DEVELOPING PROFESSIONAL SKILLS THROUGH GROUP DESIGN PROJECTS AND PARTICIPATION IN STUDENT COMPETITIONS

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ABSTRACT

The development of integrated professional skills in Aerospace Engineering and Automotive Engineering through group design projects is analysed. We discuss how these activities provide a broad engineering education for our students, which is in response to industry's need for graduates with an appreciation of the multi-disciplinary nature of engineering.

INTRODUCTION

In most of the disciplines, art or science, there are some kind of student prizes for undergraduates. These are popular among the students due to the possible effect on their future job prospects especially for the creative industries where small companies employ few staff, Ford(1).

We report on our experience in constructing and supervising group design projects and the benefits of participation in student competitions within the UK. Competitions include the Merlin and the Heavy-Lift competitions for aircraft design and the Formula Student Racing Car competition.

The design projects are relevant from the point of view of effective teaching and professional training, students being required to collect information, synthesise a solution and produce a physical model. During this process, knowledge, skills and professional attitudes are simultaneously addressed, educating the students who will become technical members of product development teams, Ramsden(2), Dutson(3), Conrad *et al*(4). The total performance makes the assessment task easier since the final outcome represents an active demonstration of the knowledge specific to a number of courses like aircraft conceptual design, aerodynamics etc. The task of producing an actual airplane or car as a concept demonstrator leads to efforts beyond the usual mastery of analytical skills and basic engineering knowledge, developing a creative approach to problem solving.

The students have autonomy during the project development but must meet the deadlines and perform the model development within the given budget.

We are reviewing in the main part of the paper, the structure of these projects discussing in detail an aircraft conceptual design project. We present how different desired student skills (**table 1**) are developed and exposed and the manner in which we asses the individual students engagement within the team and their contribution to the final results.

PROJECT STRUCTURE AND ASSESMENT

The structure and complexity of group projects aims at developing product and system building skills, as well as the ability to apply engineering science, in design-build experiences integrated into the curriculum. Iterating during the design process to increasing levels of design complexity reinforce students' understanding of the product and system development process and lead to deeper conceptual understanding of disciplinary skills.

In order to enter the annual Merlin competition 2006, a group project was proposed with the objective to compare the characteristics of canard and conventional configuration for a *homebuilt* aircraft. The major areas of design: layout size, weight and performance are studied for the two different concepts in order to achieve a final solution with the best overall performance. A flight test scale model will be built to validate the predicted flight characteristics.

Technical Knowledge And Reasoning	Professional Skills and Attitudes	Interpersonal skills
Advanced Engineering fundamentals	Engineering reasoning and problem solving	Communication skills
Core engineering fundamentals	System thinking	Team work
Scientific knowledge	Knowledge discovery	Leadership
	Project management	
	High ethical standards and professionalism	

Table 1: Building blocks of knowledge, skills, and attitudes blocks specific to CDIO.

The Product Design Specification was produced using the SEED's method. Some relevant data are:

- fully aerobatic/sport 2 seater airplane
- max speed between 150-200mph
- stall speed no greater than 55mph
- rate of climb greater than 1,200 ftm
- operation at max 10,000 ft ceiling
- takeoff and landing to accommodate aircraft fields
- range 500 miles
- weight max 910kg

The team had to specify the most important factors for the design process, actual performance data being decided after a study of the aircrafts in this category available on the market. Some upper bounds on certain specifications are imposed by Civil Aviation Authority (CAA) regulations. A set of product specifications were required for the validation by a scaled radio controlled model taking also into account the legal, quality and safety considerations regarding the testing as well as the time and budget constraints.

In the initial phase, the students who chose to work on this project have to present a preliminary report which should contain:

- Market research
- Analysis of previous designs
- Overview of conceptual design
- Product Design Specification
- Critical analysis of tasks
- Management procedures
- Design Development plan (GANTT Chart)
- Costing and budgeting
- Risk assessment

This phase is essential for the successful start of the project having as critical elements the Product Design Specification (PDS), critical analysis of tasks and the GANTT chart. The two lecturers (supervisors) act as 'clients' and an element of freedom was given for the final PDS, to be reassessed after the market research and overview of solutions. The students begin to form a team and elect a leader who is in responsible for the project management. The meetings between the supervisors and the design team are taking place on a weekly basis and are recorded with actions for each student. The GANTT chart has to identify the critical moments during the project and present possible actions to prevent any loss of time due to the time constraints imposed by the academic year and the final competition. At this stage the need for a real time communication between the members of the team, led to the initiative of establishing a web site where the team members could create the report and send information by emails. The role of the two supervisors was to help defining the design path, improve the critical approach of the design task, and help defining a better structure of the interim report.

At the moment of writing this paper, the design team has completely stated the problem, the project goals and objectives, and has started the conceptual design for the two solutions. After iterative refinement, the designs will be tested on the Merlin simulator which was installed at Brunel University, in the School of Engineering in 2005.

The decision regarding which solution should enter in the competition, will be taken after the analysis of the performance and flying qualities shown during the simulated flights. The test will be performed by a former test pilot, lecturer in our school.

This phase will test creativity and the critical thinking in the design process and the student's resilience required by the iterative process. The verification and validation process will lead to a better understanding of all the theoretical concepts used during the design. The team's strength and the ability to solve individual tasks are also put in evidence as the time constraints become more stringent.

In the final phase the team will build a scaled model which will be tested in flight on an airport near the University. The results of the whole project will be presented in a final report and in an oral presentation in the School of Engineering. As a final step the design will take part in the UK Merlin competition.

The status and timing and of the report, the project analysis as well as the final tests are paramount for the success of the project.

We consider that our continuous formative feed-back facilitates self-assessment. The organization of the project increases the creativity and tests the students' persistence for achieving the final targets. The work on this project encourages self-esteem and leads to an increased motivation to learn.Finally it represents a good experience for better teaching for the two supervisors.

CONCLUSIONS

In this paper we present some aspects related to the development of group projects and how these activities provide a broad engineering education for our students. These projects promote a deeper understanding of the material taught in different courses; develop a creative approach to problem solving; enhance communication and team skills; provide managerial and related professional skills; and, in the vast majority of cases, promote a rich, diverse, and rewarding learning experience.

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PROMOTING LEARNER AUTONOMY IN ENGINEERING STUDENTS

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ABSTRACT

This paper will report on a current project that is part of a Centre for Excellence in Teaching and Learning (CETL): 'The Centre for Promoting Learner Autonomy'. The paper will discuss the learning, teaching and assessment methods used on a first year undergraduate module of an engineering course. The module, 'Materials, Manufacturing and Environmental Engineering', has traditionally been taught over 2 semesters through a series of keynote lectures, followed by seminars and laboratory practical classes. Case study work is undertaken by the students in semester 2 of the module, but it does not develop autonomous learning in an effective way at present.

The potential of the semester 2 work is to link individual critical review of knowledge and skill development of the students and relate this to their Personal Development Planning (progress files) through the use of innovative learning and assessment instruments. The paper will discuss the development of 'Project-based learning' scenarios in semester 2 that promote autonomous learning skills, with assessment instruments that encourage students to undertake individual critical self-reflective reviews.

The paper will outline the project to date and by the date of the conference presentation an evaluation of the outcomes will be available for further discussion.

INTRODUCTION

The Centre for Promoting Learner Autonomy (CPLA) looks to the future and the knowledge economy in promoting self-efficacy through a partnership between large numbers of students, staff, and all involved in supporting learning. Our transformative model is built on the relationships between:

- Pedagogic learning environments
- Policy drivers, such as Learning, Teaching and Assessment (LTA) and Widening Participation (at local and national levels)
- Characteristics of an autonomous learner

'The Centre for Promoting Learner Autonomy (CPLA) empowers students at Sheffield Hallam University and beyond to acquire responsibility for their learning, to work in partnerships with tutors and other students. Learners demonstrate transformative approaches to constructing their own knowledge; they integrate into academic communities. CPLA brings together excellence in developing learner autonomy, pedagogic innovation, staff and educational development, project management, for the benefit of the sector'(1).

CPLA is needed to respond to:

- student aspirations in a knowledge economy as recognised in government and funding council reports,
- likely changes in students and their families' expectations of HE delivery
- lifelong learning needs
- needs of staff wishing to develop an effective model of learner autonomy.

Staff at Sheffield Hallam University present a model of learner autonomy they believe is new for the sector. It comprises three linked elements:

- pedagogic learning environments
- characteristics of an autonomous learner
- policy contexts.

The characteristics of an autonomous learner are:

- Critical reflection
- Self-awareness
- Taking responsibility for own learning
- Working creatively with complex situations

In educational settings, autonomy is most commonly defined as a capacity to take charge or control of one's learning(2,3). Candy(4) places the development of autonomy on a continuum with teacher-control at one end and learner-control at the other. Learners achieve different points at the learner-control end of the continuum depending upon context.

The impact of variable fees, changes in the 14 -19 curriculum, changing employment patterns, may encourage an instrumentality that undermines student-led learning initiatives. We do not accept this gloomy scenario. We wish to show excellence in enthusing students whose self-efficacy and management of prospective situations is transformed(5). Many academic staff espouse the values of learner autonomy but find such values difficult to put into practice. CPLA supports academic staff across the sector in this work.

Most recent research agrees that autonomy is a developmental process which cannot be taught or learnt(3). However, the Sheffield Hallam model with constant interactions between pedagogic learning environments, learner autonomy characteristics, policy impacts, achieves 'pedagogic resonance' for students(6) - creating a space for new learning partnerships. We draw upon different traditions e.g. constructivist theories of learning, particularly experiential learning(7,8,9) and also the central idea of a learner-led curriculum(10) that is increasingly made possible through the appropriate use of technology. Constructivism is based on the premise that knowledge is constructed by each learner through processes of social interaction. CPLA will impact on all aspects of the student experience.

We concur with Boud(11) that 'assessment practices are often the major barrier to developing increasing student responsibility: if students look to others for judgements of their competence, how can they develop their ability to assess their own learning?', and with Heron(12) that the balance of power between staff and students in assessment critically affects the transactions between them.

LEARNER AUTONOMY IN ENGINEERING

One project, which is part of the CPLA, is concerned with working with first year (level 4) undergraduate engineering students. The module, 'Materials, Manufacturing and Environmental Engineering' has been traditionally taught over 2 semesters, with keynote lectures and laboratories/ tutorials in semester 1, flowed by case studies in semester 2. However, learner autonomy is not explicitly developed within these case studies and so a new learning and teaching methodology is being used under the CPLA development work.

The main objectives of the project are:

- To develop learner autonomy in engineering first year students.
- To link individual critical review of knowledge and skill development of the students and relate this to their Personal Development Planning (progress files) through the use of project and problem based learning.
- For students to work effectively in teams and independently to develop communication, presentation, enterprising, creative and problem solving skills.

Students are therefore undertaking two new types of project work. In one set of assignments one half of the first year group of students are required to produce short video clips (less than 2 minutes) related to materials, manufacturing or environmental processes. This project – 'Users as Producers', requires the engineering students to learn and develop skills in video and media production, including editing. The resultant clip (or nugget) can be embedded within a Powerpoint presentation, or located within the Blackboard VLE for other students to view. The video clip will be presented together with a set of learning outcomes to reinforce the objective.

As well as developing skills in media production there is also an opportunity for students to develop key skills such as presentation techniques, project management skills and conflict resolution (whilst working together in groups).

The assignment that the other half of the first year group are undertaking is based on the theme of ‘Engineering Disaster Management’. Initially (within 2 weeks) the students are required to develop a half page ‘brief’ related to an engineering disaster that has happened anywhere in the world. This brief must detail:

- Background to the disaster and where it fits in within the context of materials and/or manufacturing and/or environmental engineering
- Define the project/ problem, give details, outcomes, solutions (future prevention)
- Work programme/ Project Plan of how they are going to undertake the project, e.g. find information, the type of information, who is responsible for the different aspects – team roles etc.

They work as a group within one topic area from the list below:

TOPICS:

1. Automotive
2. Aerospace
3. Civil/ construction
4. Environmental
5. Railway

During semester 2 they carry out the project and report back at certain milestone points on progress.

Students are being prepared for their project work in a number of ways. A series of seminars on video and media production were given during semester 1 and reinforced in semester 2 with ‘drop-in’ sessions available. Also, students have been introduced to the Belbin(13) model of team roles to help them get the most from their group working. Students undertook a self-perception Belbin questionnaire in class which highlights their perceived team role. This can then be reflected upon both during, and at the end of the project.

Ultimately, both groups of students will present their project at the end of module ‘Student Conference’. This presentation will be a Powerpoint presentation and they may use video clips from existing sources or use the ones that they have produced.

The project work requires that both staff and students are trained and supported in the use of new teaching methodologies, particularly the use and production of video material.

ASSESSMENT

The module is currently assessed by coursework only, with one of the elements of assessment being an in-class time constrained multi-choice test. It is planned to hold the end of module ‘student conference’ during the latter part of semester 2, but early enough to be able to have the in-class test a few weeks afterwards, so that questions based on the knowledge disseminated at the conference can be included. This will mean that the students have to engage with all the student presentations, as staff will be using the conference to produce more multi-choice questions from the day’s event. In addition an external speaker has been invited to give a keynote presentation at the conference on ‘Engineering disasters’. This gives more realism to the conference and allows students to get the feel of a ‘real-world’ conference event.

The assessment of the students will also be on their presentations, with a panel of staff and external industrialists marking them. Copies of the presentations will be obtained from the students prior to the conference day in order to formulate the conference programme. The staff are therefore only marking the presentations with no group reports, which reduces the staff assessment burden and allows for a fast turn around of feedback to the student.

It is also planned that these project assignments give students the opportunity to reflect on their participation A pro-forma is being produced that will guide students through their personal development and help them to reflect within their Personal Development Planning (PDP) progress files. Students could include their Belbin analysis and critically reflect upon how the assignment went, the role they played and what they have learnt about their strengths and areas for future development.

EVALUATION

At the beginning of semester 2, a questionnaire will be given out that finds out from the students what they perceive as learner autonomy; also seeking to evidence their current learning styles and expectations. A follow up questionnaire at the end of the module, with some focus group discussions will be used to further evaluate the student view of the assignments in order to evaluate the benefits of this type of learning and teaching methodology. Details of these evaluations will be presented at the conference.

FUTURE WORK

It is planned to use three main outputs within the CETL project:

Output 1: taking level 4 courses with high student numbers, developing our learner autonomy model across such courses, including inquiry-based learning (IBL), use of personal development plans (PDPs); the activity is then developed across a network of Subject Centres before 'returning' to the University for further development on other courses. The resulting university-wide output will gain from this broadening process.

Output 2: developing the model across subject pairings, e.g. History and Languages, Engineering and Art & Design, expanding discipline-based learner autonomy, using already established good practice in the university.

Output 3: transferring the model from one level to another, e.g. from postgraduate to undergraduate levels in the same subject area.

Taken together the three outputs provide a cascade model of mentoring to support innovation and achieve staff 'buy in'. CPLA creates linkages between disciplines, a key requirement of Sheffield Hallam University's Corporate Review (2003-2008).

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ARE ENGINEERING STUDENTS ENGAGED WITH THEIR LEARNING?

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INTRODUCTION

There have been considerable changes in Higher Education in the UK, particularly over the last two decades. Universities today continue to face key challenges in order to maintain standards and to provide business and industry with the necessary skills and knowledge for the future economic wellbeing of the country.

The key recipients of higher education, the undergraduate students, also are facing key challenges that directly impact on their learning. The higher education theory and literature tend to tacitly assume a desire to learn and a thirst for knowledge that drives engagement on the part of students. The reality is somewhat different; the key motivator for students is the exchange value of the qualification and, as a result, learning is pragmatically strategic.

This study sets out to determine, of engineering students, the degree to which they engage with their studies. The study examines the same issues across two universities with different historical backgrounds using a questionnaire for the collection of data. Focus groups were conducted to extract deeper qualitative data. Data was collected from students at similar stages of study in the respective institutions to determine any significant institutional differences.

THE NEED FOR ENGAGEMENT BY STUDENTS

Learning is a complicated phenomenon. Much work has been done on understanding learning: many theories abound about what constitutes and what facilitates learning. We think it's fair to say that whilst many of the theories are helpful in informing the approaches to the practices associated with teaching and learning in Higher Education, tutors and students have the responsibility for operating in a pragmatic compromise which best fits the requirements of all stakeholders in higher education. The consequence of this is that graduates are produced who 'meet the grade' but industry, through professional bodies and other employer stakeholders, is suggesting that perhaps the 'grade' is not high enough.

This thesis hinges on the crucial question of how students learn. It is a matter which has concerned educational psychologists, scientists, academics, philosophers and 'ordinary' individuals since education has become the norm of civilised society.

If we combine the thoughts of the cognitive scientist with those of the theories of educational psychologists, it is fair to say that there is confusion and a lack of full understanding of the learning process. The individual human mind is probably much too complex in its workings to allow for general analysis and a concrete view of the learning process. Although the studies of human information processing and cognitive development improve our insight into learning and provoke ideas to facilitate learning, it appears in summary that each individual probably learns in a different way and each theory to be learned is probably learned in a different way.

How do students learn best?

This question does not have a universal answer. In terms of University student learning, there are several reasons for this of which the following are most pertinent:

1. Students are individuals with individual attributes governing their learning skills;
2. Each subject/module has practical attributes which require particular modes of teaching; eg the teaching of Engineering or laboratory based subjects naturally has

a more practical approach in its delivery to that of, say, Law or Management. This directly influences how the student learns that subject.

Much research has been carried out to analyse the process of learning, to understand the educational and cognitive psychology of learning, to understand human abilities and their relationship with learning and, indeed, to simply understand student learning. A significant proportion of the research examining the relationship between teaching methods and their products, in terms of what and how students learn, has been based on the undifferentiated criterion of 'achievement'. What constitutes 'achievement', however, can vary from definition to definition. Entwistle(1) stated:

'*The precise definition of achievement varies from institution to institution, from discipline to discipline and even from department to department . . . thus there is often rather little objective evidence available to indicate the strength and consistency of the influence of particular teaching methods on specific learning outcomes*.'

Approaches to learning

Marton and Saljo(2), Pask(3), and Entwistle and Ramsden(4) and many others have, in their research, identified student approaches to learning which may be classified broadly as either 'surface' or 'deep' processing of information. The two approaches to learning were categorised by Ference Marton(2) as:

1. The Deep Approach, and
2. The Surface Approach.

The Deep Approach stems from an intention to develop a personal understanding of the material presented (to the learner). To do this, the learner has to interact critically with the content, relating it to previous knowledge and experience as well as examining evidence and evaluating the logical steps by which conclusions have been reached.

Rote/Passive learning v Active/Experiential learning

The various theories of educational psychology have been considered and the theories of human information processing have been examined. No clear conclusions as to how University students learn best can be directly derived from these studies. Experience of student learning has led to a more definitive conclusion as to how students learn best if it is agreed that learning can be classified into the two types, viz:

1. **ROTE** learning – where the learner adopts a passive role;
2. **EXPERIENTIAL** learning – where the learner adopts an active role.

Experiential/active learning induces the storing of memories in the 'semantic long-term memory'. This requires effective storing which depends upon appropriate 'cataloguing' and 'cross-referencing'. In Ausubel's(5) terms, this would be relating and anchoring new materials to relevant established ideas in cognitive structure.

Rote learning, in contrast, can be described as 'the repetitive over learning of materials which are treated as meaningless and are presumably stored ultimately in 'episodic long-term memory' Entwistle,(6).

Summary

The theory and evidence established from practice makes explicit that the key component of effective learning is engagement by students with a clearly defined and curriculum and appropriate learning resources. Student engagement is a pedagogical management and student motivation. Therefore it is incumbent upon the Institutions to facilitate this function and improve student engagement. This paper uses data extracted from a larger study currently being undertaken by the authors to illustrate this point.

KEY FINDINGS OF THE RESEARCH

The paper is based on qualitative and quantitative data obtained from Engineering students from two Universities. The method of data collection was by round table discussion with Engineering students focus groups and on responses to questionnaires distributed to two samples of Engineering students.

The research indicated no significant discernible differences in responses from students between the Institutions.

Time management

The student focus groups highlighted the fact that timetables did not optimally facilitate study patterns. The timetable was described as 'an inefficient use of time'. It clearly did not fit with the extra-curricular activities of students, particularly part-time working commitments. 'Time' was a recurring word used by students in the focus groups and indicated that time management was a major issue for students and concessions on timetabling were not addressed by the Institutions. This issue manifests itself in higher than acceptable or appropriate absenteeism rates. When a student has conflicting demands on time, attendance at classes can often take a lower priority.

Attendance

The student responses to questions on attendance indicated that student perceptions of attendance were that it was relatively good. Out of the 121 students who responded to the questionnaire the perception was that their mean average attendance was 90%. This is an interesting perception because the tutor attendance records for this particular group show that the mean average attendance did not exceed 55%. There has been much discussion amongst tutors about the falling attendance of students and this suggests that there is a considerable discrepancy between what these students perceive their attendance to be and what it actually is.

Learning environment

Fifty percent of this group of students stated that a large lecture class adversely affected their learning. Forty-three percent stated that it did not.

Fifty percent stated that a large seminar class adversely affected their learning. Thirty-four percent stated that it did not and the remaining sixteen percent had no opinion. These responses seemed to contradict a further question in which the students were asked what was the optimal class size for lectures and seminars for effective learning for them. The preferred class size for lectures was in the range 16-25; and the preferred class size for seminars was equally divided amongst sizes 1-10 and 11-15 and 16-25.

These results indicate that for effective learning these students prefer a class size of 16-25 for lectures and a class size of no more than 25 for seminar classes. These views of the students contradict the current drive in higher education for efficiency through large group teaching.

Learning medium

The students were asked, 'What are the sources of your learning material?' They were asked to rank their responses. The responses were analysed and the results placed in rank order. The source of learning material ranked highest was 'Lecture Notes'. The indications from this aspect of the survey were that students' orientations to study are that engagement is related to lecture material with less engagement with independent study. This is contrary to the institutional emphasis on student-centred learning with students taking responsibility for their own learning through directed reading.

Reason for study

Students were asked: 'What is the prime reason for doing your course'. The responses are listed in rank order. That is:

- to get a degree to enhance employment opportunities:
- to accumulate knowledge about the subject: to get a degree
- to learn key skills
- for the social life
- to be trained in research methodology
- to do research
- for the sports facilities
- to put off working for some time

The responses to this aspect of the study suggest that whilst learning theory is based on the premise that students in higher education have a willingness to learn, in fact their prime reason for undertaking a course is the exchange value of the qualification and their motivation is to pass the assessments.

CONCLUSION – INTENSIFYING STUDENT ENGAGEMENT

An immediate and relatively simple timetabling change could facilitate learning through a more efficient use of time and structure of the module which would impact positively on attendance. Modules are a means of standardising learning. Learning is facilitated if the goals are clear. The learning time spent on a module consists of contact time with tutors and non-contact time. Different amounts of contact time are required for different modules: the norm varies from 3 hours per week to 6 hours per week; therefore a full-time course requires classroom attendance of between 9 hours and 18 hours. Current timetabling scatters the required attendance hours throughout the week with one hour here, two hours there etc. The causes of this are availability of rooms and programming of tutors. This leads to a lot of unproductive time for both students and tutors. Contact time should be better structured and timetabled with appropriate rooms scheduled for the learning activity: Therefore MODULE DAYS should be scheduled. Modules should be standardised in terms of amounts of contact time and non-contact time.

Learning environments should be allocated to suit the planned learning activity. A proportion of non-contact time should be structured for the student and learning facilities made available. A cultural shift away from large lectures in which students take notes towards more independent research and problem solving activities would promote, as a natural consequence, student engagement.

Student engagement needs to be championed by motivated and enthusiastic teaching staff. The Higher Education system needs a fundamental shift in priority which places emphasis and commensurate reward for teaching staff as against research and analogous activities McLernon and Hughes(7).

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PREPARATION FOR GROUP PROJECT WORK – A STRUCTURED APPROACH

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ABSTRACT

This paper describes the introduction of a series of structured activities into the second year tutorials (SYT), designed to prepare students for a team project in the following semester. The tutorial activities take the form of a series of five linked problems, which simulate aspects of a practical team project, developing team working, project planning and group presentation skills. A problem-based learning (PBL) approach was taken, which provided a model for problem solving in structured team meetings.

An integrative evaluation of the tutorial system was conducted using confidence logs, attitude surveys, questionnaires and a number of focus groups. It was found that the activity was appreciated by participating staff and students. However, there was a need to assign credit to this activity to improve engagement.

INTRODUCTION

The development of professional and personal skills in engineering students is becoming increasingly important. A recent survey of employers, conducted by the IEE (Institution of Electrical Engineers[1]), highlighted a mismatch in the skills required by electronic engineers, and the skills that graduates possessed. This finding is in line with similar studies and engineering educational reviews in both America and Australia, reported by Mills and Treagust(2). These studies emphasise a lack of teamwork and communication skills. There has been debate about the most appropriate method of embedding these skills into the curricula, whether PBL or project-based learning approaches are more suitable for engineering subjects([2] and Perrenet *et al*[3]). This paper describes a development where these approaches are used to complement each other. PBL is used to provide a structured approach and framework to prepare students for project-based learning.

BACKGROUND

This development takes place in a background of increased interest in PBL and enquiry based learning (EBL) of which PBL and project based learning are examples.

The University of Manchester has been working in collaboration with University College London and the University of Bristol(1) on the implementation of PBL into the third year of engineering degree programmes. This work has been supported by the IEE and the Higher Education Funding Council for England (HEFCE). In Manchester, PBL has been introduced into three third year units, in the areas of VLSI design, Optoelectronics and Robotics.

The University of Manchester has recently won one of the HEFCE awards for Centre of Excellence in Teaching and Learning (CETL) in EBL, (CEEBL[4]), which is supporting a number of projects across the University, including the one described in this paper.

This development draws on the support and expertise of the above initiatives.

The School of Electrical and Electronic Engineering at the University of Manchester offers five related degree programmes: Electrical and Electronic Engineering (EEE); Electronic Systems Engineering (ESE); Mechatronic Engineering (MTE); Computing and Communications Systems Engineering (CCSE); and Computer Systems Engineering (CSE), as 3 year BEng or 4 year MEng degrees. These programs have a common first year, specialised second year through core units and further specialisation in the third and fourth years through core and optional units.

The current second year consists of 132 students, divided into 24 tutorial groups of 5-6 students from a mix of degree programmes.

RATIONALE

The stimulus for the present exercise arose from experience gained in a practical team project that the school has recently introduced into the second year of its programmes. Known as the Embedded Systems Project (ESP), this ran for the first time in the 2004-05 session, after having been piloted in the MTE programme in the previous year. The ESP represents a 10 credit unit of continually assessed project based learning.

In the ESP students work in teams of typically 4-5 throughout Semester 2 on the design and implementation of a microcontroller based product. Each programme had a different project, reflecting the specialities of that programme:

- EEE worked on a model of a 11kV ring circuit;
- MTE designed and constructed a robot buggy;
- CCSE looked at data transfer between two microcontroller boards, initially over wires then over a radio link;
- CSE and ESE implemented a weather recording station with pressure sensors, liquid crystal display and FPGA controller programmed in VHDL.

All of these projects have substantial hardware and software components.

Staff feedback suggested that the students had learnt a lot from the activity but were slow to engage with the project, taking time to understand the required amount of commitment and the shift from passive to active learning. Students' feedback suggested that they required more preparation in the skills of teamwork, project planning and group presentation prior to engaging on a full unit that demanded these skills for its success.

It was decided to use the SYT in Semester 1, to develop these skills in preparation for the ESP in Semester 2. This would provide an opportunity for students to develop and practise these skills through a structured series of problems, allowing the students to focus on a few of these skills at a time, in contrast with a full scale project where competence in all of these skills would be required for a successful outcome.

It is anticipated that with this preparation, students will be able to form functional teams with effective team processes much quicker and consequently begin to make constructive progress on the ESP at an earlier stage.

There were also a number of practical, electronics based skills that it would be useful for the students to develop as preparation for the ESP. These included designing operational amplifier circuits, selecting electrical components, and planning the layout of a prototype circuit on stripboard. These requirements informed the design of the scenario and the problems that it contained.

THE APPROACH

Introduction

A series of linked problems were designed for students to work through during the semester. These problems simulate aspects of a project. Tutors and students would meet fortnightly. Students would report on their solution of the previous problem, the tutor providing appropriate feedback. The next problem would then be presented and the tutor facilitated the students' initial discussions about the problem.

The Scenario

An industrially inspired scenario was developed to contain these problems, which provided an example of electronic engineering supporting another industry. An industry was chosen whose products would be tangible and familiar to the students, although the processes involved may not be fully understood.

The scenario chosen was based on a hypothetical decorative tile company, Baked Earth, which has become aware of inconsistencies in the quality of a new high temperature glaze. They are working partnership with Euro-Tunnel Kilns to find a solution to this problem. They need to measure the temperature profile of a kiln using portable temperature sensors. The Agency for Consultancy in Electronics (ACE) has been commissioned to design the electronics for this task; the students took the role of a team of consultant engineers in this agency.

Problems

Five linked problems took the students through various stages of this project.

1. Design a Circuit
A senior consultant had recommended that a thermistor should be used for this project. The students were asked to design a circuit for a thermistor sensor to interface with a PIC control board.

2. Choose a Sensor
It was revealed that the thermistor would not measure the kiln temperatures required and they were asked to find another sensor that would.

3. Plan a Project
Noting that the earlier misdirection of the senior consultant had caused some slippage to the project, the students were asked to review the project plan and recommend a revision.

4. Practical Implementation
The students were asked to redesign their circuit for the new temperature sensor and plan how to lay out a prototype circuit on the stripboard.

5. Group Presentation
Finally, the students were asked to present their findings for the problems.

Lectures

A series of lectures supported this activity, providing timely advice:

- Introduction
- Searching Skills
- Working in Groups
- Project Planning
- Presentation Skills

Guides

In addition, a series of guides were written to reinforce the lectures:

- Second Year Tutorials
- Manchester Steps
- Small Group and Team Work
- Searching for Information
- Project Planning
- Group Presentations
- The Marking Scheme

The Manchester Steps takes the steps associated with PBL(4) and fitted them to the acronym of MANCHESTER.

Tutor Briefings

Tutors were supported through this activity via a series of tutor briefings. These were deliberately succinct, highlighting the key points of each session through trigger phrases.

Assessment

The tutorials were not formally assessed. However, formative assessment was conducted to indicate how the students would have performed on the ESP if they had made a similar level of contribution. Each week the tutor would grade individual contribution on a five-point scale. The group presentation was also marked against: preparation, delivery, contents and responses to questions, in equal measures. The contribution of each student to the presentation was also recorded.

The scores from the contributions to the tutorials and presentation were averaged. A projected grade was calculated, based on the mark they would have gained if they were part of an averagely performing team, whose project achieved a mark of 60% using the formula used in the ESP that allows a shift up to half the project mark in either direction, based on the level of individual contribution.

EVALUATION

Method

Integrative evaluation was conducted, based on the process described by Draper *et al*(5), where the focus is on understanding the experience of the students engaged in the learning activity. A series of evaluation questionnaires were used.

Initial questionnaires were administered on-line, through links distributed via e?mail. The response rates were low, consequently later questionnaires were administered on paper, during the group presentation sessions.

Confidence Logs
These were used to record the confidence of the students on the learning objectives of the SYT(5) and were applied pre and post the SYT.

Study Process Questionnaire
Developed by Biggs *et al*(6), this measures the students' approaches to learning, whether deep or surface. This was applied prior to the semester to give an indication of the types of learner engaged on the activity.

Learning Resource Questionnaire
Developed by Brown *et al*(7), this measures the frequency of use and usefulness of resources.

Perceptions of PBL Questionnaire
This gauges students' perceptions to PBL and conventional learning.

Post Course Questionnaire
This open response was used to gather more general feedback.

Focus Groups
In addition three focus groups were conducted, one part way through the semester and two at the end.

Outcomes

These results should be treated with caution, since the response rates where low (22%-28%) and there is likely to be an element of self-selection in those who responded. Those who filled in the on-line questionnaire are possibly more motivated students and those that filled in the paper questionnaires are those who gave a presentation. The focus groups were based on volunteer samples, so may have attracted students who had something to say about the tutorials, whether positive or negative.

Learning Outcome	Pre PBL	Post PBL
selecting components	2.84	2.57
designing circuits	3.13	2.46
team working	2.00	1.89
defining problems	2.28	2.08
problem solving	2.38	2.22
project planning	2.66	2.57
project managing	2.63	2.54
self-directed learning	2.53	2.38
communicating ideas	2.53	2.32
searching for information	2.06	1.97
presenting information	2.47	2.59
giving feedback	2.75	2.59
Number of Responses	*32*	*37*
1 – Very Confident *to* 5 – No Confidence		

Table 1: Confidence Logs

Despite that, they provide a useful indication of what was happening during the learning experience.

Confidence Logs
Table 1 shows the score against the intended learning outcomes of the SYT. There appear to be modest increases to all the learning outcomes, with the exception of presenting information.

Study Process Questionnaire
On average the cohort came out as having a Deep Learning Attitude of 28.3 and Surface Learning Attitude of 22.9, on a scale of 10 to 50. This is a very similar result to an independent group of third years on whom this questionnaire was applied, so are probably typical of the profile of our students.

It is anticipated that correlating these results with other measures it will be possible to discern if there are differences in behaviours between students with deep or surface attitudes to learning. This analysis will be the subject of further work.

Resource	Frequency of Use
textbooks	2.97
own notes lectures or labs	3.43
borrowed notes	2.20
discussion with tutors	3.00
discussion with students	3.50
internet	3.77
other	2.74
Number of Responses	*30*
1 – Did not use to 4 – Used Regularly	

Table 2: Frequency of resource use

Resource	Usefulness
lectures	3.10
textbooks	3.15
own notes lectures or labs	3.23
borrowed notes	2.36
discussion with tutors	3.28
discussion with students	3.14
internet	3.52
other	2.71
Number of Responses	*30*
1 – Useless *to* 4 – Vital	

Table 3: Usefulness of resource

Learning Resource Questionnaire

Table 2 shows the frequency of use of resources and **table 3** their usefulness. Clearly a wide range of resources were used with the internet being used as a primary resource. Encouragingly, the discussion with other students and tutors registered highly, indicating that the students found the group work, both facilitated and unfacilitated useful.

Students that indicated other resources mentioned: the library, the intranet, company data sheets and catalogues, magazines and the results of previous project research.

Perceptions of PBL Questionnaire

Table 4 shows the responses of the students to this questionnaire. The results come out positively towards PBL. Despite recognising the increase in time and responsibility that PBL entails, the students seem happy with the support they got and would be prepared to learn this way again. Their enjoyment of group work is of particular note. There is a preference for lectures, which may not be surprising since this is the mode of teaching in which they have predominantly been taught.

Post Course Questionnaire

The questionnaire consisted of three value-neutral, open questions and an opportunity for further comments:

What did you learn from the SYT?

Most mentioned team working, though some suggested negative experiences. Project, presentation, problem solving and research skills were also mentioned.

What did you not like about the SYT?

Most complained that it was not marked, others complained of competing workloads from other units, some mentioned dysfunctional teams.

What would you like to see changed about the SYT?

Suggestions included adding marks, reducing workload and better teamwork.

Other Comments

Some were supportive of the initiative but reiterated credit and workload issues. There were a few who did not value the initiative and would prefer using the tutorials in other ways.

Focus Groups

The focus groups reiterated the need for credit and the balance of workload. The team work

Statement	Score
I like PBL	3.60
I learn more from PBL	3.23
PBL takes more time	3.53
more responsibility for learning	3.60
I enjoy group work	3.87
I understood the problem	3.67
I understood what was required	3.57
I was happy with staff support	3.67
I prefer to learn through lectures	3.10
would like to learn this way again	3.57
PBL has made me better at … finding and using information	3.57
Number of Responses	*30*
1 – Disagree Strongly, 5 – Agree Strongly	

Table 4: Perceptions of PBL

and problem solving aspects were generally appreciated, though some commented that getting the full team to participate was difficult. Some felt that the project planning was not well enough supported. The introduction of example circuits into Problem 4 confused some students. Some thought that the problems were very difficult to subdivide into 6 different tasks.

Attendance

The attendance dropped off for this activity, beginning at 92% and dropping to 45%. This seems to reinforce the idea that the lack of credit associated with the activity made it appear optional and easy to ignore, especially as competing workloads increased over the semester.

Tutor Feedback

Tutors expressed that it was a worthwhile activity but considered that it required credit to maintain motivation throughout the semester.

Further Evaluation

During Semester 2, ESP supervisors will monitor the progress of the groups and further focus groups will be conducted to evaluate whether exposure to the SYT has improved their performance.

FURTHER DEVELOPMENT

The SYT will be run again next year. An appropriate amount of credit will be borrowed from related units to enhance student motivation and provide a clear signal that the activity is valued and compulsory. The problems will be fine tuned, based on the feedback from the focus groups, with more structure and guidance on how the problems can be divided into tasks. Additional support will be provided for the project planning aspect.

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KEYNOTE PLENARY
CREATIVITY IN ENGINEERING EDUCATION

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ABSTRACT

Engineering educators often pose the question: how can I help my students think more creatively, think up innovative solutions and perhaps even enhance their creative potential? However, one of the most common comments I hear whenever I speak to students and faculty about creativity, especially in my area of engineering, is that they are simply not creative people and it is not something that can be 'taught'. The study of individual creative people, especially those who are considered to be genius, is often dismissed as irrelevant to the average person with no special talent. However, it is the conditions surrounding the creative breakthrough that seem to be important and which we can learn from, if we want to help support any emerging creativity, however limited. Furthermore, if we are aware of some of the features of a person who is trying to express themselves creatively we will develop conditions which will support them. In our publication 'CASE: Creativity in Art, Science and Engineering', (Dewulf and Baillie, 1999) we explored the conditions that enhance and suppress the creative potential *of an individual, both internally and externally. The general thesis being that everyone has a creative potential which can be suppressed or enhanced from early childhood to make us what we are today and which can be additionally encouraged by a whole range of techniques and tools.*

We can apply these techniques and tools in an engineering context to help support our students develop creative thinking. The next stage, however, is often neglected - to support the emergence of creative potential when we see it. Gruber (1981) concluded that a ' "whole thinking" person' harbours 'a number of interacting subsystems': the organisation of knowledge to produce a coherent system, a guiding purpose or quest, the use of strong metaphors, a strong tie to the subject of curiosity and often the willingness to embark on a solitary journey where the chances of failure are high, to deviate from the pack, and face rejection in some cases. We need to develop mechanisms for supporting students and for encouraging further growth when they show signs such as these. For instance, Gardner shows that not only do creative people usually have some kind of support system in place, but that this system has several components - the need for affective support from someone the creator feels comfortable with as well as cognitive support from someone who could understand the nature of the breakthrough, however small (Gardner, 1993).

In the paper I will discuss the conditions which help to enhance or suppress creative potential in an individual, the techniques that may be used to help promote this potential in engineering students, and the mechanisms to develop and support students once the creative potential begins to emerge.

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