Engineering for Sustainable Development: Graduate and Undergraduate Education

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Conference Key Areas: Sustainability in engineering education; New learning concepts for engineering education; Specialized versus generic engineering education

INTRODUCTION

In the last 40 years, the concepts of “sustainability” and “sustainable development” have been introduced in order to address the causes and effects of humanity's increasing impact on the world. It became clear that moving towards sustainability requires changes in the way of life of those living in developed countries. Since the publication of the *Brundtland Report: Our Common Future*, the concept of sustainable development came into focus and has increasingly gained attention at international, national, local, public and private levels. Thereafter several organizations have been involved in research and development of measures and strategies to provide long-term ability for nature and human beings to survive and prosper together, as well as to guide planning and policy making in the transition to sustainable development.

The recognition that society needs a new direction to achieve a more sustainable future inevitably passes through Engineering. With the pressures of rising population

and declining resources, engineers will be called to design more eco-efficient systems and technologies, to deal with ever-increasing uncertainty, and to consider the social and economic impacts of engineering choices in both a national and global setting.

Now and in the future, the practices of research, design and development activities associated with Engineering must be integrated into the concept of Sustainable Development. At the same time, while the European Space for Higher Education must be open and attractive to the rest of the world, the contribution of institutions to achieve education for all should be based on the principle of sustainable development and be in accordance with current international work on developing guidelines for quality provision of cross-border higher education [1].

Sustainable development is surrounded by uncertainty and ambiguity. There are nowadays a lot of constraints and opportunities in terms of resources available and also in terms of energy crisis and climate change, among others, reason why the modern engineer needs to be equipped with the knowledge and skills to manage this uncertainty and make judgments about the best course of action based on the available evidence. This requires engineers of this century to have creative problem-solving skills and to evaluate the implications of their solutions beyond their immediate technical context.

The purpose of this work is to describe the importance of sustainable development in engineering higher education (graduate and undergraduate programs) and the growing need for skilled professionals in engineering to develop their skills and competences in sustainability. In response to the relevance of engineering practices to improve sustainable development the work developed at ISEL/Portugal is presented along with the main conclusions reached.

1. SUSTAINABLE DEVELOPMENT AND HIGHER EDUCATION ENGINEERING

Universities have an essential role in the developing knowledge, by including a large number of graduate and undergraduate courses, such as engineering, law, management, economics and so many others.

Most of the graduate and undergraduate courses, including the engineering area, contain many compulsory subjects that not include topics such as sustainable development or sustainability, besides having little time available to consider new subjects to be taught.

Unfortunately, these days still occurs that most of the people at university receive little education about sustainable development and sustainability, unless they were specifically involved in the subject or have personal interest.

Sustainable development needs a multidisciplinary and interdisciplinary approach because such subject encompasses several technical and scientific areas of knowledge. So, the graduate or undergraduate programmes must predict that students have a basic training in a range of disciplines regardless of the specific content of their course.

In the last 30-40 years the technology revolutionized the society and social issues are at stake at every innovation process. For this reason an academic engineer should be trained as a ‘social’ engineer and must be able to address the social, economic and environmental issues regarding technology.

Engineers have a responsibility to maximise the value of their activity towards building a sustainable world. This requires an understanding of what society demands and what is achievable, and a recognition that these change over time. They should:

- Recognise that though their activity may be local and immediate, the potential impacts of their work may be global and long-lasting;
- Have an understanding of other relevant social and cultural structures outside their own normal community of practice;
- Understand the important potential role for engineers in the sustainable development;
- Recognise the impacts of engineering, at a local and global scale, and consider the views of the society.

Engineering schools have a key role in this new way of thinking and in the promotion of sustainable practices on large scale in industry and society. It is requisite that engineering schools adapt their curriculum structures to this reality and provide education in engineering for sustainable development, through the creation of specialized training, at a higher level, in this area.

2. TOPICS IN ENGINEERING FOR SUSTAINABLE DEVELOPMENT

Engineering for Sustainable Development should respect the following principles [2]:

- Look beyond your own locality and the immediate future;
- Innovate and be creative;
- Seek a balanced solution;
- Seek engagement from all stakeholders;
- Make sure you know the needs and wants;
- Plan and manage effectively;
- Give sustainability the benefit of any doubt;
- If polluters must pollute... then they must pay as well;
- Adopt a holistic, ‘cradle-to-grave’ approach;
- Do things right, having decided on the right thing to do;
- Beware cost reductions that masquerade as value engineering;
- Practice what you preach.

and curricula should include in the educational objectives:

- The development of student awareness of issues in areas of sustainable development (eg., global warming, destruction of ozone layer, deforestation, pollution, ethics and public policies, etc.);
- Exploration and demonstration of the role and impacts of various aspects of engineering (technology, design, process, materials, etc.) and policy decisions on environmental, societal and economic problems.

- Equipping students with engineering and decision making tools and methodologies and providing them opportunities to apply them on issues related to sustainable development. The decision analysis have an very important role in sustainable development, because helps professional engineers to operate and act responsibly taking into account the need to undertake engineering activities in a way that contributes to sustainable development. Decisions concerning social, environmental, and economic issues are by nature complex and involve multiple criteria and so decision analysis can play a valuable role helping engineers to make better decisions. Sustainable development also involves multiple decision makers and a difficult task of incorporating different points of view throughout the process as well as the need of building legitimacy through the whole process. Also in this case the decision analysis and decision support tools will help professionals to better frame the problems and have a clear understanding how their decisions affect groups of people whose attitudes and values differ greatly.

3. HIGHER ENGINEERING EDUCATION AND PROBLEM-BASED LEARNING (PBL)

Graduate and undergraduate education on engineering should be in accordance with the principles for sustainable development in order to give students a more integrated perspective as well as the skills for achieving sustainable solutions in their future engineering projects. For being able to discuss, discover, and implement engineering solutions that most fit the sustainable principles, the teaching method should encourage student collaboration among their tasks, which will enhance teamwork among people with different profiles, predominantly multidisciplinary. Therefore, the problem-based learning methodology becomes the most suitable approach for developing an active learning environment, student centered, for graduate and undergraduate programs.

Within problem based learning methodology, students develop knowledge by solving real problems. With this approach active learning is promoted and the way that classes are usually taught in most universities are radically changed. In this context, it is proposed that class time is spent essentially on hands-on activities and problems, and during this period, students sit in groups of 3 or 4 students in separated tables. During the class, teachers circulate and interact with the groups, answering questions, debating possible solutions, engaging them in a similar way to the Socratic Method [3]. This approach will be a strong contribution to educate engineers with more problem-solving skills, essential for evaluating and developing solutions that go in accordance with the principles of sustainability, that demand adaptable solutions.

4. ENGINEERING FOR SUSTAINABLE DEVELOPMENT (E4SD) AT ISEL/PORTUGAL

Engineering professionals are coming under increased pressure to practise engineering more sustainable.

In response to this trend Instituto Superior de Engenharia de Lisboa (ISEL/Portugal) has developed work towards to ensure inclusion sustainable development in its formative offer (graduate and undergraduate programmes) in engineering.

Engineering for Sustainable Development (E4SD) at ISEL/Portugal is designed for engineers who wish to enhance their technical education with the knowledge, skills, and experiences important to working on sustainable solutions in a global society.

E4SD programme is designed to develop the following broad themes:

- Engineering for Sustainability;
- Engineering and Management;
- Society, Ethics and Public Policy for Sustainable Engineering;
- Innovation, Entrepreneurship and Sustainable Engineering.

Students must attend 10 modules (8 core modules and 2 electives modules) and they have the freedom to choose elective modules that will allow them to follow a programme which is relevant to their interests and career aspirations.

E4SD will be held in a learning environment where students will be faced with a problem to which must investigate alternatives and develop an implementation plan for their resolution based in sustainable development. They will take ownership of their project and the problem-solving process, as would an engineer in real situation. Problem based learning its more motivating and stimulant for students and can help them gain experience in problem solving engineering. In the experiences that we had in ISEL/Portugal, most of students appreciated their freedom in PBL.

Fig. 1. 1st Workshop in Engineering for Sustainable Development in ISEL

CONCLUSION

Successful integration of sustainable development into graduate or undergraduate in engineering programs requires a change in the approach to education. Students need not only the base knowledge to generate effective engineering solutions but they also need the intellectual development and awareness to understand the impact of their decisions.

In the experiences that we've had at ISEL/Portugal, with workshops and short courses, students were able to learn about engineering for sustainable development through the problem-based learning process. In turn, problem-based learning provided a motivating context for learning and for acquiring practical problem-solving skills.

These experiences have demonstrated not only a way to implement sustainable development in engineering, but also a way to help students learn critical skills for problem solving and professional practice.

Overall, the level of knowledge and understanding of sustainable development is not satisfactory and therefore much more work is needed in educating engineering students in this field. Students appear to be relatively knowledgeable about environmental issues, but it is apparent that significant knowledge gaps exist with respect to the other two (social and economic) components of sustainable development. However, they are aware that sustainable development is important for them personally and even more important for them as Engineers.

Both, sustainable development and problem-based learning are relatively young within university environment, and will require commitment and creativity.

Sustainable Development must be at the core of the higher engineering education and will require a global commitment at social and economic levels and in ISEL/Portugal we are focused in this form of learn and to do engineering.

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