The Challenge Facing Engineering Educators Everywhere-The UNESCO Experience

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Summary

Engineering education requires a transformation to meet the needs of employers and the challenges facing the profession communities as a consequence of the rapid development of technology, the demands of large and complex projects and the need for socially responsible multidisciplinary innovation. The paper addresses the changes, in both curriculum and teaching strategies, which are urgently required in engineering education and make suggestions in relation to how Academies may facilitate the implementation of the necessary changes.

Abstract

In almost all countries engineers are in high demand to enhance infrastructure, undertake major resource development projects, improve the sustainability of our environment, achieve a viable manufacturing sector, and utilise the information and communication technology developments effectively and responsibly. Living in the middle of the IT revolution, the creativity and innovative capabilities of engineers are essential for the operation and advancement of our societies. Engineers are the key contributors to the innovation process which is of fundamental importance for our national economies. For more than a decade we have been graduating fewer engineers than have been required. Comprehensive investigations of this problem have been undertaken by the professional engineering academies and organisations in many countries. Their conclusions, typified by the Carnegie report (1), state that not only are insufficient engineers being educated, but the skills possessed by engineering graduates do not adequately prepare them for engineering practice. They are suggesting that engineering education requires a transformation if we are to educate sufficient engineers with the essential capabilities. Following the UNESCO Report on Engineering (2), the author was requested to write (with co-author Prof. Roger Hadgraft) a monograph titled “Engineering Education: Transformation and Innovation” (3) for UNESCO. Engineering education was considered as a system engineering problem. What are the desired objectives, what is happening currently, what are the factors that determine the outcome, how could the process be improved, what is preventing the desired outcome and how can these factors be influenced? The research associated with this publication, identified the following as important issues:

- Employers are dissatisfied with the capabilities of many engineering graduates.
- Many students consider engineering education to be boring.
- Engineering education fails to attract those students who are interested in contributing responsibly to the development of their society.
- Engineering is not a well understood profession within the community.
- Engineering education programs are reputed to be difficult causing them to be avoided by students.

- Engineering requires multi-disciplinary knowledge, but the educational curriculums of the universities are overloaded with specialised technical detail as a consequence of the technology explosion.
- Work experience in courses is valued and important, but uncommon.
- Program content does not develop the skills essential for practice as a professional engineer.
- The abilities to evaluate, to be creative, to identify what is relevant, to learn as it is necessary, and to apply this learning responsibly and efficiently, are not adequately addressed.
- The essential attributes required to be possessed by all graduate engineers have been identified in the Washington Accord (WA). However, these attributes are inadequately addressed by universities and Accrediting Authorities. (The WA Graduate Attributes address engineering knowledge, problem analysis, investigation, design/development of solutions, modern tool usage, the engineer and society, environment and society, ethics, leadership and team work, communications, project management and finance, and life-long learning).
- The structure of University programs has changed little over 40 years,
- Universities have not utilised the opportunities provided by the Information Technology revolution.
- Engineering education research has proven some very positive approaches which can improve the effectiveness of student learning, but they have not been widely adopted.
- Project Based Learning (PBL) or Project Centred Learning (PCL) is a proven approach which can enhance engineering education when used as at least 25% of the program in every semester.
- Universities should also change their programs, facilities and methods to embrace the IT revolution as quality engineering educational material on every engineering topic is available on the web.
- Facilitated student learning should be the educational strategy instead of the commonly used, traditional lecture-based approach. Students are now well equipped to utilise inquiry-based learning.
- Many universities complain that they have inadequate financial resources, but they do not consider the utilisation of the more economical, and more effective, student-centred learning methods.
- Some web-based engineering programs (e.g. MIT & Stanford) are now offered free of charge.
- The conservative university culture acts to prevent change.
- External action is essential to precipitate the transformation of engineering education in universities.

Engineering education programs can be exciting while they are effective. The approach recommended is that students should be considered as engineers-in-training and be given the opportunity to undertake engineering tasks of progressively increasing complexity throughout each semester of their study program. The core of the course becomes the Project Stream. These Projects can: provide insight into what engineers do, provide motivation, develop the personal attributes that are required to be an engineer, be undertaken in teams of up to 6 members, provide a reason to study and master the topics specified in the curriculum, develop team and leadership skills, provide opportunities to

interact with engineers and engineering organisations, encourage individual learning skills and the development of the essential engineering attributes.

Engineering curriculums must contain: foundation mathematics and science, fundamental engineering principles, the development of specialised expertise in a chosen field of engineering, and consideration of broad engineering practice issues. It is suggested that, in addition to the project stream, the former two become the focus of the first two years and the latter two the focus of the final two years. This suggests that the first two years could provide breadth while the final two years focus upon the students chosen specialisation. This would enable a more extensive use of the common first two years, to provide the students with an appropriate increase in their breadth of engineering knowledge, while reducing the cost of education.

It is recommended that a “home room” (or engineering studio), be provided for up to 50 students as their “normal” work space. This enables students to work on their projects and to develop their understanding of the supporting technical topics, through the exploration of web material, while working in an interactive environment with access to the designated learning facilitators. Students also learn much from each other in such an environment. Project team meeting rooms and technical facilities should also be available nearby.

The current educational strategy of universities is primarily focussed upon the provision of lectures and formal examinations to assess learning. They are utilised because they are the part of the university culture, and provide academic identity to staff while being the easiest way for them to fulfil their responsibilities. However, learning is an activity undertaken by the students; it is the student’s responsibility. The role of academic staff is to facilitate the student’s learning experience and to assist the students by defining what they are required to learn, assisting and encouraging them as they require or request, and to assess their realisation of the learning objectives to the required standard. These responsibilities can be more effectively fulfilled without lectures! The key goal is the development of graduates who are effective independent learners, with the attributes and capabilities which have been defined as essential for practising engineers. If this objective was realised the students would have a very different academic experience from that currently provided at most universities.

However the transformation of engineering education will be very difficult for universities to implement. They are conservative institutions with long established traditions and practices. The changes required are extensive and include: rebalancing the research/teaching emphasis, changing educational strategies from lecturing to learning facilitation, changing program structures to be project centred, facilitating work experience, provision of learning space instead of large lecture theatres, modifying assessment practices and policies, changing staff promotion criteria, enhancing project and IT facilities and improving partnerships with employers.

Universities will require the leadership, support and assistance of the Engineering Academies and Authorities responsible for engineering program accreditation, major engineering employers and governments, to implement the necessary changes. Each of these entities has a role to play and it will be necessary for them to act in a committed and coordinated manner:

- Engineering Academies need to develop a comprehensive and consistent relationship with the major employers and advocate a coherent message to

government and universities in relation to the need for major change in engineering education, in their national interest.

- Governments will need to recognise the strategic importance of the transformation of engineering education when the need for increased numbers of engineers, that are more effectively educated, is presented jointly by Academies and employers. They can assist universities by funding a trial program that can demonstrate the effectiveness of a student-inquiry approach to education built around PBL. They can also facilitate the sharing of this experience and the developed material between universities and the conduct of Training Programs for the key university staff who will lead the transformation of the engineering education programs in each university.
- Employers, as major beneficiaries, must become strong advocates of the need for change and then become committed ongoing partners with the universities in achieving these mutually beneficial outcomes. They can assist by suggesting projects to universities, initiating joint projects, providing students with employment experiences, enabling staff to participate as learning facilitators, encouraging staff exchange, and by facilitating access to engineering software, while acting in their own best interest.
- Engineering Accrediting Authorities (who may also be Engineering Academies) have a key role. If they adopt as the criteria for accreditation, the student capability attributes which are similar, or equivalent, to those of the Washington Accord, and insist upon their achievement by every engineering graduate, then universities would be required to modify their programs, their relationship with students, the role of their academic staff, their facilities, their relationship with employers, their assessment methods and hence their effectiveness.

While the participation of each of the above groups is essential, the implementation of this action by the Accrediting Authorities is considered to be the most effective tool to assist the universities to deliver the necessary transformation in engineering education. The outcome would be that more students are encouraged to enter engineering programs, the graduation rates would be enhanced, employers will find that graduates are better prepared for their engineering careers, countries will benefit socially and economically from the technological expertise of their engineers, universities will use the changes introduced by engineering to enhance other academic disciplines, and engineering academies will be recognised as effective in initiating change to facilitate national development.

1. Sheppard. S., et al, Educating Engineers: Designing for the Future of the Field, Carnegie Foundation, 2008.

2. Engineering: Issues, Challenges and Opportunities for Development, UNESCO Report, 2010.

3. Engineering Education: Transformation and Innovation, D.Beanland & R.Hadgraft, UNESCO Report, 2013.