THE SYSTEMATIC DEVELOPMENT OF A NEW INTRODUCTORY COURSE

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Abstract

Continuing curriculum reform and a commitment to enhancing the quality of student learning in the School of Mechanical and Aerospace Engineering at Queen's University Belfast has influenced it to comply with CDIO Standard 4, and design and implement an Introduction to Engineering Course at Stage 1 (first year students). This type of course must motivate and excite the students and engage them in the practice of engineering. The design and implementation of such an introductory course is therefore a very complex issue which inevitably depends on the resources available in terms of personnel, workspaces and finance, and the number of students involved.

This paper explains the systematic approach that the School adopted to ensure that the prime objective of designing and implementing such an introductory course was achievable within a given time frame and with the available resources of personnel and workspaces. The means of achieving this, and the content chosen for the course is described in detail in order to illustrate the context of the change and the methodology adopted. Of particular interest is the change management process employed, which was accomplished in collaboration with an external agency. The execution of this change management process is also described.

The structure of this introductory course and its underlying objectives are all described in detail. The successful application of the change management process adopted and its implications for general curriculum change are also discussed.

Keywords: engineering education, introductory course, curriculum reform, change management, CDIO

Introduction

In 2003 the School of Mechanical and Aerospace Engineering at Queen's University Belfast (QUB) joined the CDIO initiative [1]. This is a major international initiative that is seeking to reform engineering education. Its participants have developed a comprehensive and logical

methodology for redesigning and enhancing engineering programs. This methodology is based on the guiding principle that engineering graduates should understand how to **c**onceive, **d**esign, **i**mplement and **o**perate the value-added products and systems associated with their discipline.

Incorporated in this methodology is a CDIO Syllabus [3] which provides detailed information on the knowledge and skills that students should acquire during an engineering program. In addition, there are a set of CDIO Standards [4] which define the essential features of an engineering program.

To date, the School is partway through a plan to implement CDIO in its established BEng and MEng programs, as well as a new degree program in Product Design and Development [2]. The primary objective is to ensure that its students receive an education which is both appropriate and of the highest quality. Implementing CDIO involves significant change and, to accelerate the implementation plan, support was sought from an external agency - the UK Centre for Materials Education (UKCME). A package of funding and support was awarded to the School in the academic year 2004/05.

A key part of the implementation plan was to develop a Stage 1 Introductory Course (CDIO Standard 4) for the Mechanical and Aerospace program. This was quickly identified as a key area where the UKCME support [5] could focus.

CDIO Standard Four – Introduction to Engineering [4], states that an introductory course should be one of the first required courses in a program and *"provide the framework for the practice of engineering"*. As such, it should engage the students in the practice of engineering and provide a broad outline of the tasks and responsibilities of an engineer. It should also develop essential personal and interpersonal skills. This required CDIO course should provide students with a hands-on introduction to their engineering discipline. It should motivate and inform them and demonstrate that theoretical topics covered in other courses have relevant practical applications.

With this in mind, it was established from the outset that an introductory course, in the School of Mechanical and Aerospace Engineering at QUB, could include a series of mini design-build-experiences (DBEs) which would be linked to topics covered in the first year curriculum and run throughout the year. These DBEs could run concurrently with professional skills lectures from an existing module to help fulfill the skills requirements set out in CDIO Standard Four [4]. At this point it should be noted that the typical number of students enrolled in Stage 1 for the Mechanical and Aerospace degree programs are typically eighty and forty respectively.

The Change Management Process

It was at this stage in the planning of the new introductory course that the support and participation of the UKCME was sought. Two of their staff were invited to interview academics in the School in relation to the development of the introductory course. These academics were chosen because they each had Stage 1 teaching commitments. The interviews were conducted based on issues regarding current and future practice. From these interviews and a subsequent meeting with relevant faculty members the UKCME staff were able to formulate advice on a realistic process to facilitate the development of the introductory course.

The interviews conducted by the UKCME were of the highest quality. They provided academics in the School with the opportunity to share their perceptions regarding the proposed introductory course in a very positive environment. As a result they established a forward momentum that enabled the academic staff to progress as a group and build curriculum development based on their own experiences, expertise and established practice.

As a result of these interviews, three specific areas were clearly identified in relation to assisting the development of the new introductory course. These areas formed the basis of the change management process and are described under the headings:

- Departmental Strengths
- Issues relating to course development
- Indication of a possible way forward

Departmental Strengths

It was important to establish a rationale for the proposed curriculum development and several of the most significant motives to proceed with such a task are described in this section. Most of these will seem obvious, but upon reflection are essential for any new course realization.

Amongst the staff interviewed, this introductory course was not seen as an isolated event, but as part of a sequence of ongoing curriculum change. The School had already given considerable thought to exploring how additional resources and facilities could be obtained to promote a high quality learning experience for the students engaged in this new course.

As a leading participant in the CDIO initiative the School had already committed to a structured CDIO implementation plan. Therefore there was strong support from the Head of Department for the new introductory course. In addition, there was a genuine concern to establish ownership of this development amongst the staff involved in Stage 1 teaching. There was also a consensus between colleagues for proceeding with the proposed introductory course; the need for change had been accepted.

The staff acknowledged that the proposed introductory course represented a major commitment and agreed that it should be seen as a coherent learning experience for the participants rather than a set of isolated, disconnected and bolt-on activities. In this way it would enable a number of learning objectives to be addressed in due course. However, it was essential to have a clear idea of the expected learning outcomes for this new course.

In this vein there was a general agreement on the main introductory course objectives. Seven were clearly identified and are described in table 1 in order of priority. The framework for learning had therefore been established.

The interviews provided clear evidence that, within the School, there already existed expertise and experience associated with both the organization and delivery of learning activities which were highly relevant to the introductory course. This was specifically in relation to course content, an appreciation of what constitutes effective practice, and development of active/collaborative learning experiences for specific courses. It represented a valuable resource on which the School could build.

As part of its CDIO implementation plan the School had already engaged in systematically collecting evidence relevant to this initiative through stakeholder surveys (alumni, students and staff) and collection of data in relation to workspaces. Evidence from these activities provided credible data for the School to guide the planning and development of this introductory course. For example, there was a clear appreciation about the limitations and potential of the workspaces currently available. Significant consideration had already been given to how such spaces could be used more effectively to meet student learning needs.

In addition, the school constantly reviews internal teaching, which serves to identify 'gaps' in the students' learning experiences. One such 'gap', for example, related to the improvement of oral communication skills and clearly had implications for the development of the introductory course.

However, the most crucial evidence that informed the new course development came from the direct experience of individual academics who had engaged in incorporating 'new' activities into their courses. It was essential that they had an opportunity to articulate the problems that they had encountered, the blockages to student learning that had emerged, the benefits that had accrued, and their implications in relation to time, resources and sequencing.

Finally, there was an appreciation of other resources and practices relevant to such an introductory course that were already prevalent at other CDIO collaborating universities [6, 7]. However, it was recognized that each of these institutions had different resource issues that inevitably affected the content of their respective resulting courses.

Issues Relating to Course Development

The context necessary for the introductory course to evolve was based on two realities: having to cope with a wider diversity of student intake resulting in some students arriving on the course ill-prepared to meet its demands; an increasing expectation from employers that graduates must emerge from the course ready to 'hit the ground running' as 'ready-made' engineers.

There was a clear consensus from the staff interviewed as to the main learning objectives for such a new introductory course. Table 1 presents these objectives in order of decreasing importance as rated by the interviewees.

One of the goals of this initiative was to prepare students more effectively for employment as functioning engineers. Interviewees stressed that this would have serious implications for the learning culture of the students in that they would have to change their mind-set to adjust to the new learning styles that would be involved. Table 2 summarizes the potential changes in the characteristics of the students' learning culture that the interviewees considered would be inherent in the new introductory course.

Table 1. Seven Learning Objectives for the Introductory Course in Order of Decreasing Importance

Level of Importance	Objectives of the Introductory Course
1 (most important)	Motivate and excite students.
2	Demonstrate the relevance of the engineering and materials science covered in Stage 1, and show that it can be applied to real-world problems. (Students frequently don't see the point of various topics they are being taught).
3	Introduce students to Mechanical and Manufacturing Engineering, and clarify their understanding of the nature of engineering and what engineers do.
4	Improve students' understanding of both fundamental engineering and engineering science concepts.
5	Provide practical engineering experience to compensate for the fact that, unlike in the past, current students seldom have practical experience (work at cars, repairing appliances, generally taking things apart, etc).
6	Begin the process of developing professional skills: computing, report writing, information retrieval, presentation skills, team working, etc.
7 (least important)	Bridge the gap between school and university, by ensuring that students can cope with the change in learning methods, the need for personal organisation, the problems of balancing paid work with academic work, etc.

It was clearly evident that an effective introductory course must promote active and collaborative learning; providing students with hands-on experiences and opportunities to learn form each other. This would obviously have serious implications for the planning and development of the introductory course.

With regard to constructing the new introductory course, it was unanimously agreed that it should strive to promote integration between as many of the current Stage 1 courses as feasibly possible. Involving all the relevant staff in the planning process would be critical in achieving this, no matter what their involvement in the final outcome. In trying to achieve such an integrated course, consideration would have to given to the development of the individual elements within the course and how they could be effectively transposed from their particular courses to successfully meet the learning needs of the students. It was also agreed that the timing of these individual elements within the introductory course would be essential in order to ensure proper integration with the other courses and to achieve the intended learning outcomes.

The content of the introductory course would have to be very well structured. As stated earlier, it would have to be based around activities which promoted learning that is hands-on, active and collaborative. The interviews identified several examples of such activities that were already

taking place in the School, several of which at Stage 1. It was acknowledged that with further staff collaboration, these could form the starting point for developing activities for inclusion in the introductory course. Inevitably, all such incorporated activity should have the potential to develop communication skills, team working skills, problem solving skills and the capacity to reflect on learning and achievement.

Table 2. Perceived Changes in the Characteristics of the Learning Culture for the Introductory Course

From	To
Learning as individuals	Learning with others
Competition (between students)	Collaboration (between students)
'Pupil' at school being told / spoon-fed	Adult learner challenged / stretched
Strong drive to get the right answer, with mode of assessment operating to promote this	Opportunities to make and learn from mistakes, with mode of assessment operating to reward this
Curriculum content that is compartmentalised	Curriculum content that is integrated
Artificially contrived practical exercises (recipe-book approach)	'Real-life' situations
Theory dominating learning	Theory 'by stealth'
Theory perceived as a chore to learn, and so abandoned when problem-solving	Theory is trusted, and so is seen as a necessary tool in problem-solving (as a short-cut to problem-solving)
Students are diffident	Students taking responsibility and caring about outcomes
Mind-set orientated in the present	Mind-set future orientated
Problem-seeking	Problem-solving

One of the main resource issues for a course pertaining to develop the skills aforementioned is providing suitable workspaces. Fortunately, an investigation and survey of workspaces had already been performed in conjunction with other CDIO collaborating institutions [7]. This provided the necessary information that there were indeed the prerequisite workspaces to accommodate the introductory course.

The ownership of the introductory course was always going to be an important issue. It was decided that one academic would have the overall responsibility as coordinator for the course, but that as many staff as possible would be involved, with the onus on being seen by the students to be involved; this would not only introduce the students to as many staff as possible, but also help emphasize the relevance of the course. This was described as a key factor in the introductory course developed at the University of Liverpool, another CDIO collaborator, and indeed was paramount in the "icebreaker" activities within their course [8].

The assessment of the introductory course required careful consideration. Feedback from the interviews concluded that the assessment methods chosen should neither be onerous nor time consuming for either the students or the staff involved. This was based on the prime directive

that the course was intended to motivate and excite the students, and to help them perceive the relevance of the course.

A key feature of developing a successful introductory course was to ensure that suitable evaluation was established to ensure that it could be sustained and fulfill its objectives. This is standard practice in the School for all courses, but a more extensive evaluation plan was deemed necessary to ensure that all of the new activities fulfilled their goals and learning objectives.

Indication of a Possible Way Forward

The collaboration with the UKCME culminated in a specific five phase plan for the preparation and development of the new introductory course as specified below:

- Phase 1 – Review own practice
- Phase 2 – Explore potential
- Phase 3 – Identify practical implications
- Phase 4 – Develop the 'wrap-around'
- Phase 5 – Establish sequence

These five phases are described in detail below:

Phase 1 – Review own practice

Identify aspects of practice that have evolved in their own subject areas, (or through collaboration with one or two academic staff from other areas), which promote active, collaborative student learning. This should identify the aims for these activities, the lessons learned from putting them in place, issues relating to assessment, and crucially, impact on student learning.

Phase 2 – Explore potential

Explore the potential of each activity as a possible 'candidate' for inclusion into the Introductory Course, identifying where and how the activity could be modified, incorporating input from other subject areas / disciplines.

Phase 3 – Identify practical implications

Identify the potential implications of incorporating such activity, in terms of resources, facilities, staff time, etc.

Phase 4 – Develop the 'wrap-around'

Determine what other input would be required within the Introductory Course, (preparation, appropriate theory, review, etc.), to enable students to gain fully from understanding that activity.

Phase 5 – Establish sequence

Give an indication to how activities would be sequenced within the Introductory Course to maximise learning potential.

The onus was now on the School to implement each phase of this plan and engage the relevant staff members to further collaborate in developing the introductory course. A small development committee was established and tasked with implementing the five-phase plan. Although the

committee only consisted of six academics, it was important to keep as many colleagues as possible engaged in the process. The learning objectives and learning culture changes illustrated in tables 1 and 2 respectively formed a crucial resource for the development of the introductory course as they essentially defined the necessary learning outcomes.

Introductory Course Structure and Content

The introductory course for Stage 1 Mechanical and Aerospace students was developed based on the five-phase plan described in the previous section. It involves seventy two hours of student learning over two twelve-week semesters, with three hours scheduled per week.

Content

The module is structured around *three team-based design-build-test projects*, each lasting between six and eight weeks and all culminating in a competitive test session and reflection on the outcomes. Running concurrently with the projects are professional skills lectures which cover the necessary IT skill set (Microsoft Office) along with relevant personal and interpersonal skills. As part of this it was decided to use external instructors where appropriate, and a key area that was suited to this was teamwork as it is vital to the success of the projects. The content of the introductory course and the teaching methods used are shown in table 3.

Table 3. Module Content and Delivery Modes

Component	Delivery Mode	Hours
Module Overview	Lecture	1
Intro to Project 1	Lecture	1
Project 1	Design-Build-Test Project	8
Project 1 Racecar Competition	Organized Racing Event	3
Reflection on Project 1	Lecture	3
Intro to Project 2	Lecture	1
Project 2	Design-Build-Test Project	12
Project 2 Lab Test	Laboratory Testing	3
Reflection on Project 2	Lecture	3
Intro to Project 3	Lecture	1
Project 3	Design-Build-Test Project	10
Project 3 Robot Challenge	Organized Test Event	3
Reflection on Project 3	Lecture	3
Professional Skills	Lecture/practical	9
Building High Performance Teams	lecture/practical	6
Private Study		5
TOTAL		**72**

It is evident from this content in table 3 that the module conforms to several of the other CDIO Standards [4]. The three design-build-test projects were specifically chosen from other Stage 1 modules and are intended to provide an integrated learning experience that requires the students to apply disciplinary knowledge from those respective modules (CDIO Standard 7). It also holds true that because explicit connections are made between related content and learning outcomes that a *mutually supporting* curriculum has been designed and the plan implemented (CDIO Standard 3). By structuring the module around the three design-build-test projects (CDIO Standard 5) and including relevant disciplinary and professional skills content, many different teaching and learning approaches are achieved (CDIO Standard 8) in the coverage of key CDIO syllabus topics [3] (CDIO Standard 2).

Assessment

The assessment of the module was split evenly between the three design-build-test projects. The assessment methods were chosen to be consistent for each project. This simply meant that there were group marks for the competitive test session of each project combined with a group assignment based on the skills acquired from the lecture elements already described, and finally individual group member marks based on peer review forms, instructor observations and attendance records.

Evaluation

The evaluation of the module was based on staff observations, informal and formal student feedback, attendance and retention. Comments form the students on the positive and negative aspects of the course not only provided encouraging evidence, beyond the assessment scores, that the key learning outcomes had been realized, but more significantly, that the key objectives for the course, described in table 1, were also appreciated. In addition, there were even some valuable ideas to improve the course for the following year. However, the most popular comments from the students were those pertaining to an enjoyment of this learning environment and working with their peers.

Discussion

The School of Mechanical and Aerospace Engineering at Queens University Belfast is heavily committed to implementing CDIO principles, which has a strongly informed methodology for curriculum planning and development. As a consequence of this there was a determination to enhance the quality of student learning through a new introductory course. Within the School there was a lucid awareness that successfully implementing such a change would be a difficult process.

The initial strategy adopted was to engage in a critical appraisal of such a course through an agenda of in-depth interviews conducted by staff from the UK Centre for Materials Education These interviews were conducted individually with staff involved in Stage 1 teaching.

These interviews generated a wealth of material. They identified ideas, and aspects of good practice already in place, on which the development of the introductory course could build. This information was then revealed to all who participated and represented a powerful resource for

influencing the planned change. Significantly, the summaries of staff perceptions that emerged form the interviews were used to inform and shape the introductory course development process.

The interviews provided an opportunity for staff to share their insights and expertise in regard to planning the potential way forward for the development of the introductory course; they gave staff a voice and provided a platform for further collaboration in relation to developing the course.

This approach of interviewing staff and analyzing the responses took approximately four months and was relatively time consuming. The resource implications for this form of 'change management' should not be underestimated, but it must be appreciated that the relevant development potential that resulted far outweighed the effort expended. It could also be accepted that such a collaborative approach, based on supportive yet critical appraisal, is necessary if sustainable curriculum development is to be achieved.

Although this 'change management process' described was specific to the School of Mechanical and Aerospace Engineering at Queen's University Belfast, it is feasible to state that this type of process could be applied generically to most curriculum reform activities, and this is a key outcome of this paper.

In total it took nine months to completely plan and prepare this introductory course. Because of the short space of time available to plan and develop the contents for this course, it would be remiss not to mention that a fairly 'safe' or conservative attitude guided the choice of its eventual contents. Two out of the three design-build-test-projects chosen were closely based on good practice already in place in other modules. Obviously, the knock-on effects of this were carefully considered for these other modules. In addition, the Professional Skills lectures were merged from a previous half module.

Unfortunately, there were also several preferable ideas that the development committee could not consider due to particular constraints on the Stage 1 timetable and the available resources. For example, the introductory course at the University of Liverpool [8] was able to fully implement "immersive" (and "semi-immersive") learning experiences in that they could manipulate their timetables to facilitate one hundred percent (or fifty percent) of student time being completely devoted to particular activities within the course. Their subsequent evaluations showed that this was particularly beneficial to student learning.

This being said, an introductory course such as the one developed and implemented in the School of Mechanical and Aerospace Engineering at Queen's University Belfast, and described in this paper, with all its active and collaborative learning and teaching approaches and their relevant continuous assessment, not to mention the other implications on resources such as workspaces, staff and funding, is probably one of the most difficult forms of curriculum development to successfully accomplish. It is therefore the authors' contention that the change management process used here was invaluable to this end.

Conclusions

By using a definitive, but simple, change management process, the School was able to instigate changes in its curriculum. This process successfully analysed information from individual, high quality interviews with the relevant teaching staff, by an external agency, to foster collaboration, awareness of existing good practice and perceptions that helped to successfully shape the development process for the planned curriculum change: a new introductory course.

The interviews identified three key areas that formed the basis of the change management process: departmental strengths; issues relating to course development; indication of a possible way forward.

These in turn identified seven learning objectives for the introductory course in order of decreasing importance, and the potential changes in the characteristics of the students' learning culture that would be inherent in the new introductory course. In addition, the practicalities of workspaces, course content, course assessment and evaluation were finalized.

This all culminated in a specific five phase plan for the preparation and development of the new introductory course; a plan that was successfully implemented by the realization of an introductory course in the 2006/2007 academic calendar.

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