Activating Engineering Education

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CAETS 2013, Budapest - June 27, 2013

Summary

There is no shortage of potential innovations in engineering education. My personal database of internationally published work on engineering education contains about 2000 publications and a dozen books. Almost all of them describe more active approaches to education than the traditional lecture. However few of these approaches have yet been widely adopted. In this presentation I reflect on the purpose of engineering education and draw conclusions about:

Why innovation is necessary – the drivers for change;

What might be done by teachers and schools of engineering, and;

How schools of engineering might be able to embed some effective and innovative changes.

In presenting these conclusions I draw on several recent evidence-based reports published by the Royal Academy of Engineering in the UK, as well as my own experience as a teacher, manager, author and leader in engineering education.

Abstract

Several recent reports and activities have identified the need for significant changes in the way graduate professional engineers are educated. The principal driver for change is the economic need for engineering graduates to be quickly employable in the many industries which depend on engineering skills. This driver was clearly identified and articulated in two reports from the Royal Academy of Engineering entitled Educating Engineers for the 21st Century [1] and Engineering Graduates for Industry [2]. These reports confirmed and built on the key conclusions of the Cox Report [3] that industry's requirements of new graduates were, in decreasing order of importance, practical application of their knowledge (top priority), theoretical understanding, creativity and innovation, team working, technical breadth and (last by a long way) business skills. The CDIO initiative (www.cdio.org) came to similar conclusions in 2000 and set about re-engineering engineering education to correct the perceived imbalance between theory (maths and bookwork) and its application (ability to design, build and test an artefact or product and work in a team) [4]. The membership of the CDIO initiative now numbers more than 100 schools of engineering on four continents and is having a large impact on engineering education.

All the analyses discussed in the previous paragraph imply that students should be encouraged to behave more like engineers during their education: As well as understanding the fundamentals of their chosen discipline, they should be able to do something with them. This implies a more active approach to education, which has variously been called *active learning*, or (in [2]) *experience-led learning* and usually involves one or more design-build-test (DBT) exercises. For example, CDIO members commit to include team working and at least two DBT exercises in every undergraduate programme.

If engineering education is to become more active, what might it look like? It is clear that in the drive to make students more active, more creative and more innovative [5], they must not be encouraged to neglect their developing understanding of fundamental engineering science. Student activity, and their experience of applying their understanding, should not replace their depth of understanding, it should enhance it.

An education in engineering must involve the acquisition of some relevant knowledge and some experience of applying and interpreting this knowledge. It is fairly obvious that the application of knowledge can be facilitated by project work, team activities and DBT exercises. Many Schools of Engineering, both CDIO members and others, now include such activities in their Engineering curricula. However the acquisition of knowledge can also be made more effective by increasing student activity. The conventional lecture is one of the least effective methods for transmitting knowledge, as was authoritatively pointed out as long ago as 1972 by Bligh [6]. There are a multitude of ways of improving the effectiveness of the lecture and myriad ways of replacing it. Many of them are described in the recent book "Teaching Engineering" [7]. They include problem-based learning, personal response systems (clickers) combined with concept questions [e.g. 8], simulations and games, recitations and mud cards – all described in [7].

Recently there has been much written about "flipping the classroom" [e.g. 9]. In essence this involves the students acquiring knowledge before entering the classroom, and the use of face-to-face class time to reinforce and embed the knowledge and to give the students practice at using and applying their knowledge. The logic behind this approach is that knowledge acquisition is easier than assimilating or applying it, so that precious time with the academic staff member should be reserved for the more difficult task of using the knowledge productively. It is too early to tell whether the used of flipped classrooms in engineering will be effective but it shows great promise.

It is clear that we know <u>why</u> we wish to change engineering education and we know <u>how</u> to do it. The crucial final step is to embed the desired changes into our education systems. In the UK this means persuading autonomous university departments and schools of engineering to adopt and maintain new teaching and learning methodologies. A recent report by Graham [10] describes, using interviews with seventy experienced educators and six case studies from around the world, the characteristics of successful change in engineering education. Graham's conclusions are that sustainable change is driven at Department or School level and not just by one or two enthusiasts. Change must be holistic, relating to the whole curriculum, must be approved and encouraged by senior management (e.g. Deans and Vice-Chancellors or Principals) and must be driven by a Head of School or Department. Changes at module level (however worthy) are, on their own, unlikely to be sustained or embedded. Many highly effective educational practices, adopted only by a small number of staff in a few modules, tend to be lost when these individual staff move on or are promoted.

In conclusion, engineering education in the UK (and indeed in much of the world) is entering a period of change which could lead to graduates with greatly enhanced skills and capabilities. The engineering education community knows how to make substantial improvements to the experience of students but these improvements are unlikely to become main-streamed without the drive and support of Heads of Department or School.

References

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