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ESCAPING THE STRAITJACKET OF ENGINEERING EDUCATION

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ABSTRACT
Engineering education in the United Kingdom might be characterized by a conservative and pragmatic approach. It has developed from the approaches constructed during the age of enlightenment and industrial revolution and has since been subject to a number of reviews and evolutionary changes. Engineering degrees in some cases have been taught by a combination of distinctly identifiable modules, which, despite good intentions and encouragement by accreditation bodies, are rarely explicitly interlinked or interrelated. The use of a VLE (virtual learning environment) to support a problem-based approach to learning, in order to facilitate the acquisition of a wide range of interdisciplinary skills, is explored within this paper. Students are asked to design a transmission system for a compressor by a fictional OEM (original equipment manufacturer). The activity requires marketing, business planning, project management, specification, conceptual design, detailed design, preparation for manufacture, teamwork and liaison with a number of individuals and organizations. The mechanism of running the project is described here along with the challenges its delivery presented.

Keywords: engineering & design education; problem-based learning; virtual learning environment; higher education

1 INTRODUCTION

Engineering education in the UK finds itself in the context of a declining national industry. In the 1960s engineering activity contributed approximately 40% of the UK GDP; by 2002 this had fallen to approximately 17% [1]. Engineering education in the UK has seen a number of significant changes stemming from the Finniston report [2] and more recently the attempt encapsulated in SARTOR (Standards and Routes to Accreditation) [3] to improve the standard of those graduating in engineering disciplines.

Education in the UK has also seen significant changes. Higher education has been significantly expanded so that now 43% of the population is involved in learning at higher education level [4]. Subjects such as English literature, psychology and media-studies are highly popular and traditional subjects must compete with these in their attempt to attract students. It is within the context of a declining engineering industry, increased competition and higher student expectations and aspirations that the challenges for a newer approach to the provision of learning in a traditional engineering area were set.

2 TEACHING & LEARNING APPROACHES FOR ENGINEERING

By the 1950s techniques such as the use of board and chalk were widely being hailed as archaic following the advent of television and the innovative techniques developed by the UK Open University. In their place came interactive, project based and case study learning. There is a strong movement in higher education now towards the use of teaching and learning methods which promote a 'deep' approach to learning such as: collaborative learning, problem based learning and resource-based learning [5], [6]. These approaches have benefited immensely from the advent of web-based learning technologies such as VLEs (virtual learning environments) which provide students working in groups with an 'anytime any place' means of online access to learning materials, other resources and bulletin boards for group discussion.

Engineering requires a refined set of analytical skills alongside a practical sense of what works. Recent technological developments in design processes mean that engineers will need to do progressively more work by computer alone without the benefit of creating and testing physical prototypes. The teaching of engineering therefore faces the challenge that it must accommodate this move from the use of physical to 'virtual' or computer-based design processes. As well as gaining experience of specific computer-based design tools it is vital that students are given the opportunity to develop competence and become comfortable working in the virtual world as an integral part of their learning experience. Graduate engineers are increasingly being required to work on design problems as pro-active professionals in multi-disciplinary project teams. So as students, they need to learn how to deal with problem-based situations, develop research skills, to draw on a wide range of resources, and communication skills to work effectively as part of a team.

The teaching of engineering at Sussex has tended to be traditional in nature. The use of conventional lecture facilities, with paper-based calculation exercises discussed during large "problem classes" has been the norm. However the final year project, where students work more independently, has proved to be a popular and successful means of consolidating course material. This experience suggested that a closer relationship between formal tuition and the related problem solving would provide a more effective learning experience.

2.1 A new approach to teaching Design and Manufacture at Sussex

We focused our attention on a third year undergraduate module Design and Manufacture that is taken by students on three types of degree programme: Mechanical Engineering, Automotive Engineering and Product Design. This module runs for one term and aims to develop the students' understanding about design aspects of engineering components such as gears, belts, bearing etc and their interrelationship. This module was taught traditionally with lectures and calculation exercise classes and we planned to replace this with a problem-based learning approach. Students would work in small teams using the web-based resources to learn specific design principles in order to develop a 'transmission design' in response to a brief. They would receive feedback on their preliminary designs from their peers at a design review part way through the course and present their final design formally to the 'customers' at the end of the course. The teaching material delivered previously in lectures would be provided as resources in a VLE. The teams would be supported by limited access to a "design consultant" in the form of their personal tutor, and unlimited access to a discussion forum on the VLE where they could ask questions of the teaching team. By implementing a resource-based learning strategy utilizing the virtual learning environment we aimed to develop greater independence in the students while at the same time giving them the opportunity to develop their group-working and computer-based research and communication skills. At the outset it was envisaged that, additionally, benefits to staff would include a redistribution of teaching load to a wider range of faculty and less pressure on general teaching space. The course lecturer would be released from the lecturing task and be able to relate to students through the more useful means of questions, answers and explanations.

3 PROJECT DESCRIPTION

3.1 Project Outline

A detailed project specification was developed by the teaching team in conjunction with the Educational Technologist and covered: pedagogic and overall course design and delivery; operation of the VLE (which was WebCT) and development of associated faculty IT skills; the design of web-page templates; the dissemination of information about on-line learning to students and evaluation of student and faculty experience. A graphic artist contributed in the early stages to the overall look and feel of the course website, and decisions on navigation routes through the learning resources were addressed at this stage.

The learning resources, derived in part from a recent textbook [7], were converted from large PDF files to much shorter web-pages by a research student using Microsoft FrontPage then up-loaded into WebCT forming discrete subject blocks. Additional interactive resources were developed including: specialist design spreadsheets written by the academic consultant [8]; Failure Modes and Effects Assessment guidelines [9] and short (2-3 minutes) QuickTime (trademark of Apple Computer Inc.) videos of the academic consultant describing each of the key engineering components and their functions.

An aspect all too frequently overlooked in curriculum development is project planning. A project timetable was drawn up by the team at the outset and is given in Table 1. This timetable was developed to allow the course to be taken in the first term of Year 3 of the students' degree programme (Oct – Dec 2003). The development phase thus occurred through the preceding summer.

Table 1. Project timetable, continued over page (RS = course lecturer, PC = academic consultant, LR = educationalist, GM = programmer, TB= academic IT support manager, NC = administrative assistant, LC = timetabler)

Done by	Activity	People
June to mid-July	Meetings to establish overall course design & agree project plan	PC; LR; RS
30/7	Specification of web-based teaching materials	PC; LR; RS; GM
30/7	Registering & set up of WebCT course	TB
31/7	Training of project staff on webCT	LR
1/8	Specification of detailed design WebCT course	PC; LR; RS
1/8	Development of student briefing pack	PC; GM
29/8	Development of web-based teaching materials	GM
29/8	Development of student WebCT training materials	LR
3/9	Briefing personal tutors about course & their role	RS
3/9	Staff development in facilitating group working	RS; TLDU

3/9	Training of personal tutors in WebCT	PC; LR; RS
5/9	Organisation of presentations	NC
5/9	Timetabling for meetings and presentations	RS; NC
30/9	Design & development of evaluation instrument	PC; LR; RS
Week 1	Training of students on WebCT	PC; LR; RS; GM
Week 8	Delivery of evaluation to students via WebCT	LR
Week 11	Analysis of data collected	LR; LC
Week 11	Evaluation of tutors' experience	RS; LR
Jan 2004	Analysis of feedback	PC; LR; RS
Feb 2004	Action plan for changes drawn up	PC; LR; RS

3.2 Evaluation

Testing of the web-site proceeded with a small team of final year students and was then made available to the students. The educational technologist, course lecturer and a number of colleagues monitored first use and provided feedback for future development. Feedback was collected from several sources: direct observation of the final presentations; an online questionnaire for the students; feedback questions posed directly to the students; monitoring of their performance in a related subsequent module and interviews with the teaching staff involved with both modules.

4 COURSE DETAIL

4.1 Formation of the teams and role of the "design consultant"

Pre-existing personal tutor groups worked together with a 'design consultant' (their personal tutor) to produce their solution to the brief. The design consultant (personal tutor) for each group was intended to act as an advisor to the team whenever requested. They would help students identify the key knowledge and issues associated with answering the questions and guide students to and through the web-based learning resources where necessary. As the personal tutor they would have a role to play in facilitating team-building and monitoring students' individual progress with the task and team working. Four meetings of the team and the design consultant were time-tabled, beyond this the students themselves would take responsibility for managing and scheduling activities as a part of the team-working process. In fact the process broke down in this area, several of the personal tutors failed to engage with the new process and their groups worked mainly unsupported. The implications of this are discussed later.

There was a course discussion area on WebCT where any team member was able to ask questions or seek clarification. It was intended that this would be monitored on a daily basis by course tutors. This did not in reality occur and monitoring instead was on an ad-hoc basis or following a complaint or dose of frustration from a student or colleague. In addition each team was given a private discussion area on WebCT. There was no expectation that the design consultant would access this every day, however they would be contactable by normal communication methods ex gratis visit, phone and email.

4.2 Learning Resources

The web-based learning materials covered the subjects of: bearings; gears; clutches and brakes; shafts and other machine elements, in small discrete chunks of learning. These could be navigated either by 'component' or 'process' in order to support a variety of learning styles.

Table 2. WebCT content

Each resource block included:	Other documents provided in WebCT:
• the nature of the problem • theories & diagrams • worked examples of calculations • Failure modes and effects assessment (FMEA) guidelines • Specialist design spreadsheets	• course description, • project brief, • design review guidelines & forms • customer presentation guidance notes • assessment details • readings about group working • timetable

In addition students had access to the Pro/Engineer CAD software package (Parametric Technology Corporation) and face-to-face workshops were scheduled to support their use of this.

4.3 Assessment

4.3.1 Formative feedback

Each team received feedback on their draft design from a peer group during a 'design review' in week 6. Each reviewing team completed a form recording their feedback and grading aspects of the design from unsatisfactory to excellent. The reviewed team drew up an action plan for revision of their design based on the feedback given and recorded this on another form. Both design consultants were present at the 50 minutes meeting, one of whom chaired it. Guidance notes on the review process were provided for both the reviewing team and the reviewed team.

4.3.2 Presentation to customer

At the end of the course each team submitted their design and presented it as a group to a 'customer panel' comprising the Head of Department and visitors from industry. The presentations took place in the plush surroundings of the University's conference suite and the dress code was formal. At the end of the session the customers "awarded the contract" to one of the teams, and the 'winning' design would be showcased by the department on WebCT.

4.3.3 Summative assessment

Summative assessment was in the form of an individual detailed analysis report explaining and justifying/critiquing the choices/decisions embodied in the group design. It included a reflexive analysis of the action plan, its implementation and the group working process.

5 FEEDBACK AND RESULTS

5.1 WebCT Usage

A total of 208 web-pages containing learning resources were created for the course. During the period of the course a total of 2772 page hits were recorded and this constituted 179:32:16 hours of usage with an average time of 3:53 minutes per page. Unfortunately these figures include use by everyone associated with the course and are, therefore, not exclusive to students, however it is not unreasonable to assume that the students contributed the major proportion of the use.

5.2 Student feedback

Immediately after the presentations the course lecturer held an informal feedback discussion with the students and some useful evaluative points came out of this:

- the level and quality of support from the design consultant had been very variable across the group – from excellent to no contact at all for one group
- the students had felt that this had taken more of their time than other equivalent courses
- students had become extremely frustrated by the slow response from faculty to their questions posted on WebCT

All of these issues were reiterated by students in their comments on the standard departmental end of course paper-based evaluation form.

Only a small number of students (11/49) completed the online structured questionnaire in the last week of the course, so we cannot generalize from these results. However it is interesting to note that in response to the statement '*Overall I feel I've learned more on this Design & Manufacture course than I have on other more conventional courses (ones with lectures) on my degree.*' 7 students 'disagreed/strongly disagreed'; 1 student 'didn't know' and 3 'agreed'. In response to the statement '*Doing this Design and Manufacture course has made me better prepared for working in a project team when I go out into employment.*' 5 students 'disagreed/strongly disagreed'; 3 students 'didn't know' and 3 agreed/strongly agreed.

However when 40 of the same group of students, taking part in an assessed 3 day group design exercise 5 weeks later, were asked the open question '*Did your project work in last term's course Design & Manufacture, help you with this Design Seminar?*' 31 replied positively while only 7 replied negatively; 2 didn't answer the question directly. In response to the sub-question '*If so, then why?',* experience of teamwork was the most frequently mentioned reason, practical experience of the design process and methodology of the design were also mentioned. Some of the most positive comments were:

'yes - learned a lot on that course; valuable preparation for this design seminar; learned that teamwork is essential – that organization saves time; effort needed is more than you think'

' ... we had to learn how to make sensible assumptions ...'

'yes - learned the methodology of design – how to go about it .... Very useful'

'... group project was a first and it was an "eye-opening" experience of open-ended problems; first experience of trail (sic) and iteration'

5.3 Observation of the final presentations

The final presentations were observed by the educational technologist (who has 15 years experience of teaching in higher education.) The venue was excellent in conveying the right atmosphere for the event and turnout was high. Over 96% of the students were present on time and extremely well turned out – most were in suits. Students were attentive through all the presentations – the atmosphere was competitive with respect to the design solutions – many comparative comments about the technical merits of the designs being presented were being made in the audience around me as each presentation was made. All of the groups described the way they had organized their teams, how they had planned and tackled the problem brief (including methodologies for approaching the design task); the decisions they had focused on and what they had had to find out in order to make them. Some had even reflected on the effectiveness of their approach at key stages in the process and had made changes to their team working in response to this. The best presentations came from groups that played to the strengths of their team members and that had obviously worked cohesively as multi-disciplinary teams. They all spoke confidently on the technical detail of their designs and many spoke convincingly of why their product was superior. Generally they stood up to questioning well when put on the spot, and it was evident in most cases that every member of the group had been equally involved in the production of the design.

To summarize there was evidence of:

- a deep approach to learning
- active and independent learning
- synthesis of a diverse range of subject knowledge and practice – beyond that covered by the content of this course
- strong team spirit and effective team-working
- intelligent analysis of each other's designs
- an enthusiastic and professional attitude towards the project; the presentations, the customer panel and each other

6. CONCLUSIONS & RECOMMENDATIONS

There is often a certain level of enthusiasm for a new project. For example, if it has had to be championed in order to secure resources then to an extent, professional credibility is at stake and individuals can feel inclined to claim a success if at all possible. The authors are not going to disappoint here. The student feedback described in Section 5.2 is indeed mixed. It does, however provide a strong indication that the course has assisted the students in appreciating and developing skills in both the design process and group working. Tutors involved have indicated that students were so motivated on this course that they devoted a disproportionate amount of their time on this course to the detriment of their other work.

Although the key learning outcomes have been achieved, it has been at a price. The course required a substantial effort to mount. The time required to support the delivery of the course was comparable with that of the established lecture mode; the course traditionally occupies approximately 60 hours of faculty time in lecture presentation, revision classes, examination setting and marking, and with the new approach 70 hours of faculty time were used in expert /design consultant sessions with students. However the planning discussions and generation of the VLE required some 150 hours to create the web pages, 20 hours of training for faculty on WebCT and 40 hours of meetings.

At the introductory meeting students were assured that the provision of the VLE was not intended as a substitute for faculty time and that queries raised by the students through the VLE discussion area would be dealt with promptly. For various reasons this did not occur; replies were sporadic and concentrated near deadlines with whole weeks going by in some cases without responses. The authors feel this contributed significantly to the students' initial negative response to the project and needs to be addressed for next year.

However this combination of problem-based learning supported by a VLE provided an environment within which students worked considerably harder than in previous years when similar learning material had been presented more conventionally. The student work was, in the words of one of the external industrial judges, 'at worst satisfactory, at best absolutely stunning'. This raising of the overall standard is surely worth the additional effort that went into to generating the VLE that should, with relatively minor modifications be useful for three further years.

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