

This report was commissioned by UNESCO to address why there is a need for transformation of the education of engineers, what it would entail and to consider how it could be achieved. There have been many calls for transformation as a consequence of the widespread undersupply of new entrants to the profession and concern about inadequacies in their preparation. The authors explore the educational approaches that can be used to address this important problem. Transformation of engineering education requires an understanding of the issues and a commitment to implement change by the key stakeholders. We have endeavoured to define the pathway that needs to be travelled.

## **The Role of Engineering in Society**

Engineering is one of our major professions. As implementers of the technological solutions upon which our communities depend, engineers fulfil an essential role. Engineers have the ability to solve the issues relating to the development of our communities in efficient, effective and sustainable ways using appropriate technology. They provide the leadership in the technology related issues that have an impact on our societies. They have a key role in delivering the innovations upon which the progress of our societies depends. As our dependence on technology is increasing rapidly and advances in technology are proceeding at an ever increasing pace, it is apparent that our dependence upon engineers will be even greater in the future.

## **Review of International Reports**

Engineering Education has been the subject of many reviews and reports over the last decade. Reports have emphasised the need for transformation, the strategies which are available to drive change and the importance of action in a rapidly changing technological environment. The key international issues and contributions are discussed and interpreted to establish a foundation for the consideration of this subject and the development of recommendations that could lead to the transformation of engineering education.

## **Attraction of Students into Engineering and Meeting their Needs**

There are many reasons why students are not attracted to the study of engineering. The role of engineers is not well understood in our societies. It is considered to be less rewarding than some other professions. Also engineering courses are viewed as being uninteresting or too difficult and so fewer students than our societies require are motivated to undertake them. The important contribution that engineers make to society is not sufficiently emphasised for, or promoted effectively to, potential students. In almost every country, problems exist because insufficient engineers to meet the employer's requirements are graduating from our universities as a consequence of the poor attraction power of engineering education programs and high failure/dropout rates.

Some of the larger developing countries have strongly encouraged the growth of engineering education enrolments to meet the significant number of employment opportunities. However, the variation in standards achieved by engineering graduates is also a significant problem for a profession which operates internationally. The continuing rapid rate of expansion of technology with the evolution of numerous fields of specialisation, and the importance of the development of the appropriate personal attributes, capabilities and characteristics for successful engineering practice, are issues that require attention in engineering education everywhere.

### **Achieving Community Relevant Engineering Education**

In many countries there are problems with the quality of the graduates. There is also an under representation of females in the cohort of graduate engineers. A key issue has been the tendency for engineering education to become engineering science education through an overemphasis on the technology content with a consequent neglect of the personal capabilities and attributes that successful engineers require to develop and implement responsibly appropriate technological solutions. This has led to numerous calls for transformation in engineering education by individuals and organisations. However they have not resulted in the necessary changes by the universities. This publication seeks to address all of the many aspects associated with this complex issue. Key questions include: Why is there a shortage of engineers? How can it be addressed? Why does engineering education need to change? What are the principles that should guide change? What methods can be utilised? How should courses be constructed? Why have universities been reluctant to change? How can the conditions to achieve the necessary changes be established?

Much of this publication addresses the requirements for a quality engineering education and how it can be best delivered within an academic institution. It considers the issues faced by engineering education, why it needs a transformation, what should be its objectives and how they could be realised. The role and relationship with the professional bodies and the engineering employers is also considered. The international accords which have specified the behaviours that are required to be demonstrated by engineering graduates are considered, as they provide the foundation for a more effective pathway to the education of engineers. These accords must have a direct relationship to the objectives of engineering education programs at all levels and the curriculum that should be designed and presented by the educational institutions to achieve their realisation.

### **Curriculum Design**

The primary focus of this publication is the development of best-practice engineering education to ensure the required outcomes. Consequently it places particular emphasis on the detail of curriculum design for transformation and proposes possible implementation strategies. The approach proposed for transformation is innovative, while being practical, as it is based on the experience of various institutions which have introduced some elements of the changes recommended. It is applicable to both existing and planned engineering academic programs and while it can also be cost and performance effective for the former, it may be easier for the latter. This publication has relevance for engineering education programs in all specialisations. Engineering education must become relevant to the needs of the profession in a rapidly changing world and move from its current focus on engineering science to providing graduates with the expertise to responsibly apply technology to the benefit of their communities.

### **Exemplars**

It is encouraging to note that the approaches to engineering education which are recommended in this publication are being practised in the Franklin W Olin College in USA and have been chosen by the new Singapore University of Technology and Design, to form the basis of its engineering education program commencing in 2012.

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## **Project Based Learning**

A new curriculum is proposed with sufficient detail to facilitate the implementation of the proposed approach. It utilises the concepts of project based learning and the formation of learning communities. The curriculum is broadly based and does not require the choice of a particular engineering specialisation in the first two years. Projects are used as a vehicle to provide interest, context and motivation while developing the desired engineering attributes such as creative problem solving and innovation, capability to analyse the issues involved in a system problem, ability to find, understand and utilise information, teamwork, leadership and communication skills, ethical and environmental responsibility, and awareness of business issues. Projects would be used throughout the program with increasing complexity.

## **Student-centred Learning, Collaborative Learning and e-Portfolios**

The essential theoretical topics in the curriculum would be designed to assist with the projects that the students are undertaking. They would utilise student centred learning using learning communities with facilitation by academic staff, senior students, experienced engineers from industry and/or retired engineers. Each student would create their own e-portfolio around their own career plan. The portfolio is their collection of evidence of their attainment of the required graduate capabilities required for their intended engineering practice. The objective is to encourage a move away from the ineffective staff dominated, lecture based, taught mode, by implementing a sustainable and more effective student-centred learning format that can be built around student inquiry and utilise the extensive web-based engineering education resources which are now available. Information technology based resources would also be used for communication between students and staff, topic presentations, assessment, student portfolios, simulation, computation and design. This publication explores the issues associated with the implementation of these innovations.

## **Multidisciplinary Fundamentals**

Projects create the incentive to explore the mathematical, scientific and engineering principles whose understanding is essential for their exploration. They also provide students with the opportunity to act as trainee engineers from the beginning of their course. Their involvement with issues across the spectrum of engineering activity reflects the multidisciplinary nature of most realistic engineering projects. They also assist the student to select a field of specialisation for the later years of their program, based upon the interests that they have acquired.

## **Learning Technologies**

The many issues associated with implementation of a realistic approach to effective and efficient engineering education using information and communication technologies as an effective learning medium are explored. These technologies utilise the skills that many students now possess, while being consistent with the methods utilised in engineering organisations. However, it will be a major change experience for most university education systems, and guidance in how to realise this objective is given. It is also important for the development of the graduates to be effective life-long learners.

## **Suggested Program Implementation**

The achievement of change is dependent upon the acceptance that program transformation should and can be implemented by the key stakeholders. There is consideration of, and detailed suggestions relating to, program implementation so that clear guidance can be available to those universities, departments and staff that are committed to pursuing transformation.

### **Change within Universities**

Universities are respected and responsible institutions that fulfil a number of essential roles in our communities. Their mission embraces teaching, research and community outreach across many disciplines. They aspire to leadership and status which is usually accorded through research performance. This, unfortunately, places the educational role, which is usually their major business, in a secondary position. As institutions they have been resistant to change, especially in education where the dominant paradigm remains staff-centred teaching, in contrast to student-centred learning which should be the objective.

Universities must take responsibility for the problems created by the current deficiencies in engineering education. No other organisations can solve the problems which exist. No other organisations are responsible for the curriculum details, the learning processes utilised, the student's formation and their assessment. They are ultimately responsible for defining the role that they require the academic staff to undertake and the outcomes that they are expected to achieve.

The professional engineering organisations, which have set clear attributes that should be achieved by engineering graduates, are responsible for the accreditation processes that have been proven inadequate to achieve the transformation required. They must play a more effective role by ensuring that the specified essential graduate attributes are possessed by all graduates. While they are unable to control the internal processes of the universities, they do control the educational standards required and must be encouraged to play a leading role in achieving the desired transformation.

The challenge which this publication delivers is for universities to examine how the internal barriers to transformational change in relation to engineering education can be removed, and incentives provided to implement the new approach which is outlined. The employers, professional engineering organisations and governments as key stakeholders also have a role to play in achieving the necessary changes. The content of the publication is applicable to all countries, independent of their stage of development.

### **An Action Plan**

The need to transform engineering education is relevant to every country. It has escaped attention for too long. As engineering is a major profession, it is essential in the public's interest. Its implementation requires the participation and commitment of all major stakeholders. Cooperation and collaboration is essential. It is recommended that an appropriate Action Plan is developed by the stakeholders in each country to achieve the required transformation of their engineering education provision.