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An Innovative Approach By ENTER Network: Integrating Sustainable Development Into Professional Training For Engineering Educators

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ABSTRACT

This paper discusses the development of a new pedagogical training program for engineering educators, created by the ENTER Network and co-funded by the EU. The program consists of modules that include courses designed to develop specific competencies. The selection of courses and competencies was based on surveys conducted with various stakeholders, including engineering educators, HEI administration, HEI engineering students, potential employers of HEI engineering graduates, and representatives of governmental bodies involved in education. The paper focuses on the relevance and origin of competencies addressed in the Sustainable Development Course, and presents the syllabus for this course, including information on its objectives, content, teaching materials, structure, and assessment procedures.

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1 INTRODUCTION

The prevailing complexities of the 21st century necessitate an intersection of various disciplines to address the challenges that our world currently faces. Engineering, a crucial player in societal development, has a significant role in navigating these issues. Notably, the United Nations Sustainable Development Goals (SDGs), agreed upon by 193 member states in 2015, encompass several engineering-related targets that aim to better the quality of life for humanity. To this end, the need to align engineering education with the principles of sustainable development is paramount. The rationale for integrating sustainable development in engineering training is manifold. Primarily, the engineering profession directly influences human health, safety, and overall wellbeing. As such, engineering educators bear a significant responsibility to ensure that their teachings are aligned with SDGs. Traditional education often falls short in this regard as it provides limited opportunities for educators to explore and solve real-world problems. Hence, the necessity to incorporate sustainable development principles into engineering education becomes evident.

The ENTER Network's pedagogical training programs for engineering educators is an innovative approach to integrating sustainable development principles into engineering education. Embarking on a mission to revamp professional development programs for engineering educators, the ENTER Network developed a comprehensive, multi-level modular system. The programs, grounded in international cooperation and available in various formats, were designed to cater to the evolving needs of educators in this field.

To tailor the programs effectively, a broad survey was conducted across several countries to identify essential competences. Stakeholders ranging from engineering educators, higher education institutions' administration, students, employers, to government educational bodies were involved, ensuring a comprehensive perspective on the competences required for advanced engineering pedagogy

2 SELECTION OF COMPETENCES FOR THE PROFESSIONAL DEVELOPMENT PROGRAM

Under the ENTER Project, a major aim was to identifying the competences to be addressed in professional development programs for engineering educators. These programs were conceived as multi-level modular system for pedagogical training of engineering educators based on an international network cooperation, offered in different formats: onsite, online, and blended learning.

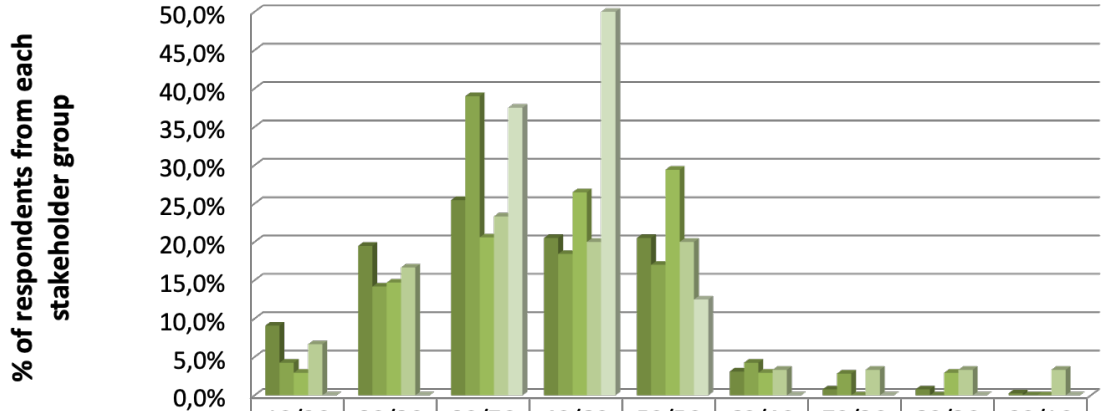
A broad survey was implemented in several countries to identify essential competences for these programs, as suggested by various stakeholders. The stakeholders' importance value, the proportion of universal and professional competences, and the final rating of competences and courses were key areas of discussion. The final examine survey resultsed on competences proposed by different stakeholders. Five stakeholder groups were identified:

- Engineering Educators/Faculty members,
- Higher Education Institutions (HEI) administration,
- Engineering students,
- Employers,
- Representatives of governmental educational bodies.

The survey result for the five groups of stakeholders was: 497 out of 600 Engineering Educators/Faculty members, 163 out of 200 from HEI's administration, 56 out of 60 Engineering students, 75 out of 100 Employers, and 22 out of 40 Representatives of governmental educational bodies, totaling to 813 out of a possible 1000 respondents.

2.1 Survey Results

The survey provided valuable insights into the proportion of interpersonal competences (IC) and professional competences (PC) required for advanced training programs. The summary of this survey weighting IC/PC is depicted in figure 1.



	10/90	20/80	30/70	40/60	50/50	60/40	70/30	80/20	90/10
Engineering Educators	9,1%	19,5%	25,5%	20,5%	20,5%	3,1%	0,8%	0,8%	0,3%
HEI administration	4,3%	14,2%	39,0%	18,4%	17,0%	4,3%	2,8%	0,0%	0,0%
Employers	2,9%	14,7%	20,6%	26,5%	29,4%	2,9%	0,0%	2,9%	0,0%
Students	6,7%	16,7%	23,3%	20,0%	20,0%	3,3%	3,3%	3,3%	3,3%
Government reps	0,0%	0,0%	37,5%	50,0%	12,5%	0,0%	0,0%	0,0%	0,0%

Fig. 1. The interpersonal competences (IC) and professional competences (PC) ratio for advanced training programs (% IC / % PC)

Interestingly, four competences were eliminated from the final rating. These included specific knowledge areas in pedagogy and engineering, the ability to represent one's professional group, and a deep understanding of the teaching course area and teaching methods. The remaining competences were mapped to the proposed professional development program courses.

2.2 Competence Rating

Participants were asked to assess the importance value of each stakeholder group. This process led to a unit weight of stakeholder's importance, which was critical in determining the final rating of competences and courses.
Based on the survey results and stakeholder importance, a final rating of competences (top 14) was produced. Considering these competences, courses were created and divided into 3 modules of Professional Development Programs..
The competences considered relevant by the stakeholders were the following 14 competences:
1 - Innovations in engineering pedagogy.

Ability to choose optimal strategies and teaching methods using traditional and innovative means, taking into account technosphere development paths, trends and challenges in engineering education

2 - Time management

Ability to manage time efficiently and prioritize professional activities

3 – Effective interaction

Ability to effectively interact with audience and increase students' interest in the discipline, using psychological tools and multimedia technologies

4 - Enhancement of learning interactivity

Ability to develop, adapt and implement modern interactive teaching and learning methods and technologies (inter alia, aimed at increasing students' motivation)

5 - Systems analysis in education

Ability to apply system approach to solving problems of Engineering education

6 - Pedagogical psychology and communication

Ability to apply psychological and pedagogical technologies to professional activities of a teacher

7 - Interaction with stakeholders

Ability to work efficiently with the results of scientific research to ensure their publication, to cooperate with labor market and other stakeholders

8 - Sustainable development

Ability to apply the principles of Sustainable development in the global context

9 - Digital education

Ability to design, organize and accompany educational process in X-learning environment

10 - Problem-based, project-based and Practice oriented learning

Ability to form students' experience of individual and team work on solving real engineering problems and developing of new engineering solutions

11 - Learning outcomes' assessment

Ability to design forms and methods of continuous monitoring, feedback and final assessment of education quality

12 - Course design

Ability to develop teaching materials that foster students' competences formation

13- Engineering innovation process

Ability to lead research, innovative and design activities (work) of students and student teams, and to foster students to generate innovative ideas, to operate their development and implementation stages.

14 – Lifelong learning

Ability to "ongoing, voluntary, and self-motivated" pursuit of knowledge for either personal or professional reasons, enhancing social inclusion, active citizenship, and personal development, as well

The insights gained from this analisys are considered instrumental in shaping the future of engineering pedagogy, thus equipping the next generation of engineers with the skills and competences they need to succeed in their profession.

3 SUSTAINABLE DEVELOPMENT COURSE: DESIGN AND DEVELOPMENT

The Sustainable Development course, a key component of the program, seeks to improve and develop the knowledge, understanding, skills, and abilities of engineering educators to teach students to recognize that engineers operates in a

broad societal context and to take that context into account in their professional activity. The main aim of the course is to develop strategy to incorporate sustainable development principles into engineering education at large, including specific engineering courses.

3.1 Course Aims and Structure

The course aims to instill sustainable development (SD) mindsets on both professional and personal levels. It promotes critical thinking, holistic systems thinking, entrepreneurial thinking, global mindset, cultural agility, and valuing learning over knowing[^2^]. These qualities are unique to humans and cannot be replicated by machines, highlighting their importance in the education of future engineers.
The course also seeks to design learning for human needs. In the 21st century, higher education must shift the learners' perception that learning is not just about the acquisition of knowledge and skills, but also about developing human qualities and dispositions to cope with an uncertain world[^3^]. As such, the course is designed to focus on gaining skills to learn and relearn, and to change perspectives. It implies that the current faculty-centred curricula (anchored by existing physical spaces, staff resources, time-bound schedules) have to be transformed into (more) learner-centred and meaningful curricula with freedom of choice for the students.
Importantly, the course also aims to nurture a culture of experimentation and innovation, promote impact-focused education, develop the necessity of analysis through the prism of a green society, integrate scientific and professional integrity in the curricula, strengthen university-industry collaboration, and empower students to foster leadership and ethical behavior[^4^].

3.2 Methodology

The approach taken in the creation of the Sustainable Development Course began with the identification of key competencies required for effective teaching of sustainable development principles in engineering education.
The ENTER Network applied an innovative approach to the development of the training program, utilizing a blend of traditional and modern pedagogical techniques, such as Problem-Based Learning (PBL), Forum Theater, Jigsaw, Team-work, and Case study. This methodological approach was designed to promote active learning, critical thinking, and creativity, essential skills for engineering educators seeking to incorporate sustainability into their teaching (Thomas et al., 2019).
The course syllabus was structured to provide a comprehensive overview of the concepts and practices of sustainable development, with a specific focus on their application to engineering education.

3.3 Course Description

The Sustainable Development Course, as part of the IPET 2 Program, is a compulsory course offering a total contact time of 20 hours, divided between lectures, tutorials, and practical or project work. The course is designed to foster the development of sustainable development (SD) mindsets on both a professional and personal level, and the design of learning experiences that meet human needs. The course also emphasizes impact-focused education, the importance of green society analysis, the culture of experimentation and innovation, the integration of scientific

and professional integrity in the curricula, university-industry collaboration, and the empowerment of students to foster leadership and ethical behavior.
The course content is distributed as follows: an Introduction to Sustainable Development, comprising 10% of the course; Engineering Curriculum and Education for Sustainable Development, comprising 20%; Pedagogical Strategies for Learning Sustainability in Engineering Education, comprising 30%; SDG Challenge as the capstone project, comprising 25%; and Extracurricular Activities to Foster SD Ethos, comprising 15%.
The teaching materials for the course include a variety of sources such as handbooks, resource guides, journal articles, and technical reports. The main teaching materials are provided by Mulder (2006), Leal Filho and Nesbit (2017), Sivapalan, Clifford, and Speight (2016), and WFEO (2015), with complementary teaching materials sourced from Graham (2018), Grasso and Burkins (2010), Henderikx and Jansen (2018), Kamp (2016), and UN (2015).

3.4 Course Learning Outcomes

Upon successful completion of the Sustainable Development Course, in conformity with EUR-ACE accreditation criteria, the students should be able to demonstrate the following learning outcomes as shown in Table 1.

Table 1. Sustainable Development Course Learning Outcomes

Group of outcomes	**Outcome (number & name)**
Knowledge and Understanding	LO1 - Nurture mindsets and meanings in curricula; LO2 - Develop agile curricula with flexibility and freedom of choice for the students;
Engineering Analysis	LO3 - Develop the necessity of the analysis through the prism of green technologies;
Engineering Design	LO4 - Promote impact-focused education through interdisciplinary student-centred projects with societal relevance (where societal relevance is the centre of engineering).
Investigations	LO5 - Nurture a culture of experimentation and innovation in education on a limited scale, within a strategy for implementing more widely successful innovations;
Engineering Practice	LO6 - Integrate scientific and professional integrity and business ethics in engineering curricula; LO7 - Intensify the collaboration with industrial partners and create more opportunities for engineering practitioners in the classroom, engineering projects and internships at companies;
Transferable Skills	LO8 - Empower students (intra- and extracurricular) to foster leadership, ethical behaviour, deep collaboration, interdisciplinarity and creativity.

3.5 Assessment Procedures

The assessment for the course involves an initial self-assessment, designed to diagnose the SD ethos of enrolled educators. This does not impact the course evaluation but serves to inform educators of their starting point. The main form of assessment is through the creation of a portfolio, which engineering educators compile over the course of the professional development program elaborating their own strategy in integrating SD in a real course (given by them at their higher education institutions) in order to demonstrate the acquired skills and knowledge to ensure SD ethos among engineering educators.
The final assessment involves submission of portfolio itself, oral presentation and discussion.

The portfolio's evaluation is rooted in the quality and breadth of reflection on the course's material and concepts, the application of learned skills and knowledge, and the ability to integrate and synthesize different concepts. This is executed through a four-part rubric: a checklist ensuring all necessary components are included (25%), an assessment of whether the work is correctly executed (mechanics) (25%), an evaluation of the work's completeness (information) (25%), and an appraisal of the work's comprehensive nature (depth) (25%). Each area is rated on a scale from 1 to 5, where 1 signifies "not at all", 2 denotes "somewhat", 3 indicates "mostly", 4 represents "entirely", and 5 equates to "above expectations".

4 SUSTAINABLE DEVELOPMENT COURSE IMPLEMENTATION

The Sustainable Development Course, part of the iPET program, was introduced in 2021 across six higher education institutions that are members of the ENTER Project consortium. Given the Covid-19 restrictions, the course was primarily offered online or in a blended format. This course attracted a total of 186 teachers from various engineering disciplines, all of whom were required to integrate sustainable development principles into their courses at their respective universities. This involved the development of unique teaching strategies and adjustments at the micro-curricular and, in some instances, program levels.

To assure the quality of the course, the enrolled students were asked to complete a short questionnaire, aimed at gathering feedback regarding their satisfaction levels and aspects of the course that could be improved.

In response to the question, "What did you like most about the course?", several themes emerged. Participants enjoyed the balanced module layout and the opportunity to learn new teaching methods aimed at achieving Sustainable Development Goals. The relevance of the information on sustainable development within engineering education was also appreciated. Moreover, participants noted the value of involving all trainees in the learning process, particularly through practical tasks. The team-based practical exercises were a particular highlight, allowing for an interesting mix of people from different universities, including international colleagues. Lastly, participants praised the course for providing new and useful information and facilitating an exchange of experiences and perspectives on teaching engineering disciplines.

As for the question, "What aspects of the course could be improved?", suggestions were made to supplement the course with video materials and e-courses, and to expand the

possibilities for individual consultation. Some participants suggested reconsidering the scheduling of zoom-classes, as balancing these with job responsibilities was occasionally challenging. Finally, feedback indicated that the amount of project-based activities could be reduced.

5 CONCLUSIONS

The ENTER Network has successfully identified competences for professional development of engineering educators through a broad survey across multiple stakeholder groups. The resulting pedagogical program, comprising onsite, online, and blended learning, is modular and adaptable to various teaching styles. The survey analysis revealed a distinct ratio of interpersonal and professional competences required, with 14 key competences being identified as essential. An innovative course on Sustainable Development was developed, with a focus on fostering human-centric, impact-focused education, promoting a culture of experimentation, and encouraging lifelong learning. The course assessment method encourages educators to integrate sustainability principles into their teaching practices. Future improvements could include the addition of video materials, e-courses, and individual consultation sessions. The feedback from the first runs of the course was generally positive, with some minor suggestions for improvements.

As the field of sustainable development is rapidly evolving, the Sustainable Development course, as part of the professional development program for engineering educators, should be dynamically revised to stay current. This involves continuous monitoring of emerging trends, challenges, and innovations in the field, and integrating this knowledge into the course curriculum. This would ensure that the course remains relevant, comprehensive, and effective in equipping engineering educators with the skills and knowledge they need to educate the next generation of engineers to address the sustainability challenges of the future. Additionally, feedback from educators and students should be regularly solicited and used to improve and refine the course. Regular updates and revisions will ensure that the course continues to meet its aims and remains at the forefront of sustainable development education.

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