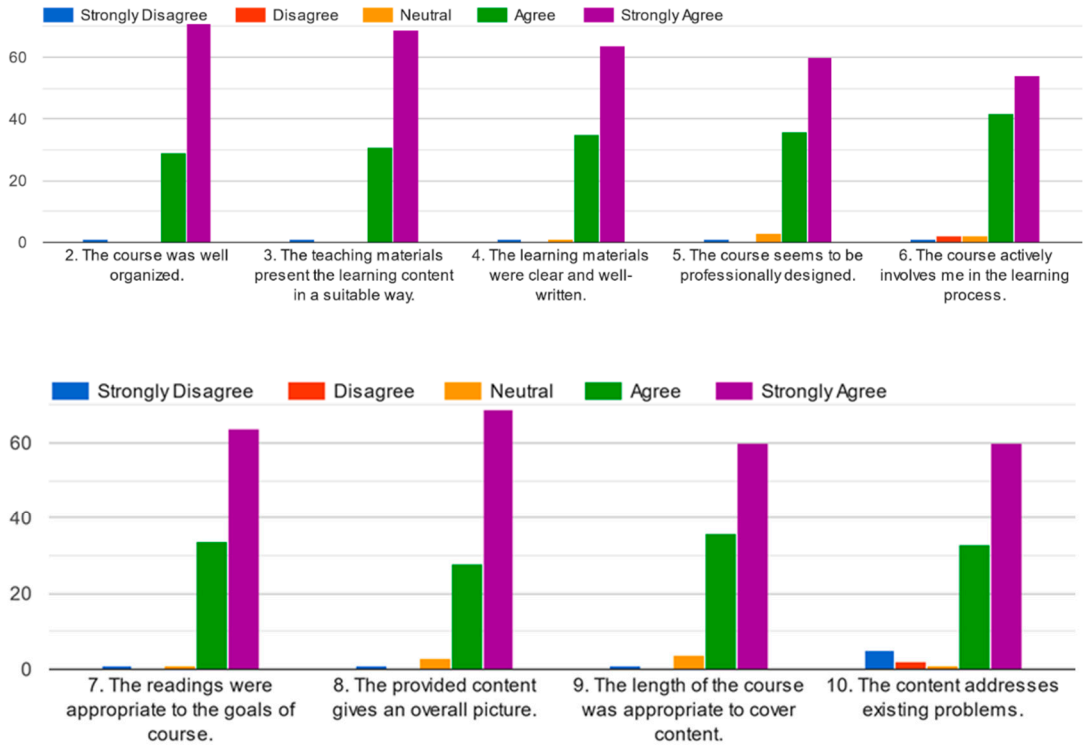


Figure 3. Course content.

Table 1. Importance of different questions in the survey.

	Total		UKLO		UFT		UPB		HSO	
Questions	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
II Course Content (2. The course was well organised.)	4.67	0.58	4.75	0.44	4.64	0.50	4.65	0.67	4.83	0.41
II Course Content (3. The teaching materials present the learning content in a suitable way.)	4.65	0.59	4.88	0.34	4.73	0.47	4.58	0.68	4.50	0.55
II Course Content (4. The learning materials were clear and well-written.)	4.59	0.62	4.79	0.41	4.45	0.52	4.56	0.71	4.50	0.55
II Course Content (5. The course seems to be professionally designed.)	4.53	0.66	4.42	0.50	4.00	0.77	4.63	0.67	5.00	0.00
II Course Content (6. The course actively involves me in the learning process.)	4.45	0.73	4.46	0.72	4.64	0.50	4.46	0.78	4.17	0.75
II Course Content (7. The readings were appropriate to the goals of course.)	4.56	0.71	4.71	0.46	4.36	1.21	4.58	0.71	4.50	0.55
II Course Content (8. The provided content gives an overall picture.)	4.62	0.65	4.58	0.50	4.73	0.47	4.58	0.75	5.00	0.00
II Course Content (9. The length of the course was appropriate to cover content.)	4.52	0.67	4.42	0.65	4.82	0.40	4.54	0.73	4.50	0.55
II Course Content (10. The content addresses existing problems.)	4.40	0.99	4.67	0.48	4.55	0.52	4.23	1.23	4.50	0.55
III Learning Outcomes (11. This course helped me develop intellectual skills (e.g., critical or creative thinking, quantitative reasoning, problem solving, etc.).)	4.44	0.67	4.42	0.58	4.36	0.81	4.51	0.68	4.00	0.63
III Learning Outcomes (12. This course helped me develop professional skills (e.g., written or oral communication, computer literacy, teamwork, etc.).)	4.47	0.63	4.46	0.51	4.45	0.69	4.51	0.68	4.33	0.52
III Learning Outcomes (13. The course improves my understanding of the topic.)	4.67	0.51	4.71	0.46	4.73	0.47	4.63	0.56	4.83	0.41
III Learning Outcomes (14. The course gave me the confidence to do more advanced work in the subject.)	4.56	0.57	4.63	0.49	4.82	0.40	4.54	0.63	4.33	0.52
IV Overall (15. I would recommend this course to others.)	4.64	0.52	4.83	0.38	4.82	0.40	4.58	0.57	4.50	0.55
IV Overall (16. The course was helpful in progress toward my degree.)	4.62	0.55	4.79	0.51	4.82	0.40	4.56	0.57	4.33	0.52
IV Overall (17. Overall, this course stimulated my interest in this subject.)	4.69	0.46	4.75	0.44	4.73	0.47	4.67	0.48	4.67	0.52
IV Overall (18. Overall, this course met my expectations for the quality of the course)	4.75	0.46	4.79	0.41	4.91	0.30	4.74	0.48	4.50	0.55

Figure 4 shows the results of respondents' answers on learning outcomes. Evaluating learning outcomes is critical to measuring the success of a course. Although online quizzes or other types of assessments can be used for evaluation, it is valuable to gather learners' opinions on the final outcome. The primary goal of an online course is to move learners from one level of knowledge to another, so it is important to determine whether this goal has been met, and to what extent, and to identify opportunities to improve the course for future learners. According to the survey results, participants agreed or strongly agreed that the courses helped them achieve additional competencies and skills.

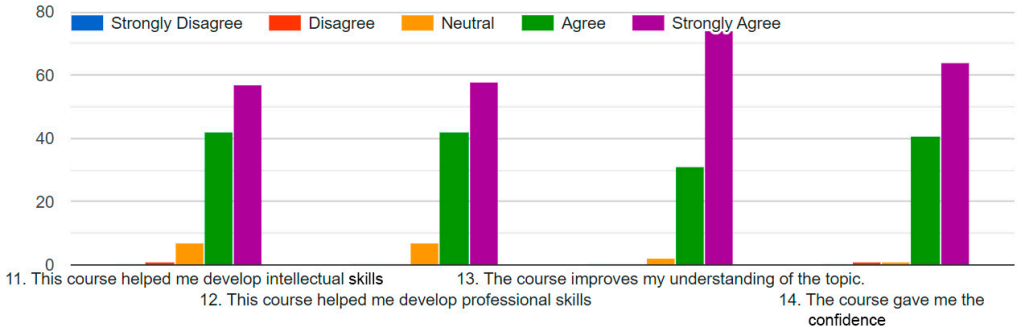


Figure 4. Learning outcomes.

Figure 5 illustrates the general impression of the courses. The responses to these questions confirm the success of the courses, and their usefulness, effectiveness and benefit to the students' educational process. Although more general, this type of information can be used to refine the marketing message and attract new learners.

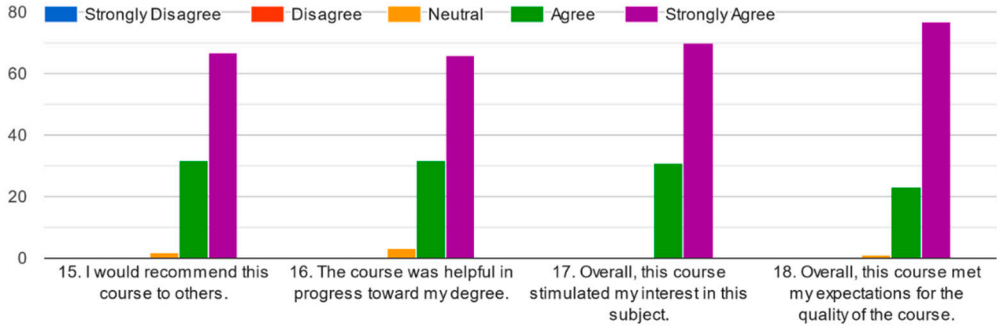
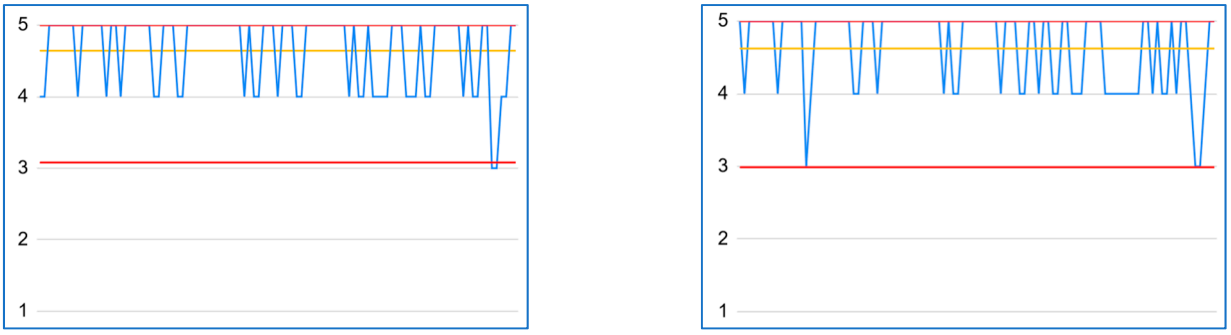


Figure 5. Overall.

Distributions of the responses for questions IV Overall 15 (I would recommend this course to others) and IV Overall 16 (The course was helpful in progress toward my degree) are illustrated in Figure 6. The provided data clearly show that a significant majority of respondents allocated the highest possible scores, falling within the range of Mean–3·SD up to a maximum value of 5 (indicated by red lines) for both questions.



(**a**) (**b**)

Figure 6. Distribution of the responses for questions (**a**) IV Overall 15. I would recommend this course to others. (**b**) IV Overall 16. The course was helpful in progress toward my degree.

At the end of the survey questionnaire, open-ended questions are provided to collect additional feedback and general responses from students, making the survey complete. The purpose of these questions is to gather qualitative feedback that is open ended, allowing more detailed information and explanations to be gathered.

The analysis of the survey data provides valuable insights that can be used to improve the virtual toolkit and innovative teaching program.

4. Discussion

COVID-19 presented humanity with a huge challenge, but arguably also provided a much-needed catalyst for industry, forcing it into a trend towards digitisation that was undoubtedly going to come sooner or later. Thus, the EREMI project comes at the right time, when the need for new digital and sustainability skills in the engineering field, as well as the need for adaptable digital learning platforms, is at its greatest.

Based on the lessons learned throughout the entire runtime of the project, the EREMI undertaking has also provided feedback to policy makers based on the lessons learned in order to have an even wider impact on the education system. This happened in the form of policy recommendations, expressed during the final conference event at UFT, which brought together prominent representatives from industry, education, and R&D, as well as policy makers. Some of the relevant necessary guidelines for policy makers that are and will be the focus of attention are the following:

- Create a better link between theory and practice throughout the education process, as this is likely to lead to the best outcomes for both individual learners and industry.
- Create a more flexible education system that allows easy knowledge transfer and the development of new courses aimed at future professionals.
- Allow teaching staff to upgrade their qualifications more easily in order to bring classical university courses closer to the needs of modern industry.
- Enable industry professionals from outside academia to teach and transfer much-needed knowledge and skills to higher education institutions.
- Connecting different disciplines in an interdisciplinary curriculum is the right formula for generating the much-needed human capital of the future highly digitised yet physical industrial European landscape.

How can we reach interested but uninformed learners and future practitioners more effectively? Information campaigns among graduates and working professionals? Naturally, one of the biggest hurdles for any project is how to reach an interested audience. One of the most sensible ways, especially in a highly digital world, is to use the Internet and its various platforms. An example of this is the use of social media, especially LinkedIn, for outreach campaigns, such as sharing lessons learned and achieving key project objectives. In addition, dissemination is also done through the publication of scientific articles that are announced on relevant social media channels.

It will be crucial in the future not only to optimise the learning content of EREMI and its follow-up projects based on the improved feedback system put in place, but also to do so on the basis of continuously improving quality feedback questionnaires. This means that the quality feedback questionnaire systems themselves need to be continuously improved, as they serve as a guarantor for the optimisation of the learning content.

EREMI has reached its goals in terms of setting up a solid base for further development towards achieving efficient comprehensive and accessible transfer to scholars based on the principles and applications of sustainability in all its forms, in the context of the highly necessary reduction in resource consumption in manufacturing industries.

5. Conclusions

The implementation of EREMI's learning content resulted in the creation and expansion of higher education courses and programmes that have become integral and sustainable components of the educational process in partner universities and organisations around Europe, aiming at achieving a well-designed and greatly needed industrial transition towards resource efficiency, circularity and, finally, sustainability, by integrating digitisation in industrial planning and operation processes. This ensures their long-term availability and accessibility to all individuals seeking to utilise and benefit from them. This project also paved the way for the development of an international joint Master's

programme on resource efficiency in manufacturing industries, known as EREMI, which will later be finalised and accredited at the national level in the four partner countries. To support this large-scale endeavour, collaborations with ERASMUS Mundus, as well as local and regional industrial stakeholders, will be pursued to secure additional funding. The envisioned outcome is the cultivation of internationally trained and experienced interdisciplinary engineering professionals, who will play a pivotal role in shaping the sustainable and resource-efficient manufacturing industries of the future.

Currently, EREMI's interactive educational resources are accessible to all interested stakeholders, simply by registering with the learning platform. These resources are designed to be utilised not only within the technical specialties of higher education, but also by training centres, business organisations, and enterprises, all aiming to reach higher levels of sustainability in all of its forms within their operations and structures.

The digital format of these resources, combined with augmented reality/virtual reality (AR/VR)-based learning content and live interdisciplinary discussions, allows for adaptability to different contexts and facilitates knowledge transfer for entering new areas. Furthermore, this approach will influence future higher education policies and practices. The sustainability of the project is further ensured through the support of stakeholders, including active participation from relevant sector partners like the Trakia Economic Zone, the largest agglomeration of industrial parks in Bulgaria and the Balkans.

The quality feedback survey system will be further developed, as it clearly provides the project team, and teachers in general, with crucial insights, on the basis of which further optimisation of the teaching content is carried out on a daily basis [42].

The overall result is a high level of sustainability in both senses: (a) in the continuity of the educational system and its constant further optimisation and development; and (b) as a main outcome of the educational process, by embedding the EREMI's graduates into the industrial landscape and network of Europe.

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