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Editorial

Innovation in Engineering Education for Sustainable Development—Introduction to a Special Issue

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Abstract: Sustainability plays a key role in engineering education. Engineering students must learn to think long-term and understand that, in order to achieve a better world, they must situate their future professional activities within the framework of sustainable solutions. To this end, future engineers must be aware of the complexities of the social environment in which they are developing their work, and of the need to harmonize short-term improvements with sustainable development based on the long term. Education for Sustainable Development (ESD) in engineering is essential for the training of agents of change and transformation that can promote policies, strategies, and methods that enable a more sustainable future to be built. This Special Issue gathers six original research papers in the field of ESD in engineering, ranging from general issues such as formulating key issues required for any course in EDS, to the experience of introducing sustainability into very specific subjects. Therefore, this Special Issue is of particular value for both academic researchers and lecturers interested in introducing sustainability into their own teaching subjects.

Keywords: education for sustainable development; engineering education; deep transformation; sustainability assessment; social responsibility

Future engineers must be aware of the complexities of the world in which they will develop their work, and of the need to harmonize short-term improvements with sustainable development based on the long term. Education for Sustainable Development (ESD) in engineering is essential for the training of future engineers as agents of change and transformation that can promote policies, strategies, and methods that enable a more sustainable future to be built. Engineering is necessary for achieving all of the 17 Sustainable Development Goals (SDGs) defined in the 2030 UN Agenda for Sustainable Development. Engineering projects are essential in implementing the technologies and systems necessary for some of the goals, like clear water and sanitation (Goal 6), affordable and clean energy (Goal 7), industry, innovation and infrastructure (Goal 9), sustainable cities and communities (Goal 11) or climate action (Goal 13). However, engineering projects can have an enormous impact in all the other goals.

In this Special Issue, we can find six different ways to approach ESD implementation in engineering studies. Some present general questions, and others present particular experiences in some subjects. Together, these papers reveal the complexity of implementing ESD and the challenge it sometimes presents, but also the wide range of solutions that can be developed.

What are the key issues required for a quality ESD course? Peter Glavič's paper identifies twelve key issues required for courses in ESD, organized into four groups (approach, contents, teaching and organization). The first group (approach) contains three key issues: ESD scope (definitions and

competencies), policy (vision, mission) and cooperation. The second group deals with the content, and is divided in three issues based on the three pillars of sustainability: the environmental, the social and the economic. The third group (teaching) deals with the pedagogies of ESD, including methodology, transformative teaching and capacity building. Finally, for an education of quality, it is required to have reliable information (documents), some organizations leading the ESD process (institutions) and tools to measure the quality of education (metrics); these three key issues constitute the fourth group (organization). This research can help teachers, school leaders and policy makers to introduce new courses on ESD or contribute to introduce sustainability issues in existing courses.

Creating a new subject in sustainability and ethics from scratch allow teachers to adapt general ideas in sustainability and ethics to the particular studies to which the subject belongs. This is the case of the paper by Casañ, Alier and Llorens, which presents 29 years of experience in teaching courses with the subject of social, environmental and ethical issues to students of Informatics Engineering. The paper shows the evolution of the content of the courses during these years, according with the evolution of Informatics Engineering and the evolution of the concept of sustainability itself. The authors discuss the importance of improving student's knowledge of philosophy, history, ethics and other disciplines like sociology, economy and pedagogy. They stress the high importance of the discussion of current events in class (like fake news) to change discussions from a mere academic exercise to a real-world issue.

Another important strategy is to introduce sustainability into many (or all) subjects in a curriculum. How to do this is not always intuitive, and it is important to decide which teaching methodologies are the most appropriate for ESD. Pujol and Tomás' paper describes a group activity concerning climate change, oriented to introduce ESD into a Robotics Engineering degree. The authors propose to use active learning methodologies, promoting cooperative work and role-playing, highlighting the importance of the participation of students in the construction of their own knowledge, and analyze students' perception about sustainable development in different issues: commitment, attitude, practices, and motivation. The authors also analyze whether there is a bias due to elements such as gender or the type of participation in the activities carried out.

One of the most powerful learning methodologies regarding ESD is the service learning methodology. The paper by Terrón-López, Velasco-Quintana, Lavado-Anguera, and Espinosa-Elvira describes a case study of project-based learning (PBL) experience in a real cooperation project in Lebanon implemented by two Non-governmental Organizations (NGO), one in Spain (the country where the students are studying) and the other on the ground in Lebanon. The authors highlight how real-world projects offer learning opportunities that allow students to gain hands-on experience, while provoking deep learning in relation to topics such as sustainability, ethics or real-world issues. The authors point out that these kinds of projects are not easy to implement, requiring a lot of institutional support and a lot of planning. However, the project presented can be especially inspiring for those who want a high degree of involvement from the students, in addition to having a real impact.

SDG goal 4 is described as "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all", while goal 5 refers to "achieve gender equality and empower all women and girls". The paper by Benavent et al. points out the evidence that women are enrolling in engineering studies in a smaller percentage than men. Increasing the number of women studying and working in Science, Technology, Engineering and Mathematics (STEM) fields is "fundamental towards achieving better solutions to the global challenges, since the potential for innovation is larger". The authors present the Girls4STEM project, oriented to break the stereotypes linked to STEM fields, trying to widening the range of career options for young girls by means of a) family talks, b) professional talks where the audience interact with female STEM experts, and c) Initial Training Seminars for teachers. The preliminary results show that there is not a general understanding about what STEM disciplines imply, and also that girls seem to be less self-confident about their performance in STEM disciplines. The authors point out that self-perception and perception from others (family, teachers) are key in deciding future professional paths.

One of the problems that most concern teachers with regard to the implementation of ESD is how to guide students in the learning process of sustainability issues (often far from the issues of expertise of teachers) and, above all, how to evaluate the acquisition of these skills. The sixth paper of this Special Issue is the one written by Sánchez-Carracedo et al. The authors introduce a tool designed to guide and assess the sustainability of engineering projects. The tool, named "the Sustainability Matrix", is a set of organized questions that students must answer when developing their final degree project, with the aim of provoking reflection, guiding the design and development of sustainable projects, and helping teachers evaluate the sustainability of the project. The authors pointed out the importance of encouraging students to think carefully about the consequences of their work, helping to integrate sustainability as part of an engineer's day-to-day professional practice.

The six papers in this Special Issue show good examples of efforts to introduce ESD into engineering studies. They range from general key issues to implementation in specific subjects. They present subjects oriented uniquely to sustainability or general subjects where sustainability issues have been incorporated. They cover several educational methodologies, how to guide students and how to assess their competences in sustainability, highlighting the gender problem in STEM studies. In view of these works, it can be concluded that the introduction of ESD in engineering studies is a subject that still requires a lot of research work.

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