2nd International CDIO Conference
Linkoping University
Linkoping, Sweden
13-14 June 2006

THE VALUE OF IMMERSIVE LEARNING EXPERIENCES WITHIN AN *'INTRODUCTION TO ENGINEERING'* MODULE

M.L. Murphy, T.J. Bullough, M.W. Johnson, S.G. Millard, A.T. Shenton and C.J. Sutcliffe

Department of Engineering, University of Liverpool, Liverpool, UK

ABSTRACT

Students usually choose Engineering because they have an enthusiasm for creating new products, structures or systems. One purpose of *'Introduction to Engineering'* modules is to implement active learning principles and build on this enthusiasm by engaging students, early in their programme, in the practice of engineering through problem solving and simple design-build-test exercises.

Introductory modules should seek to introduce the roles and responsibilities of professional engineers and the people they interact with; to illustrate how disciplinary knowledge is applied in the solution of engineering problems; and to target the development of knowledge, skills, and attitudes essential to professional engineering.

The University of Liverpool has developed a new introductory module for all year-one students across six engineering disciplines: Aerospace, Civil, Design, Integrated, Materials & Mechanical. The module is structured around an intensive, team-based project in which students spend two weeks, full time, on the design-build-test of either a rocket, an aeroplane or a bridge (depending on their discipline). These immersive practical projects have been termed 'Two Week Creations' (TWCs). The module also includes an intensive CAD training week and a range of topics such as design theory, engineering drawing, professional practice, sustainable development, project management and personal development planning.

The module begins in Week 1, Semester 1 with a four-afternoon, team based project that engages all new students in a basic build-test exercise: introducing topics such as time management, work planning, team-working and experimental technique. This 'Ice-breaker' project is designed to prepare students for the TWCs and other learning experiences to come; and to introduce them to the Department, to its staff, and to each other. The ice-breaker is one of the students' very first experiences of undergraduate teaching and it provides a sound foundation for study by helping to foster a sense of responsibility towards learning, a sense of community within the Department and perhaps most importantly a sense of fun and enthusiasm.

This paper describes the design, implementation and evaluation of this module; explores how it serves to integrate different elements of the first year curriculum; and discusses the learning outcomes delivered.

INTRODUCTION

An effective engineering education should equip graduates with not only disciplinary knowledge and understanding, but also the skills, experience and attitudes that will underpin their professional and personal futures. Evidence suggests that Engineering degree programmes have become focussed more towards theoretical rather than practical education, and many no longer meet the expectations of students, employers and other stakeholders [1-4]. The University of Liverpool has allocated £30 million to the redevelopment of research and teaching facilities within the Department of Engineering. To complement this investment the Department is developing several new degree programmes that will begin to graduate distinctive, well rounded and highly employable *Liverpool Engineers* from 2010.

The challenge is to introduce programmes that maintain a thorough coverage of engineering science whilst increasing the emphasis placed on the development of skills such as communication, team-work, professional practice, creativity and practical problem solving. Significant innovation in teaching practice will be required if this is to be achieved within the limited contact time available. The overarching aim of the learning and teaching developments underway at Liverpool is to introduce more active and cooperative learning [5-8], and to develop approaches to teaching and assessment that deliver an appropriate blend of technical, professional and personal learning.

The University of Liverpool became a CDIO collaborator in 2004 and is implementing the initiative's approach to programme design [9]. The first outcome of this work has been the development of a first year *'Introduction to Engineering'* module that was delivered for the first time in 2005/06 to 280 students from Aerospace, Civil, Design, Integrated, Materials & Mechanical engineering programmes. This paper describes the design, implementation and evaluation of this module paying particular attention to three immersive learning experiences within it.

MODULE DESIGN

The CDIO approach to engineering education suggests that all programmes should include an *'Introduction to Engineering'* module in the first year (*CDIO Standard 4*). Such introductory modules should seek to illustrate the roles and responsibilities of professional engineers and the people they interact with; to illustrate how disciplinary knowledge is applied in the solution of engineering problems; and to target the development of knowledge, skills, and attitudes essential in professional engineering [10]. Students usually choose to study Engineering because they have an enthusiasm for creating new products, structures or systems. Introductory modules should therefore also aim to build on this enthusiasm by implementing active learning principles to engage students, early in their programme, in the practice of engineering through problem solving and simple design-build-test exercises.

An *Introduction to Engineering* module has been developed to reflect these principles. It involves 150 hours of student learning over two 12-week semesters. The module is structured around a team based DBT exercise (*CDIO Standard 5*) and deploys a range of teaching approaches (*CDIO Standard 8*) in the coverage of key syllabus topics (*CDIO Standard 2*). The module is structured and scheduled to provide an integrated learning experience that requires students to apply learning from other engineering science modules within their programme (*CDIO Standard 7*). **Table 1** details the module content and the teaching modes employed.

The Two Week Creation (TWC) exercise and the 3D CAD training course are considered 'immersive learning experiences' because students devote 100% of their time to them and participate in no other activity for their duration. The Ice-breaker exercise is considered 'semi-immersive' as students are required to devote 50% of their time to its completion. The remainder of this paper describes these three activities and their evaluation.

Table 1: Module Content and Delivery Modes

Component	**Delivery Mode**	**Hours**	**% mark**
Module overview / attitudes & experience survey	Lecture / Questionnaire	1	
Ice-Breaker exercise	Build-Test Project	12	5
Intro to Total Design, teamwork & project mngt.	Lecture	1	
Engineering drawing & communication	Lecture / Practical	2	5
Sustainable Development	Lecture / Case Study Project	5	10
Teamwork, planning, risk assessment, creativity	Lecture / Practical	2	
Two Week Creation	Design-Build-Test Project	60	40
Professional Practice	Lecture	5	10
3D CAD training	Industry Standard Course	40	30
Personal Development Planning	Tutorial	2	
	Private study	20	
	Total	**150**	

THE ICE-BREAKER

To optimise student learning from the immersive design-build-test project later in the programme (the TWC) it was felt that some preparation for this kind of educational experience was required. It was decided that the new module should begin with a simple practical project to introduce the importance of several key skills. This introductory exercise was scheduled for the first week of Semester 1 so that it might also support the induction and orientation of all new students: it has therefore been termed the Ice-breaker.

Overview

This problem-based, team exercise involved the fabrication, performance analysis, loading simulation and testing of a cardboard model, truss girder bridge. The structural design of the bridge had already been carried out and working drawings of the construction and its component members were provided to the students [11]. The exercise was therefore a build-test activity with no design element, and although some basic engineering science was introduced the primary objectives were:

- To introduce the importance of experimental method, work planning, time management and team-working;

- To introduce students to the Department; to academic and technical staff; and to their peers;

- To develop amongst the students a sense of achievement and an enthusiasm for further study.

Delivery

The exercise was carried out over four three hour sessions during the students' very first week of study. Each day a brief lecture describing the expectations of the session was given, together with a handout providing detailed, step-by-step procedures for the practical activities. The final afternoon of the exercise was devoted to the load testing of each bridge under academic observation. All other groups in the laboratory were encouraged to observe the testing and a competitive, even rowdy, atmosphere developed. This added to the student enjoyment of the exercise and helped to build a sense of community within the Department.

In all undergraduate programmes students are divided into groups of five or six and each is allocated a personal tutor for the duration of their studies. The Ice-breaker project teams were based on these tutor groups to enable students to build relationships quickly with each other. All academic tutors were encouraged to visit the laboratory at certain times during the exercise to make first contact with their tutees. A linked tutorial during the week following the Ice-breaker exercise allowed staff to explore learning outcomes in more depth. This process itself introduced students to the concept of tutorials and their role in supporting other teaching, and emphasised the value of consolidating learning by reflecting on it.

Assessment

The exercise was designed to contribute 5% of the marks for the 15 credit module. It involved no written reporting and therefore the assessment scheme addressed only the students' execution of each of the practical tasks. The scheme was devised so that most students would attain 80%, with the very best constructions bearing a higher load and scoring 100%. This ensured that all students would be motivated by an early success in their very first piece of assessed work.

Evaluation

Evaluation of student learning was based in the first instance on staff observation and informal student feedback collected during the course of the exercise. The primary learning outcomes identified were:

- Experimental method: precise interpretation and execution of instructions; accurate preparation and mechanical testing of specimens; data collection and analysis; laboratory safety;

- Team-work, project planning and time management;

- Engineering science: principles of truss bridge design; concept of compressive & tensile strength; link between analysis and testing (Factor of Safety).

Tutorial discussions unearthed some additional learning outcomes valued by the students:

- Working as a team towards a common goal had enabled students to build effective relationships with their peers, and had given them the confidence to make a full contribution;

- The exercise provided the backdrop for the students' first introduction to their tutor and provided a subject for conversation: serving to reduce nervousness and ease initial communication;

- The close involvement of technical staff made students aware of their role within the Department and gave them the confidence to ask for support;

The final phase of evaluation involved interviews with a sample of 18 students by an independent, external evaluator. These were carried out during the second week of Semester 2 so that the extent to which the Ice-breaker prepared the students for further study could be explored. The interviews confirmed the learning outcomes identified above and also revealed that the students:

- Felt this experience prepared them for the more complex design-build-activity later in the programme;

- Were motivated by the fact that they had really enjoyed the exercise, and were given confidence by the fact that they had achieved an early success;

- Understood the personalities and attributes of their tutorial group members and this allowed them to work more effectively as a team;

- Were better prepared for traditional laboratory classes as a result of this introduction to experimental methods.

THE TWO WEEK CREATION

The largest component of the module is a team-based project in which students spend 60 hours on the design-build-test of either a water powered rocket, a remotely controlled aeroplane or a more challenging cardboard bridge (depending on their discipline). The project was carried out over ten days, hence the term Two Week Creation.

Overview

Each of the three TWCs involved a different set of activities but they all followed a similar format:

Week 1:	Initial design & build of artefact (limited design freedom) Experimental analysis of key performance characteristics Prediction of performance by modelling & simulation Preliminary performance testing Comparison of predicted versus actual performance
Week 2:	Advanced design & build of artefact (greater design freedom) Optimisation of performance Prediction of performance by modelling & simulation Final performance testing Comparison of predicted versus actual performance

Students were required to keep a project log-book that recorded, on a daily basis, the progress of the group design process, their own contribution, and detailed engineering workings. Emphasis was placed on teamwork, project planning and project management with students completing reflective questionnaires at the start, mid-point and end of their project. The primary objectives of these exercises were:

- To build on the introduction to key skills provided by the Ice-breaker;

- To require students to apply theoretical learning from other Engineering Science modules within their programme;
- To enthuse students through the completion of a ‘real’ engineering challenge;
- To be less prescriptive than the Ice-breaker and provide the opportunity for creativity.

Delivery

The timetable was arranged so that two full weeks were cleared of all other activity and students were able to work full time on their project: simulating a professional environment and allowing them to focus on a single goal. The exercise was scheduled for Weeks 12 and 13: late enough in the programme to ensure students had covered much of the relevant engineering science in other modules; and early enough to allow completion of the post-project reporting and assessment.

Each day began with an introductory briefing and students were then free to follow their own project plan: working in the laboratory, holding meetings or carrying out research elsewhere. This approach challenged students to manage their time effectively but it was felt that not all Year 1 students would have the required self-discipline. A 5% per day unauthorised absence penalty was therefore applied to those missing from start/end of day registers.

The majority of the activity was carried out in three large laboratories that were continuously staffed with at least one academic and one technician. The Friday of each week was devoted to performance testing under academic and peer group observation. It was possible to test the TW-bridges in the laboratory but the TW-aeroplane required a larger indoor space (a sports hall) and the TW-rocket an outside space (a football pitch).

Assessment

The TWC project contributed 40% towards the overall mark and the assessment scheme addressed performance testing (25%); an individual project report and logbook (62.5%); and a group oral presentation to an academic / peer group audience (12.5%). A simple peer assessment mechanism was used to allow teams to modify the awarded marks to reflect individual contributions. The assessment was designed to recognise a range of student learning: project reports and logbooks were assessed for technical content, authorship and the students’ reflection on teamwork, project planning and management; oral presentations on the students’ communication skills and response to questions.

Evaluation

A post-completion feedback survey asked students to score the activity according to “the extent to which the learning objectives of the project were met”. The individual results for the three exercises and an average are presented in **Table 2**.

Student comments on the positive and negative aspects of the experience confirmed that these results represented the most valued learning outcomes. Students also commented that the two-week format allowed them to focus on a major goal and made them feel like ‘real engineers’. The majority enjoyed the experience, particularly the testing of their design performance in front of an audience of their peers.

The consistently lower scores for the TW-rocket exercise are partly attributed to the fact that 25% of the students were from a Product Design programme: a group with different expectations that were clearly not met. However comments also revealed that the students felt that the TW-rocket offered limited scope for creativity compared with the other projects, and was therefore less of a challenge.

Table 2: Student Evaluation of TWC Learning Outcomes

Evaluation Scale: -2 (worst); 0 (average); +3 (best)

Learning Objective	TW-rocket	TW-plane	TW-bridge	Average
Practical application of theoretical learning	1.34	1.61	2.26	1.74
Introduction to the design-build- test process	1.25	1.75	2	1.67
Experience of working in teams	1.59	2.11	2.52	2.07
Experience of project planning & management	0.88	1.17	1.78	1.28
Provided a 'real world' engineering challenge	0.71	1.15	1.59	1.15
Provided an opportunity for creativity	0.80	1.62	1.44	1.29

It is notable that, in relation to the application of theoretical learning, both the TW-rocket and the TW-aeroplane scored lower than the TW-bridge. This is attributed to the fact that these projects required the application of engineering science that was not fully understood by all the students. The TW-bridge was more prescriptive, contained less new science, and therefore seemed more popular. Students suggested that regular feedback to validate their application of engineering science would give them the confidence to pursue more creative design solutions.

THE 3D CAD TRAINING

The Department has adopted Parametric Technology Corporation's Pro/ENGINEER Wildfire 2.0 as its standard CAD modelling software. Historically students have received Pro/E instruction during a number of sessions spread throughout their programme: an approach that has not always been effective. The *Liverpool Engineer* degree programmes under development will place a greater emphasis on engineering design, and many learning experiences will demand proficiency in 3D CAD modelling. It was therefore decided to enhance CAD teaching and require all students to complete a comprehensive Pro/E training course during their first year.

Overview

The format of the initial, basic training delivered to industrial users of Pro/E is an intensive, one-week, 40 hour course that includes lectures, practical exercises and a project to model a complex engineering assembly. It was decided to replicate this 'professional standard' course for all first year students (except Civil who were trained in AutoCAD – their industry standard). To enable this to be achieved ten academic staff completed the industrial training to qualify as student instructors. The primary objectives of this exercise were:

- To instruct students in 3D CAD modelling techniques and familiarise them with the Pro/ENGINEER tools;
- To introduce the importance of project data management;
- To demand a professional approach to the completion of a project under severe time pressure.

Delivery

The cohort of 170 students was divided into five groups and two academic instructors were allocated to each. Formal delivery of the 5-day course was between 09.00 and 17.00 with the instructors present at all times: giving introductory lectures, group demonstrations and individual guidance. 24-hour computing facilities and home software installations were made available for those students requiring additional time to reach the daily project milestones.

Assessment

This exercise contributed 30% towards the overall module mark and the assessment scheme was based solely on the students' project work. CAD files of each component part and the animated assembly were submitted electronically and assessed for accuracy and completeness. Audit tools embedded within Pro/E were used to check for plagiarism and file sharing.

Evaluation

The exercise was evaluated via a 30 question feedback survey and the most revealing answers to questions exploring student attitudes to their experience (rather than practical detail) are presented in **Table 3**.

Table 3: Student Attitudes to Pro/E Training

Statement	**(Strongly) Agree (%)**
The course was effective and I feel that I am now proficient in Pro/E	83
I found the training interesting and enjoyable	84
The intensive course was hard work but I feel that immersing myself in this was the best way to learn	75
I enjoyed using Pro/E and can't wait to use it as part of a real project	75
I have learnt something that will be useful to me throughout my career	80

It is clear that the vast majority of students found the course enjoyable, and their perception that it was effective has been supported by the assessment. This industry standard course is extremely challenging for anyone new to CAD, and inspection of submitted work revealed that most students devoted many hours of their personal time to its completion. It is encouraging that 75% recognised the value of concentrating so much effort on developing this important skill. Perhaps most important is that this course has stimulated a genuine interest in CAD modelling and students recognise its value to their future study and professional careers. In fact 77% responded that they would complete further assignments to practice and extend their skills, even if they carried no assessment credit.

OVERALL MODULE EVALUATION

A post-completion feedback survey asked students to score each component of the module according to "how well the delivery and organisation enabled the learning outcomes to be met". **Table 4** presents the evaluation score together with an estimation of the staff effort associated with the delivery and assessment of each component (neglecting the associated initial developmental effort).

Evaluation reveals that the three immersive learning experiences score significantly higher than the other components. A contributing factor might be that these activities are simply, in the words of one student, *"… a welcome relief from the crippling monotony of endless lectures and lab classes*". However many comments suggest that this type of learning is most valued because students are, for a while, removed from the university environment and treated more like professional engineers.

Table 4: Student Evaluation & Staff Effort - Overall Module

Evaluation Scale: -2 (worst); 0 (average); +3 (best)

Evaluation Score	Module Component	Credit	Staff Time (hrs)	Staff Time (hrs) /Credit
1.50	Icebreaker	0.75	30	40
-0.43	Engineering Drawing & Comms	0.75	5	7
0.62	Sustainable Development	1.5	65	43
1.17	TW-Rocket	6	534	89
2.09	TW-Aeroplane			
2.43	TW-Bridge			
0.74	Professional Practice	1.5	5	3
2.11	3D CAD Training	4.5	284	63
	Total	15	923	

The three immersive learning experiences (together with the sustainable development case study project) demand significantly more teaching effort per credit than the other components. It is clear that the introduction of such educational approaches brings real benefits to the student, but at a significant cost to the Department. This is emphasised by the fact that the overall staff time per credit for the module is around three-times that associated with a typical 'lecture plus laboratory' module delivered to a similar number of students.

CONCLUSIONS

An *Introduction to Engineering* module that targets a number of CDIO Syllabus outcomes has been developed within the framework of the CDIO Standards. In 2005/06 the module was delivered for the first time to 280 first year students from Aerospace, Civil, Design, Integrated, Materials & Mechanical engineering programmes.

Evaluation indicates that the immersive activities were most popular because, for their duration, students were removed from the usual learning environment and treated like professional engineers: devoting all of their time to the completion of a major practical challenge.

Feedback reveals that students recognised that these experiences target the development of several important technical, personal and professional skills; and they were therefore willing to devote more effort per assessment credit earned than to other types of learning.

Students were most uncomfortable when made to work under severe time pressure, or when required to apply engineering science that they hadn't been taught (or at least taught to apply) in the solution of engineering problems: situations faced every day by professional engineers.

It has been shown that the delivery and assessment of the immersive learning experiences demands far more staff time than conventionally taught modules bearing the same assessment credit. This type of active learning delivers many benefits to the student but carries significant resource implications for the department.

It is concluded that the CDIO Approach has enabled the development of an introductory module that delivers several important learning outcomes, provides valuable exposure to the practice of engineering, and is popular amongst students. This represents a positive first step in the development of the enhanced *Liverpool Engineer* degree programmes, but their delivery will only be feasible if more efficient teaching and assessment practices can be introduced.

REFERENCES

1. N.Spinks, N. Silburn & D. Birchall (2006), "Educating Engineers for the 21st Century: Phase I Report", The Royal Academy of Engineering, London, ISBN 1-903496-25-X

2. Berggren et al. (2003), "CDIO: An international initiative for reforming engineering education", World Transactions on Engineering & Technology Education, 2003 UICEE, Vol. 2, No. 1

3. Mbanguta (2003), "The Conceive-Design-Implement-Operate Initiative: A New Outcomes Based Approach for the Reform of Higher Engineering Education", Journal for Engineering Educators, vol. 7, no. 1

4. Brodeur et al. (2002), "International Collaboration in the Reform of Engineering Education", ASEE Conference, Montreal, Canada, 16-19 June 2002

5. Goodhew and Bullough (2005), "Active Learning in Materials Science and Engineering", CDIO Annual Conference, Ontario, Canada, 06-09 June 2005

6. Felder and Brent (2003), "Learning by Doing", Chem. Engr. Education, vol. 37, no. 4, pp 282-283

7. Hall et al. (2002), "Adoption of Active Learning in a Lecture-Based Engineering Class", ASEE/IEEE Frontiers in Education Conference, Boston, USA, 06-09 November 2002

8. Felder and Brent (1994), "Cooperative learning in Technical Courses: procedures, pitfalls and payoffs" ERIC Document Reproduction Service, ED 377038

9. Website of the CDIO Initiative: www.cdio.org

10. Gustafsson et al. (2002), "First-year introductory courses as a means to develop conceive – design – implement – operate skills in engineering education programmes", SEFI Annual Conference, Firenze, Italy, 8-11 September 2002

11. Ressler (2002), "Designing and Building File-Folder Bridges: A Problem-Based Introduction to Engineering", U.S. Government Printing Office, Stock No. 008-022-00328-2