The Royal Academy of Engineering

Massachusetts Institute of Technology

Commentary document

Achieving excellence in engineering education: the ingredients of successful change

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1 Background

A series of reports from The Royal Academy of Engineering (The Royal Academy of Engineering, 2006, 2007, 2010)[1] has demonstrated that change in undergraduate engineering education is urgently needed to ensure graduates remain equipped for the new and complex challenges of the 21st century.

However, the necessary transformation in the structure and delivery of undergraduate provision has yet to take place across the Higher Education sector. There is a growing appreciation that the slow pace of change reflects the difficulties of catalysing and sustaining educational reform within engineering departments and schools. The case for reform is recognised; the challenge is to make it happen. The pressing issue for engineering education is not *whether* but *how* to change.

The report turns the spotlight on this issue. It examines how positive change can be achieved across the engineering curriculum, looking specifically at how reform can be initiated, implemented and sustained within engineering departments and schools.

The report draws on the experiences of those involved in major programmes of engineering education reform across the world with the aim of distilling the common features of success and failure. A two stage study was conducted between January and October 2011. Firstly, interviews were conducted with 70 international experts from 15 countries, each with first-hand experience of curriculum change in engineering. The interviews provided insight into a wide range of examples of curricular reform from across the world, offering a high-level view of the features associated with successful and unsuccessful change. Secondly, six examples were selected from those identified through the expert interviews to investigate in detail how significant educational reform can be achieved. The six case studies are all highly-regarded, selected to provide a spectrum of drivers for reform, change strategies, levels of ambition, geographical locations and stages in the change process (see box right). A further 117 individuals were consulted for these case studies.

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Through its detailed focus on how fundamental change has been achieved, the report challenges some assumptions about the ingredients of success.

- Widespread lasting change is rarely the product of incremental reform. Rarely, for example, did a successful redesign of one component of the curriculum provide the springboard for a course-by-course diffusion of proven good practice. As this suggests, knowing how faculty execute successful change within a single course or module provides only limited insight into how to undertake broader educational reform.

- Successful programmes of reform are rarely informed by evidence demonstrating the efficacy of a particular educational approach. Instead, successful changes typically involve the development and adoption of a new approach, developed in-house. Although it may be influenced by existing examples of good practice, it is deliberately designed to be distinct and developed to fit the priorities, resource constraints and student demographic of the host institution.

1 Spinks N., Silburn, N., Birchall, D., (2006), *Educating engineers for the 21st Century: the industry view*, Henley / The Royal Academy of Engineering, London
The Royal Academy of Engineering. (2007). *Educating Engineers for the 21st Century*. Royal Academy of Engineering, London.
The Royal Academy of Engineering (2010). *Engineering Graduates for Industry*. Royal Academy of Engineering, London.

2 The features of successful change

The study identifies a set of common features of successful change that are largely independent of geography or institution type. The features relate to the questions of *why*, *what*, *who* and *how* of educational reform.

2.1 Why? The context for successful change

In most cases of successful change, there is a clear sense of shared purpose among both senior management and faculty, grounded in a widespread acknowledgement that educational reform is unavoidable. This imperative for change is typically triggered by one of the following scenarios:

- A significant threat to the continued operation of the undergraduate programme, typically related to major problems in recruitment, retention and employability. The problems are sufficiently serious to be recognised by a wide cross-section of faculty; in some cases, university management also demand fundamental reform to ensure the long-term survival of the programme and/or department. Changes triggered under these circumstances appear to be the most likely to produce successful outcomes. The vast majority (around 70–80%) of the examples of change described by the participants in the study fall into this category.

- Externally-imposed reforms, such as mandatory changes in national accreditation criteria or a university re-structuring. In responding to these changes, senior management within the department/school decide to take the opportunity to implement more fundamental educational reform. Around 10% of the examples of change included in the study fall into this group.

- An established culture of innovation within the department/school. In these cases, a high proportion of faculty already hold a sense of collective responsibility and vision for the undergraduate programmes. Such circumstances appear to be among the few where existing innovation and an engagement with engineering education research are important influences on the change process. Relatively few (5–10%) examples of change described by study participants fall into this category.

There appears to be one set of circumstances, almost exclusively US-based, where successful systemic change is not associated with widespread engagement by faculty. This is where the change process has benefitted from significant external funding. Such awards often bring external prestige, financial independence and the ability to 'buy out' faculty time. These factors all help to minimise faculty resistance to change.

Other common contexts are shared by successful change programmes. They are much more likely to involve faculty with industry experience or newly-hired faculty, often replacing those retiring. In addition, the leaders of successful curriculum-wide change have often experienced failure in previous attempts to make isolated changes at the course level, from which they concluded that "*change needed to be radical and widespread for it to stick*".

2.2 What? The strategies of successful change

Successful programmes of change share two common features in their approach.

Successful change is interconnected and wide-ranging. Change is informed by a root-and-branch review of the undergraduate programme and is embedded in a coherent and interconnected curriculum structure. The study identified numerous examples of ambitious reform that had ultimately failed because it was restricted to one or two courses and relied on a small group of enthusiastic faculty. Almost without exception, successful and sustainable change starts with a fundamental assessment of curriculum-wide goals and involves a re-alignment of the entire curriculum in which a cross-section of faculty is involved. This successful approach to educational design appears to be independent of the scale of change undertaken. Indeed even in reform programmes described as 'curriculum-wide', changes typically only involve the development of a relatively small number of new courses – usually representing less than 20% of the curriculum. What distinguishes them, however, is the extent to which the changes are interconnected within a re-designed, coherent curriculum structure with multiple horizontal and vertical dependencies.

Successful change is ambitious and aims high. Successful change programmes seek to create a premier 'brand', a unique educational approach that aspires to set the benchmark for engineering education at national and international level. Aspiring to be world-leaders energises faculty and sustains their engagement with the demanding process of educational reform – "*if we were going to have to do something, it may as well be good*".

Project-based learning is often integral to these two strategic approaches. In the majority of cases, coherent and ambitious programmes of reform involves project-based education within authentic professional engineering contexts. This pattern is evident regardless of country or institution type.

2.3 Who? The drivers of successful change

Successful programmes of change appear to rely on engagement at three critical levels.

Heads of Department are primary players. Almost without exception, successful changes are energetically supported by the Head of Department, who invariably is also the leader or co-leader of the reform. These dynamic leaders are typically internal appointments, selected from the wider staff group and highly regarded as both researchers and teachers. Because they are trusted and respected, faculty are confident that the demanding process of reform will pay dividends. They also believe that time they have invested in improving undergraduate education and the quality of the student experience will be appropriately rewarded: their Head of Department will "*fight our case*" through the promotions process.

The department is the engine of change. The successful changes described by study participants consistently involved a department-wide approach to the reform process. This is true regardless of the scale of the changes made, from a school-wide effort to a small cluster of courses. Among the school-wide reforms, long-term successful curricular changes are confined to individual departments, with very limited diffusion of good practice outside their boundaries.

Faculty engagement is critical to making change happen. Those interviewed for the study described how three faculty groups tend to emerge, each of roughly equal size. One broadly supports the change, the second is focussed on other activities and "*do not care either way*" and the third is highly resistant to change. In driving forward successful change, most successful reform leaders appear to put their "*. . . energies into supporting the third that support change and into converting the third that don't care*". In many instances, little or no pressure is exerted on the group of resistant faculty, on the basis that they are unlikely ever to be supportive of curriculum reform and attempts to force them to change their teaching practice are likely to be counterproductive. Indeed, most successful changes leave one 'ring-fenced' area of the curriculum where content and delivery remains largely unchanged, in which this group can operate.

It should be noted that the majority of successful programmes of curriculum change also enjoy vocal and committed support from university senior management. As a result of this support university regulations are sometimes waived or moulded to accommodate some of the more unconventional aspects of the reforms.

2.4 How? The mechanisms for sustaining change

The study highlights significant challenges associated with sustaining change, with the majority of reforms reverting to the *status quo ante* in the years following implementation. Indeed, even among those changes that are successfully sustained, many encounter major problems around 5–10 years after the graduation of their first cohort of students. Most experience a gradual course-by-course 'drift' back to a more traditional curriculum. In some instances, this is linked to an influx of newly-appointed faculty who had not experienced the threats that precipitated the reforms. More generally, it appears to stem from a growing sense among faculty that the new curriculum has "*become stale*" and is "*no longer cutting-edge*". No longer ahead of the curve, it is not seen as worthy of the additional effort that had been previously invested in it.

Wider changes – for example, university restructuring, a new Department Head or changes to university senior management – are often the critical test of the sustainability of an educational reform. The programmes most resilient in these conditions are typically those that exhibit at least two of the following features:

- A coherent, interconnected curriculum where a wide pool of faculty deliver the reformed courses, often through team-teaching.
- An improvement in both student intake quality and student motivation following the reform, acknowledged even by faculty who did not support curriculum change.
- A well-disseminated, long term impact evaluation of the change.
- An on-going process of reinvention, keeping the curriculum 'ahead of the game'.

These features appear to sustain successful change by reminding faculty of its value, both to themselves personally and the department/school as a whole.

3 Conclusions & recommendations

The case for fundamental change to engineering education is widely accepted – and the last decade has seen a major investment of time and energy in engineering curriculum reform across the world. This study involved many of those with first-hand experience of these reforms, supported by in-depth case studies of six highly-regarded programmes of educational change.

Its findings point to the difficulties experienced by the 'lone champions' who are currently driving reform in engineering schools and departments, where changes often prove limited and short-term. The evidence points instead to the importance of departmental leadership and widespread faculty engagement in a process of reform which is informed, coherent and ambitious.

The calls for change in engineering education are growing. These will only become more urgent as engineering graduates are called to operate in an increasingly globalised and complex environment. At the same time, educational change in engineering is becoming more challenging in many regions of the world. Many of the study participants pointed to a recent retrenchment in the momentum for change, triggered by national government cuts and an increasing emphasis on international research rankings. In such an environment, long-term strategic educational change is likely to be increasingly difficult to achieve.

The study suggests some ways forward. For engineering schools and departments, it provides a set of guidelines for curriculum reform. These are outlined in the 1-page summary overleaf. For the engineering education community, it offers some suggestions for ensuring that curricular reforms stand the best chance of achieving positive and sustainable change. The two key recommendations are:

- To focus greater effort on evaluating the impact of engineering curriculum change. The development of tools to measure the impact of educational change on programme performance metrics (such as student recruitment, retention and employability) is likely to help sustain positive reforms. In addition, the dissemination of such evidence, particularly if collected at high-ranking research-led institutions, is likely to help motivate change elsewhere.
- To allocate funding for educational change to whole departments with the explicit involvement of the Department Head, rather than to individuals or groups.

PREPARATION
Collect evidence: gather quantitative evidence of the performance of your programme, as compared to competitor institutions, with a focus on any key areas of concern to your current or future market position.
Engage the Head of Department: devote as much energy as possible to ensuring that the Department Head is actively supporting, and preferably leading, the change. If their support is limited, be aware that your chances of long-term success will be severely diminished.
Consult senior university management: open informal discussions with university management about plans for change. Identify potential conflicts and gauge levels of support.
PLANNING
Communicate need for reform to department-wide faculty: focus on the critical need for change, supported by the evidence gathered, and the potential impact of reform on faculty day-to-day activities. Avoid specifying details of what the change should look like. Underline university support for change, if this is in place.
Faculty-wide curriculum design: engage most, if not all, faculty in a department-wide educational design process. Encourage them to think outside their discipline, identify the fundamental educational priorities and design a coherent curriculum where all new elements are carefully interlinked with existing courses. The new educational approach should be distinct and something that will put your institution 'on the map'. At least one portion of the curriculum should remain unchanged.
Consult external perspectives: ensure that some external voices are heard. Possibilities include an Industrial Advisory Board with real 'teeth', sending faculty to visit peer institutions that have implemented positive changes and/or appointing an educational/industrial advisor. Such activities are particularly important where there has been little recent faculty turn-over and/or few faculty have industry experience.
Appoint a management team and release their time: carefully select a management team of 2–3 individuals who are well-respected and understand the detailed operation of the undergraduate programmes. Formally release a portion of their time to devote to detailed planning and implementation.
Establish impact evaluation: select a method by which you can collect impact data throughout and beyond the change process and collect 'base-line' data relating to the period prior to reform.
IMPLEMENTATION
Select implementers of reform: those implementing the first pilot phases of reform should not necessarily be the 'usual suspects' of existing innovators in the department. Do not attempt to force highly reluctant faculty to deliver any of the new courses at any point in the process.
Loosen direct link between faculty and individual courses: where possible, establish team teaching for all new courses, with regular rotation of faculty. Provide a dedicated forum for teams to meet.
Maintain momentum: ensure regular dialogue between faculty and change leaders. Ensure that the change is publicly noted as a priority by senior departmental and university management. Disseminate early successes internally and externally.
SUSTAINING THE CHANGE
Closely monitor impact data: continue to collect and monitor impact data for a sustained period. Continue to flag results, positive and negative, internally. Disseminate successes externally.
Make new faculty aware of the reform: ensure that all new faculty are fully aware of why the reforms were undertaken and the impact of the changes made. Assign new faculty to experienced teaching teams.
Establish an on-going focus on education: ensure that the new curriculum is not stagnant. Engage in continuous development that keeps the curriculum at the cutting edge. Establish activities that are likely to engage a range of faculty. These will vary by context, but might include an engineering education research group, membership of international communities and/or faculty development workshops.
Be aware of potential issues: during university re-structuring and/or changes to senior management place particular emphasis on above three tasks and communicate the drivers for and impact of the reforms to all faculty.

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Further information

The full report, *Achieving excellence in engineering education: the ingredients of successful change*, is available from www.raeng.org.uk/change.

The Royal Academy of Engineering

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