The Royal Academy of Engineering

# Achieving excellence in engineering education: the ingredients of successful change

## 4.1 Case study 1: Department of Civil, Environmental & Geomatic Engineering, Faculty of Engineering Sciences, UCL, UK

***Overview:*** This UK-based case study describes a department-wide reform involving a significant re-design of the first two years of the curriculum and a controversial change to entry requirements. Initial discussions on the reform effort started in 2003 and the first cohort graduated from the new BEng (3 year) curriculum in July 2009.

***Reasons for selection as a case study:*** (i) this department-wide change was undertaken within a premier research-led institution, (ii) despite a controversial broadening of the entry requirements to the degree programme, accreditation was granted, (ii) the model for change is to be rolled-out across a number of other departments within the School[3].

***Who was interviewed:*** 21 individuals were consulted for the case study investigation. Informal discussions were held with 11 current departmental undergraduates (selected at random from the 1st, 2nd and 4th years of study) and formal interviews were held with 10 other stakeholders to the undergraduate programme (including the current Head of Department, current and former Director of Studies, faculty from both the Department of Civil, Environmental Geomatic Engineering and other departments in the School, the Vice Dean (Education) for the School, the university Vice-Provost, the Director of Membership and the Institution of Civil Engineers, and a member of the department's industry advisory panel).

3 For consistency across all case studies, 'School' in this case will refer to the Faculty of Engineering Sciences

### 4.1.1 Context and drivers for change

***Context:*** UCL is a London-based university with very strong international research reputation. It is seen to be an institution that encourages "*mould-breaking and rapid*" change, a vision supported at a senior university level. For some, the UCL operating model is more akin to a corporation than a university, resulting in more decisive change, with strategic decisions often made by individuals rather than committees. Departmental structures are strong, with limited exchange between departments on educational ideas and approaches.

The Department of Civil, Environmental & Geomatic Engineering (CEGE) is one of nine departments in the School, and is home to around 40 faculty with a current undergraduate intake of around 70 students each year. The current Head of Department has been in post since 2003. Prior to the reform effort, CEGE was seen to be a "*fairly typical research-intensive engineering department... with very few changes made to the undergraduate programmes in over 30 years*". Indeed, one described the department's educational approach as "*as traditional as they come – very old school*". Although some non-traditional teaching and learning approaches had been employed prior to reform, these were largely confined to design teaching and not typical of the wider departmental practice. The demographic in the department was strongly male, with many faculty close to retirement.

***Drivers:*** The principal drivers for the change to the undergraduate education in CEGE were problems with recruitment and student engagement – "*the poor quality of students coming in [to the department] and the problem of them becoming very demotivated by the second year*". These issues were highlighted in an external examiners' review of the degree programmes, which pointed to a low 'value-added' between student entry and exit.

A number of other issues were also apparent. Within the department, there was a feeling amongst a number of the faculty that the undergraduate programme was no longer 'fit for purpose' and did not adequately respond to the societal, environmental and political challenges of the 21st century. Indeed very few changes had been made to the core curriculum in more than two decades. The department's research profile was also not aligned to subject areas taught at undergraduate level, resulting in a very uneven teaching load across the faculty.

In response to these problems, the new Head of Department was appointed in 2003 with an explicit mandate to 'turn around' the undergraduate programme. Other staffing changes followed. The new Head of Department undertook a rapid recruitment programme, appointing 10 new faculty to replace those close to retirement. A high proportion of the new faculty were young and female. With these appointments came a significant shift in the department's age and gender demographic, and an accompanying change in departmental outlook and culture.

### 4.1.2 The educational vision and changes implemented

The incoming Head of Department instituted a fundamental review of the undergraduate programmes to develop a new vision of "*what we are really trying to achieve*". To articulate their vision and goals, the review considered *both* inputs (student profile at the point of admission) and outputs (skills, knowledge and outlook at the point of graduation). The review therefore evaluated the desired demographics, aspirations and attitudes of both incoming and graduating students. It was informed by consultations with both schools and engineering industry. Only very limited external benchmarking of alternative educational approaches was conducted and no reference was made to existing research on effective pedagogies in engineering.

The consultations with schools identified a number of important markets that were being 'missed' by the department's current undergraduate recruitment – principally

highly gifted and academically able individuals who would be engaged by the challenge of an engineering education, but were not necessarily motivated to become engineers. This group were seen to be driven by a desire to "*fix the world and make it a better place to live in*" and typically would not be studying Mathematics and Physics at A level (which would usually be mandatory for an entry to a UK engineering degree programme). A key message emerging from the consultations with industry was the particular need for strong engineering leaders and problem-solvers, with a broader educational base.

Reflecting the focus on *inputs* and *outputs*, the major changes related to *recruitment* and *educational approach*:

- ***Recruitment:*** The admissions criteria were broadened, to accept prospective students studying *any* A-level or equivalent on entry to the programme, provided that they achieve at least 'straight A-grades'. Interviews for entry to the programme were replaced by a team-based PBL (problem-based learning) scenario. The marketing of the programme was refocused around the themes of *leadership* and *engineering for social responsibility*.
- ***Educational approach:*** The first two years of the curriculum has been redesigned and now operates in 5 week cycles. The first four weeks of each cycle is delivered in a largely traditional manner, but is structured around four equally-weighted 'clusters' – *context*, *mechanisms*, *tools* and *change* – rather than the traditional engineering discipline-based topics. Given that only two of the 'clusters' (*mechanisms* and *tools*) stem from engineering science, the traditional engineering curriculum content has been significantly reduced. A greatly increased emphasis has been given to topics such as *design* and *conceptualisation*. The final week of the cycle is a full-time intensive, team-based problem-based learning 'scenario', where the problem posed draws on the learning from the preceding four weeks.

The reforms also delivered three major operational benefits: (i) 50% reduction in contact hours, thus allowing faculty time for planning, delivery and assessment of the PBL-style scenarios without increasing the average teaching loads, (ii) a more equitable distribution of the teaching load across all faculty, regardless of their area of research specialism, and (iii) a reduction in the number of degree programmes from 12 to 2 – the *Civil Engineering* and *Environmental Engineering* programmes.

#### 4.1.3 Achieving change

As noted above, change was initiated by the appointment of new Head of Department in 2003, followed quickly by the recruitment of new faculty and a root-and-branch review of current provision in order to develop a new vision of the undergraduate programme. Key elements of the vision were to provide a broader, more engaging curriculum, based around problem-solving, that attracted bright, creative and socially-responsible individuals who could rise to leadership positions both within and outside the engineering profession.

Following agreement on this educational vision, two attempts were made to design a new curriculum capable of delivering it. The first 'bottom-up' approach to the educational reform did not succeed (Oct. 2003 – Oct. 2004). The second attempt, which combined a 'top-down and bottom up' approach, was successfully designed and implemented (Oct 2004. – Sept. 2006). The full change process, including both of these attempts, is outlined below.

Initial discussions among departmental senior management on the 'bottom up' approach began in summer 2003. In October 2003, a working group, comprising faculty with an interest in educational change, was established to review the existing curriculum and to re-design the educational provision in the first two years of the undergraduate degree. In July 2004, the working group presented their proposals for education reform to all departmental faculty, with a curriculum structure that was largely based around the traditional engineering science disciplines. The proposed reforms met with significant opposition, both from those who saw them as "*dumbing down*" the engineering science elements of the education, and those who viewed the change to be "*too conservative and too close to what we already had*". At this point, it was recognised that a new approach to the change process was needed – "*the bottom-up approach was too meandering. We actually needed to be forced to think about the education in a completely different way. So Nick [the Head of Department] swung in with an edict*".

A new approach to the change process was adopted in October 2004, when the Head of Department fundamentally redesigned the curriculum structure and then asked all faculty to engage in the new curriculum design. One of the most significant changes made by the Head of Department was to move the curriculum away from the traditional engineering disciplines and reshape it around four 'clusters' and project 'scenarios'. Working groups were established for each of the four cluster themes; all departmental faculty were allocated to a working group and tasked with designing that element of the curriculum. In January 2005, the educational vision and curriculum template were presented to senior university management and given provisional approval to proceed. The educational approach, including the plans to broaden the entry criteria for incoming students, was also informally discussed with the key Civil Engineering accreditation agency at this stage, to a very positive reception. Following further development of the approach and curriculum design by the four working groups, a 'dry run' of one of the scenarios was held in July 2006. Two months later, in September 2006, the first cohort of first-year students entered the reformed programmes.

#### 4.1.4 Critical factors in successful change

Four elements appear to have been critical to the success of the change process:

1. Strong and committed leadership;
2. A clear vision for the educational changes, which was well communicated to faculty, senior university management, industry advisors and the accreditation agencies at an early stage of the reform process;
3. A clarity amongst faculty that significant change was

going to happen – "*we knew that this was not going to go away, so we really needed to engage with it*";

4. A curriculum that was designed by all faculty, but through a process that required them to think outside their discipline areas.

Each of these elements is discussed in turn below.

***Strong and committed leadership.*** This was provided by a well-respected and dynamic Head of Department with strong backing from senior colleagues in the department and the university. The Head of Department has a strong international research reputation ("*his research record speaks for itself*"); he also has a personal commitment to the undergraduate experience and devotes significant time to teaching. Both those within and outside the department pointed to a step-change that occurred when the Head of Department took up his post, of which the reforms to the education were one part. In the atmosphere of a changed faculty demographic and a new energy from the top, a cultural shift was seen to take place, with a new openness to discuss educational change. It is also clear that, while the Head of Department provided the vision and leadership for the reform, its implementation was managed by two key faculty members, one of whom was the Director of Studies at the time. For many, this combination of strong and passionate leadership, on the one hand, and systematic and careful curricular implementation, on the other, provided the conditions in which successful change could be achieved.

***A clear vision for change*** ("*the intellectual case was superb*"). All stakeholders, both within and outside the department, were able to articulate the educational vision, and used similar terms to describe it. It was acknowledged to be a fundamental, but carefully considered, reform, presented (by the Head of Department) with passion, precision and complete confidence in its success. The messages resonated well at all levels, with clarity both about the goals and targets for change. For example, the drive for leadership and social global responsibility embody elements of the university's wider vision for undergraduate education. A number of the proposed changes – such as the broadening of the entry criteria – were controversial, but the articulation of a strong narrative for change helped to secure support for them. The vision was also seen to be addressing a number of fundamental concerns about UK engineering education, such as how to widen participation in engineering, particularly amongst girls, and how to improve the leadership position of UK engineers in an increasingly globalised industry. For some, the radical and fundamental nature of the change also held strong appeal – as the Head of Department in CEGE commented "*the big advantage of [the change in] our department is the image was associated with 'making the world better'. That marriage – what they are trying to do being bigger than the subject – may be more difficult in other disciplines*".

***Change is inevitable.*** From the beginning of the change process, the Head of Department was clear that a significant change was coming and that reform would be rapid and fundamental – "*You can't do this by tinkering at the edges. I didn't give them any options. There needed to be a fundamental change, and it needed to be a quick hit".* The early discussions with the university senior management, the Vice Provost of UCL, and the key accreditation agency for the programmes, the Institution of Civil Engineering, also appear to have been very significant. The radical nature of the proposed changes always carried a danger of being dismissed by faculty as unworkable or unlikely to be supported by the university or accreditation agency. Securing support at such an early stage from both the university and the accreditation body "*caught many of the staff off-guard*", helping to diffuse much of the early resistance to reform as well as demonstrating the seriousness of intent to push forward with change. As one faculty member commented "*Once Nick [the Head of Department] had sold the vision of what we were trying to do, we had support right up the chain of the university, the Vice-Dean, the Dean, the Provost and even the ICE [the key accreditation agency]. After this, it was quite hard for people to pretend that this was not happening*".

***An inclusive process of change.*** All faculty were given a voice in the design of the new curriculum, through their assigned 'cluster' working group. However, although the curriculum was developed by departmental faculty, they were not able to operate within their traditional engineering disciplines. Instead, because each working group theme cut across disciplines, faculty were "*forced to think about the curriculum from a blank sheet, rather than just fighting for their own subjects to continue*". The early stages of the change process uncovered divisions among faculty about the magnitude of change that they were willing to support; some were pushing for a wholesale problem-based learning (PBL) approach across the curriculum while others believed that the curriculum should remain entirely unchanged. In many ways, the creation of the 5-week cycles "*made everyone feel that they were getting what they wanted – the PBL group had their focused intensive periods and the traditional group could just operate in the 4 out of the 5 weeks where they could deliver the courses in any way they chose*".

#### 4.1.5 Challenges in the change process

A number of challenges were encountered during the design, implementation and continuation of the educational changes in CEGE. An early practical challenge was running the old and new curriculum concurrently for 2 years. But the major challenges for the management of the change process appear to relate to faculty attitudes and values.

The most controversial element of the reforms was the removal for the requirement for entrants to have studied Mathematics and Physics during their previous two years of school (A-levels or equivalent); as one faculty member commented "*convincing the staff to accept this was this was the biggest challenge for the department*". These changes are now broadly accepted by departmental faculty, primarily because the concerns that fuelled opposition to the changes have proven to be unfounded. The first concern was that such changes would lead to non-compliance of university/ accreditation regulations; to address this concern the widening of the intake was discussed, and explained, at an early stage with university senior management and the critical accreditation body, leading to strong support in principle in both cases. The second concern was that there would be a reduction in the quality and mathematical abilities of

the student entry. Instead, the changes resulted in dramatic increase in the overall quality of student intake, and the non-traditional intake, in particular, were outperforming their peers in the mathematically-based subjects.

A second challenge concerned a difference of view on the goals of the undergraduate programme. A number of faculty expressed concern about the shift away from educating future engineers and towards developing leaders who can operate across different professions. In most cases, these concerns do not appear to have been allayed, with a number of individuals still strongly believing that the change was mis-guided; in their view, the education and training of professional engineers should remain the primary goal.

Finally, although a large part of the curriculum design was undertaken and 'owned' by departmental faculty, it also clear that much of the change process was mandated at Head of Department level, and, in that sense, had a strong 'top-down' element. This has clearly caused some problems, leaving a number of faculty with the feeling that they "*did not get a fair hearing*" when expressing their ideas or concerns. During the process of change, the Head of Department was not seen to engage with those more resistant to change. Although this does not appear to have altered the course of reform, for some, this has left some "*simmering issues*" within the department that "*may come back to bite us once the Head of Department is replaced*".

#### 4.1.6 Impact of the changes

There is compelling evidence of improvements in intake quality, retention rates and student performance following completion of the reform programme.

***Student intake.*** Over the past 10 years, the department has seen a dramatic improvement in the academic standard of incoming students, with A level entry grades rising from CCC in 2003 to AAA in 2011. Although other departments in the School have also seen increases in intake quality during this period, the rises in Civil, Environmental and Geomatic Engineering have been much more significant. During the early years of the reform, the department experienced a decline in the application numbers from overseas students, which was presumed to stem from the shift away from a traditional education in the engineering fundamentals. However, over the past 2 years, the numbers of applications from overseas students, particularly those in China, have increased significantly. This shift is seen to be due, in part, to the reputation of the reformed education, but also due a broader improvement in the international profile of UCL and the wider engagement, particularly in China, with the need to integrate personal and professional development into engineering education.

***Student Performance.*** The curricular changes appear to have triggered a significant improvement in the end of year scores achieved by students. For example, Figure 6 illustrates the increase in the percentage of high-achieving students following reform and Figure 7 illustrates the decrease in percentage of students with low performance scores following reform. These figures were created from attainment score data spanning 2002–2010.

Most telling, perhaps, are the improvements in achievement level apparent in the third year of study, where both the curriculum and assessment approach have remained unchanged. The numbers of third year students achieving the two highest attainment classifications rose from 43% (prior to the reforms, from 2001 to 2008) to 60% (following the reforms, since 2008). In addition, the numbers of students achieving the three lowest attainment classifications during their third year decreased from 23% (prior to reform, from 2001 to 2008) to 8% (following the reform, since 2008).

***Widening participation.*** The number of students entering the programmes by the non-traditional route (i.e. those not studying Mathematics and/or Physics pre-university) has been relatively modest – less than 10% of the cohort each year. However, almost all of those consulted within the department, faculty and students, commented on the disproportionate impact that this group has on the cohort as a whole, acting as a catalyst for improved creativity, enquiry and ambition – "*they ask more questions about the background and context of problems. They are particularly hard-working, as they feel they have to make up ground in maths and physics, and this effort is infectious*".

***The student experience.*** Informal discussions with undergraduates as part of this case study revealed strongly positive attitudes to the new educational approaches, particularly the 'scenarios', which were seen to be intensive, challenging but highly beneficial. The comments of one second year student were very typical – "*we live from one scenario to the next.... They are really 'full-on'. You know those weeks are going to be really exhausting, but you are so aware of how much you are learning. They [the scenarios] are really important*". The key concern amongst the students centred on the operation of the scenarios rather than the model itself. They pointed to a lack of consistency in approach to each scenario, apparently stemming from poor communication between faculty members, and, in a number of cases, a lack of timely and informative feedback following the scenarios. It was also interesting to note that only those undergraduates with non-traditional entry into the department were aware of its radical educational approach in advance of the departmental open day or even entering the first year. In other words, the department does not appear to be actively marketing itself as effectively as hoped. This issue was also highlighted by a member of the department's industrial advisory committee – "*there is no clear indication, externally, that the course is different. They are really underplaying the virtue of what they have*".

***Faculty experience.*** Faculty feedback on the impact of the reforms is also broadly very positive. In particular, the increase in student quality and engagement has been a major motivation for faculty. A number highlighted the differences they see in recent cohorts of graduates, with enthusiastic feedback from employers and an increase in external prizes and awards in national student competitions. Some continuing concerns exist amongst a small number of faculty over the reductions seen to the traditional engineering science content in the curriculum. However, these concerns are not widespread and appear to be diminishing with time.

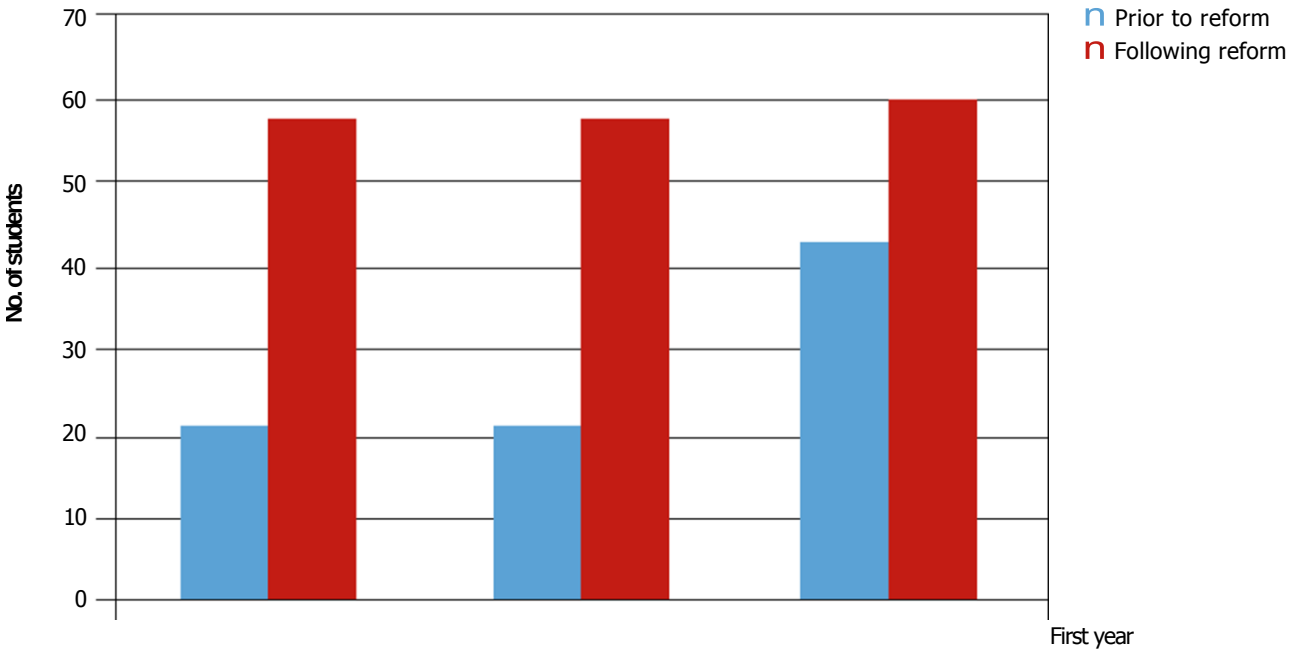


Figure 6. Percentage of students achieving the two highest attainment classifications (1st and 2:1), comparing average scores before and since reform was implemented in that year of study. Data taken from attainment score from 2002–2010.

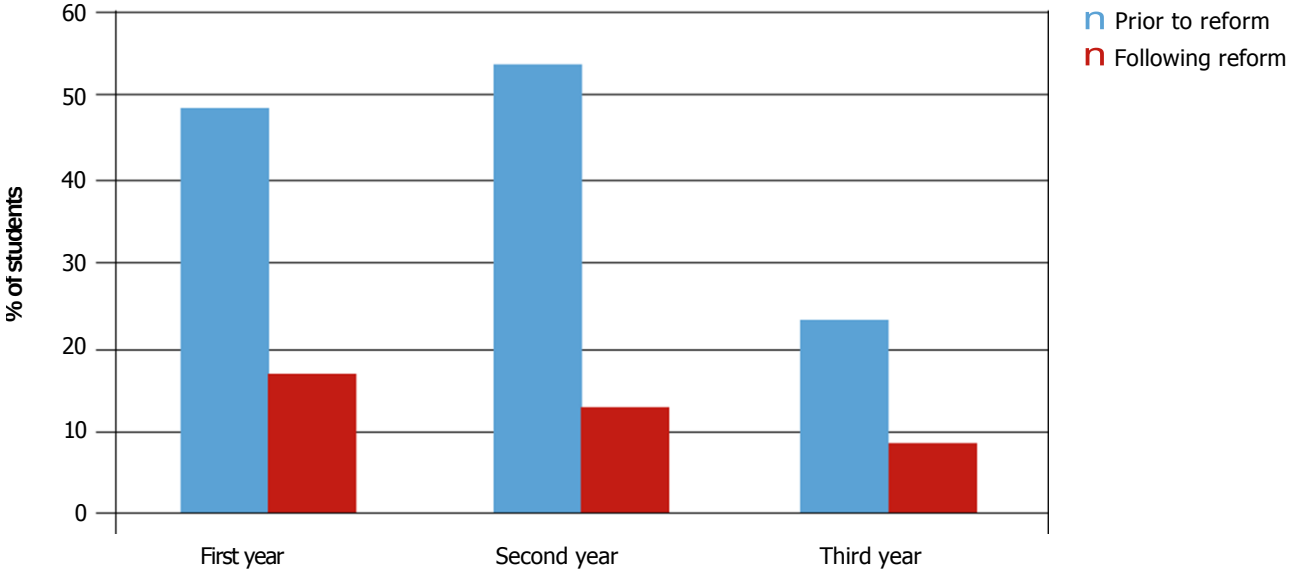


Figure 7. Percentage of students achieving the three lowest attainment classifications (3rd, ordinary pass and fail), comparing average scores before and since reform was implemented in that year of study. Data taken from attainment score from 2002–2010.

There were mixed views about the impact of the reforms on overall faculty workload. Some faculty pointed to an increase in the overall 'teaching load' resulting from the reforms, which were not seen likely to reduce, even when 'steady-state' was reached. Others experienced a reduction in contact hours, which allowed for improved preparation and creativity in their educational approach.

#### 4.1.7 Sustainability of the change

This programme of reform is widely seen to be well embedded and likely to be sustained for the foreseeable future. Any reversion back to the 'old education' appears unlikely, particularly given the very strong endorsement from senior university management, who view the reformed programme as a model for good practice within UCL, and positive response from the student body. For most, however, the real key to the sustainability of the reform is the improvement in the quality of students. Almost all faculty members, even those still unconvinced by the nature and scale of the reforms undertaken, commented on this positive outcome of the change process. As one faculty member commented "*we like teaching bright, engaged*

*students, no matter whether we agreed [with the change] or not. What would kill it [the changes], though, would be if our student numbers or quality fell*".

The vision and drive for change is clearly very closely associated with the current Head of Department. For some, continuing with such a radical approach across the curriculum may be difficult to maintain if a new Head of Department were to take post. Some concern was expressed that faculty with reservations about the approach may take this opportunity to revert back to the old curriculum within their own courses. This view, however, does not appear to be widespread. Many simply feel that "*we all are too exhausted to make any more changes for quite some time!"*.

As a result of the perceived success of the changes in CEGE, the School, with strong support from the university senior management, is planning to roll-out similar educational reforms across all engineering departments. In contrast to the CEGE reforms, change will be driven by senior management at School and university level. It is not yet clear whether this different approach to change will be equally successful; however, important elements of success, including a strong educational vision and senior university management committed to radical change, remain in place.