project based learning in engineering

A Guide to Learning Engineering Through Projects

43/99 PBLE: Project Based Learning in Engineering
University of Nottingham
Subject area: Engineering
http://www.pble.ac.uk
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FUND for the DEVELOPMENT of TEACHING and LEARNING

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Section 1 Introduction

This section of the guide:

- Indicates the purpose of the guide and the nature of projects
- Introduces the PBLE (Project Based Learning in Engineering) project
- Explains the structure of the guide and of the complete package
- Acknowledges the help of colleagues

1.1 Purpose and projects

The fundamental purpose of this guide is to help those involved in the teaching of engineering to implement or improve the use of projects in their work with students.

Projects can take many and varied forms including:

- Design and build
- Design portfolio
- Environmental impact assessment
- Management simulation
- Production of a tender document
- Reverse engineering or product analysis
- Simulated public enquiry

The main characteristics of the projects addressed in this guide are that they:

- Are student-centred
- Develop a wide range of skills
- Involve active learning
- Frequently draw on knowledge from a range of modules
- Often involve group work

Some of the main benefits of learning engineering through projects are that:

- Students are encouraged to use a wide range of skills to apply their theoretical knowledge to practical situations
- This helps them to develop a better grasp of theory and to develop new and powerful skills
- Learning engineering through projects is fun for students and for staff.

Projects can operate within hugely diverse contexts and along a broad continuum of approaches. They may be used by a single lecturer or course team within a department that mainly uses more traditional methods of teaching. Or they may be linked to a complete restructuring of the learning experience of all students.

The focus of this guide is the individual lecturer or course team; other parts of the PBLE project will consider department or faculty-wide approaches to learning engineering through projects.

Clearly different types of project will require different approaches. Rather than go into huge amounts of detail on every possible approach this guide seeks to offer general advice and to highlight areas that present particular challenges.

It is worth remembering, though, that most projects take time to develop and usually evolve over several years.

1.1.1 PBL – project-based and problem-based

The focus of this project has been on project based learning because this is a widely used approach within engineering. The term project based learning, and its abbreviation PBL, can cause confusion with problem based learning.

Part of the difficulty is the range of forms that both project based and problem based learning can take. Problem based learning can make use of projects, but does not have to. Project based learning can make use of problems but does not have to. Both can be group-based, but neither has to be. Both can be department-, faculty- or institution-wide (see Case Study 8), but neither has to be.

In engineering the similarities between the two approaches may well be greater than in some other disciplines. Engineering projects will typically address a real world problem; this may not be true of projects elsewhere.

Camille Esch, at http://pblmm.k12.ca.us/PBLGuide/PBL&PBL.htm, offers two helpful continua for distinguishing between problem based and project based learning.

> One is the extent to which the end product is the organizing center of the project. On one end of this continuum, end products are elaborate and shape the production process, such as a computer animation piece which requires extensive planning and labor. On the other end, end products are simpler and more summative, such as a group's report on their research findings. The former example is best described as project-based learning, where the end product drives the planning, production, and evaluation process. The latter example, where the inquiry and research (rather than the end product) is the primary focus of the learning process, is a better example of problem-based learning.
>
> A second continuum of variation is the extent to which a problem is the organizing center of the project. On one end of this continuum are projects in which it is implicitly assumed that any number of problems will arise and students will require problem-solving skills to overcome them. On the other end of this continuum are projects that begin with a clearly stated problem or problems and require a set of conclusions or a solution in direct response, where "the problematic situation is the organizing center

for the curriculum.". Here again, the former example typifies project-based learning, where the latter is best described as problem-based learning.

It is certainly true that the characteristics identified earlier (see page 1 above) are quite close to the characteristics of problem based learning. So it may not be very helpful to expend too much effort on over-subtle distinctions.

Or, as one authority, described by some as “the father of Project-Based Learning in California”, puts it…

> Why should we care what we call it? Are the two the same? If we can develop a meaningful way for anyone, any age, to be challenged and to learn useful skills and knowledge as they answer the challenge, why should we care if it is called project-based, problem-based, or circus-based? We should be expending our energy on more useful questions.

Joe Oakey
http://pblmm.k12.ca.us/PBLGuide/Oakey_comments.htm

1.2 The PBLE project

The PBLE project’s aims are to enhance engineering education by promoting and facilitating the use of Project Based Learning, thereby improving students' key transferable skills and their grasp of the subject content. The key skills developed by learning through projects will produce more employable graduates, ready and confident to begin their professional careers.

PBLE is a consortium project, involving engineering academics from the following institution’s engineering faculties:

- University of Nottingham
- Loughborough University
- Nottingham Trent University

The PBLE website (http://www.pble.ac.uk) has resources from the three years the project has been running, including those from the workshops on group work and assessment, mailing lists, and information on ongoing events, such as the PBLE competition for UK academics, and the 2003 conference.

The PBLE project is funded by the Higher Education Funding Council for England and the Department for Higher and Further Education, Training and Employment under the Fund for the Development of Teaching and Learning (phase 3).

1.3 How this guide is organised

This guide includes the following chapters:

1. Introduction
2. Case Studies
3. Project Design
4. Learning Outcomes
5. Learners
6. Knowledge Based Skills
7. Process Skills
8. Assessment
9. Supporting Individuals and Groups
10. Resources

This guide is divided into two parts – at the front, immediately after this introduction, are a collection of 12 case studies, real world examples from active academics, using PBL in their courses. The second part is a collection of guidelines for using project-based learning within your own curricula.

Each section – except for the Case Studies - starts with an introduction, and ends with a brief summary.

Within the chapters there are examples drawn from the case studies. These will make it possible to access detailed information about particular approaches. These examples are indicated thus…

> *"Overall, the project received very positive student feedback and the team training was extremely well regarded…students felt that they had improved a range of skills…[including] delivering presentations, time management, teamworking and problem solving."*

There are also examples of resources that are not taken from the case studies but that provide valuable practical support. These are show thus…

Budget Costs Form

Project title		Students/ departments	
Session/ semester		Supervisors/ departments	

Component/ Activity Code	Description	Cost Item	Budget cost	Department responsible	Actual cost
		Materials			
		Consumables			
		Bought-in parts			
		Manufacturing			
		Equipment buy/hire			
		Travel/ subsistence			
		Other			
		Emergency			
		Total costs			

1.4 The overall package

This guide is itself part of a more substantial pack. When complete it will also include staff development materials to allow staff/educational developers to work with academic staff to support Learning Engineering Through Projects

1.5 Project team

The team that has put the guide together comprises:

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	Norton Farrow University of Derby	Andrew McLaren University of Strathclyde
	Colin Fryer University of Derby	Colin Smith University of Sheffield
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Section 2 Case Studies

This section of the guide contains the case studies that have been provided by colleagues across HE. We are very grateful to them for their contributions.

1. Peter Hedges – Aston University
   A Simulated Public Inquiry
2. Patrick Littlehales – Aston University
   Facilitating Collaborative Design through ICT
3. Melvyn Dodridge – University of Derby
   Learning Outcomes and their Assessment in Independent Studies
4. Norton Farrow and Colin Fryer – University of Derby
   Fostering Progressive Learning through Scenario-Based Assessment
5. Warren Houghton – University of Exeter
   Intended Learning Outcomes and Assessment Criteria
6. Peter Willmot – Loughborough University
   Running Team Projects in Co-operation with Industry
7. Peter Willmot – Loughborough University
   Widening the Project Based Learning Experience with Student Mentors
8. Barry Lennox – University of Manchester
   Teaching Engineering through Problem Based Learning
9. Dave Easterbrook – University of Plymouth
   Learning Through Competition
10. Colin Smith – University of Sheffield
    Enhancing Teamwork in Group Projects through Pre-project Training Exercises
11. Simon Tait – University of Sheffield
    Introducing Business and Enterprise to Civil Engineering Students
12. Andrew McLaren – University of Strathclyde
    An Innovative Design Class for First Year Mechanical Engineers

2.1 A Simulated Public Inquiry

Author(s)	Dr Peter Hedges
Institution	Aston University
Faculty / School	School of Engineering and Applied Science
Department	Civil Engineering and Logistics
Programme(s)	Civil Engineering
Title of Module(s)	Public Inquiry Project
Award(s)	BEng, MEng Year of study 2
Module Credits	10 % project assessment 100%
Assessment Outputs	Decision report; Proof of Evidence; Oral defence; Journal/newspaper style report; Peer assessment

Industrial/ Professional Participation   Yes

Group Project: Yes   Group Size: 5 to 7   Group Selection: Tutor/Student

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Synopsis of Case Study

The simulated Public Inquiry project, run during the second year of the Civil Engineering degree programmes at Aston University, adopts a student-centred learning approach. It involves undergraduates working as a team to acquire, interpret and analyse pertinent information, and to prepare and present their case at a simulated public inquiry.

The Public Inquiry Project is based upon a real inquiry which took place at Broad Oak in Kent some years ago. Within the inquiry the student groups are allocated roles such as the water companies promoting the scheme, the county council, or local residents . Each group presents their case at the inquiry from the perspective of their allocated role. To assist in developing their case, students may request supporting documents, the majority of which have been distilled from the original reports. Throughout the inquiry the students gain practical experience of real life engineering problems.

The project has a variety of learning outcomes beyond knowledge acquisition. These include: the development of teamwork, communication and decision making skills; generating an understanding of the role of the professional engineer within society; and raising awareness of the sociological and environmental effects of a major development.

Introduction

Engineering and technology degrees tend to be highly structured with programmes biased towards the acquisition of knowledge. Somehow more time needs to be devoted to enabling students to develop inquiring and creative minds, and a project based on a student centred learning approach with role play at its heart is one answer.

The Public Inquiry Project has evolved into its present form through several iterations, and is now taken by all civil engineering undergraduates at Aston during their second year. Ten afternoon sessions are timetabled for the project (see Table 1), but a considerable amount of work takes place outside the allocated time.

The project, in which undergraduates work in groups of between five and seven, has a range of learning outcomes:

i. knowledge acquisition: e.g. water resources, construction, and the UK planning process;
ii. teamwork and communication skills development;
iii. development of decision making skills (the project is open ended);
iv. generation of an awareness of the responsibilities of the professional engineer;
v. introduction to the environmental and social implications of a major development.

Project Background

The current Public Inquiry project is based upon the Broad Oak Reservoir Scheme, which was proposed for development in 1979 as a joint venture between Southern Water Authority and Mid-Kent Water Company – but failed at the Public Inquiry stage. However, it continues to be a viable option for solving water shortages in the south east of England.

The proposed dam site is located in the valley of the Sarre Penn River north of Canterbury. This valley is lined with London Clay, and is the only viable location in Kent where a reservoir could be constructed. Broad Oak is to be a pumped storage reservoir, and will be filled from the River Ouse. Much of the land required for the reservoir has been purchased by the mid-Kent Water Company, but even so a number of people will be displaced and loose their livelihoods.

Project Structure

The project starts with students being supplied with basic information that provides the bare bones of the scheme. This outlines the relevant legislation, and gives the reasons why the water is needed, why a reservoir scheme has been selected, and a description of the proposal. Over the following weeks (see Table 1), the students, working in teams, can request additional information on any aspect that they feel is relevant. This enables them initially to decide whether they would promote such a scheme or not. Later, once their team has been allocated a role, the information is used in building up their case for the Public Inquiry.

The additional information the students can request is usually supplied as reports. These range from the technical, through demand estimation, alternative resource developments, financial matters, to sociological and environmental issues. Students may acquire access to other documents, such as the relevant Structure Plan and geological maps.

During the course of the eight weeks leading up to the day of the Inquiry, the main focus is on information acquisition and decision-making. For instance in Week 2 there is a guided discussion on the operation of the scheme, and students are shown a 'home grown' video of the Sarre Penn valley and its surrounds in Week 3.

The activities directly related to the project are interspersed with support activities aimed at raising student awareness of issues surrounding the scheme and developing transferable skills. These include ranking quotations from residents experiencing an Urban Renewal scheme, which is designed to encourage them to question the sociological impact of such developments. There is a film following the history and impacts of a reservoir, which has a variety of relevant issues embedded in it. They receive a briefing on planning procedures, and how a Public Inquiry is conducted, together with advice on preparing and presenting their evidence. Originally the project included the development of oral presentation skills (Hedges, 1991), but when the format of communication skills within the degree programme was revised, this was replaced by team skills.

Prior to the Inquiry each group will have been allocated a role (Week 4) – the promoters (or Appellants) are the Mid-Kent Water/Southern Water consortium – and there are two opposition groups: Kent County Council and the Broad Oak Action Group. The latter is a loose alliance of local representatives and pressure groups. Each group selects a Queens Council (QC) to represent them at the Inquiry, and every other student takes the role of an Expert Witness.

Two weeks before the Inquiry the Expert Witnesses write and submit a Proof of Evidence. These are copied and circulated to the other groups one week before the Inquiry. Since each of the groups will have acquired different information, the contents of its opponent's Proofs of Evidence often come as a surprise. At this stage no further information can be acquired and the week available in which to prepare for cross examination and rebuttal sees a ferment of activity.

The Inquiry

The simulated Inquiry itself follows as closely as possible the procedures of a real Inquiry. It is presided over by an Inspector, who is a consultant engineer with practical experience of Inquiries. The Inspector is assisted by an Assessor, usually a full time member of staff.

The Inquiry is opened by the Inspector, and the QCs for each group introduce their witnesses. The main procedure gets underway, when the Council for the Appellants delivers an opening speech, and the principles of the scheme are outlined. Subsequently, each of the expert witnesses is called in turn and reads their Proof of Evidence. They are then cross examined by the opposition QCs, the Assessor and the Inspector, with the Appellant's QC having the opportunity to re-examine their witness in an attempt to rebut any evidence that has been discredited.

The Appellant's case is followed by each of the opposition groups in turn following the same procedure. The Inquiry ends with each QC summing up their case in a closing speech. After the Inspector has closed the Inquiry there is a brief review and feedback session.

Reflection On Project

In the final week of the project, each student writes a report on the Inquiry in the style of a Journal, Newspaper or relevant publication. This encourages them to think about how the same information can be presented to different audiences, and forces them to reflect on the conduct of the Inquiry.

The final session is devoted to debriefing. It starts with a review of the scheme's history. This enables students to: put their project in perspective; see how important planning and feasibility studies are, and how long and costly this process can be. The students then brainstorm and feedback the learning situations they have experienced. Invariably, it is at this stage that they realise the breadth of the project and that they have not only gained new technical knowledge, but have also developed their decision-making and communication skills, and acquired an understanding of the environmental and social issues raised and impacts caused by many major development schemes. The project is rounded off by students undertaking a structured self and peer assessment exercise in their project groups (Boud, 1995).

Resourcing the Project

The information underpinning the project has been drawn from a wide variety of sources. However, at the core is the documentation produced prior to, during and after the original Broad Oak Public Inquiry. The majority of the various reports, drawings etc. have been distilled from this. Beyond the underlying data, the only resources required are: adequate room space, support from an external professional to act as the Inspector; a photocopier; and boundless energy and enthusiasm!

Trials and Tribulations of the Project Supervisor

The main pain associated with a project such as the Public Inquiry, is that it requires considerable investment of time and energy collecting data before it can even start. To enable an immediate response to the students' requests, the underlying information has to be at the supervisor's fingertips. The first few years are the most demanding, whilst the 'Additional Information' reports are prepared on the hoof, until the variety of possible questions have been largely addressed. But don’t be complacent - students will inevitably find new questions to challenge you with!

Student motivation is rarely a problem. The pressures of meeting deadlines, and the different nature of the project to their normal learning experience, suffice to generate enthusiasm. However, ensuring that the less strong students, or those lacking in self-confidence are not pushed to the periphery or threatened by some of the activities, can be a challenge. Spending some time with each group every week, discretely supporting and drawing out the strengths of these students, has been found to be the best course of action.

In conclusion, the active learning role-play model will be a challenge to any educator. It should not be seen as a static entity to be repeated year after year. New information, current attitudes, and prospective changes, together with the latest educational philosophies, can be introduced to make the project as dynamic, relevant and topical as possible.

Week 1	i)	Introductory briefing
	ii)	Issue of Project Format and Engineering Report
	iii)	Urban Renewal Case Study and ranking exercise
Week 2	i)	Discussion on operation of Broad Oak Scheme
	ii)	Film on history and consequences of a reservoir development
	iii)	First requests for information
Week 3	i)	The Planning System and the Format of a Public Inquiry
	ii)	Video of proposed development area
	iii)	Selection by each group of preferred development option (*Group Report 15%)*
	iv)	Issue of and requests for additional information
Week 4	i)	Allocation of groups' roles for Public Inquiry
	ii)	Team Skills
	iii)	Issue of and requests for additional information
Week 5	i)	Introduction to Proofs of Evidence
	ii)	The role of the Expert Witness
	iii)	Issue of and requests for additional information
Week 6	i)	Preparation of Proofs of Evidence
	ii)	Issue of and requests for additional information
Week 7	i)	Submission of Proofs of Evidence (*Individual Assignment 25%*)
	ii)	Preparation for 'reporting' on Inquiry
	iii)	Issue of and requests for additional information
Week 8	i)	Preparation for Inquiry: rebuttal of evidence
	ii)	Distribution of Proofs of Evidence
	iii)	Final issue of additional information
Week 9		PUBLIC INQUIRY (*Individual Performance 25%*)
Week 10	i)	Submission of 'reports' on Public Inquiry (*Individual Report 15%*)
	ii)	Evaluation and feedback on project
	iii)	Self/Peer-Assessment (*Peer Assessment 20%*)

Table 1 Public Inquiry Project Timetable and Assessment Pattern

References

- Boud, D. (1995), *Enhancing Learning Through Self Assessment*, Kogan Page
- Hedges, P.D. (1991), 'Communication Skills and the Undergraduate Engineer', in R.A.Smith (Ed), *Innovative Teaching in Engineering*, Ellis Horwood.

2.2 Facilitating Collaborative Design through ICT

Author(s)	Dr Patrick Littlehales
Institution	Aston University
Faculty / School	School of Engineering and Applied Science
Department	Mechanical Engineering
Title of Programme(s)	Mechanical Engineering, Product Design
Project Title:	Global Design initiative (GDi)
Award(s)	Extra curricular Year(s) of study 1/2/3/4
Module Credits	N/A % project assessment N/A
Outputs (non assessed)	Online progress records Solid Model CAD (total of X component parts)
Industrial Participation	Yes
Group Project: Yes	Group Size: (3 x 25) Group Selection: All who expressed an interest

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Synopsis of Case Study

The Global Design initiative (GDi) project provided a unique opportunity for students to learn about real world, collaborative design on a global basis. Developed within Mechanical Engineering at Aston University a team comprising students in the UK, USA and Singapore were tasked to co-operate on the engineering design of a racing car.

The project yielded a reusable model for experiential learning and proprietary recording software was used to capture and communicate a record of the design process used during the event as part of the design process and for analysis after the event.

The model developed is generic and may be easily employed in projects ranging in size from small classroom activity to large scale global events.

This case study describes the technology tools developed for the project and how they facilitated information management and exchange, helping to ensure the success of GDi.

The Global Design initiative

Within the Global Design initiative (GDi), three student teams based in UK, Singapore and USA had to design a radical concept, formula racing car within 5 days. Each international team worked for an eight hour period, at the end of this period there was a hand over to the next team. GDi was designed so that the time zone differences meant that together the three teams worked around the clock. To ensure effective communication and transfer between international teams the project was facilitated using an interactive web based learning environment developed by the author.

This design process employed commercially available computer aided design (CAD) software ‘SolidWorks’ together with internet based communication software and custom developed discussion and logging software. The teams worked in shifts conceptualising, designing and communicating with each other pushing the racing car design towards completion. They also shared responsibility for receiving and passing on key information at the beginning and end of each working day. It was important that individual student contributions were recorded in real time. Participants used the logging environment to communicate with the global team and gradually built up resources which incorporated all the research, exchange of ideas and thinking processes.

A new online environment to facilitate experiential learning projects was developed from a simple web based communications mechanism, used in undergraduate programmes (DPE 2002). This interactive environment which logged the development process overcame the need for unregulated email and had the feature of keeping all team members fully informed of progress. This record of the development process was a valuable project output, consisting of a narrative, media rich documentary.

Online logging

A project shift involved 8 hours of design and CAD work culminating in a hand over to the follow on team. It was necessary to notify the next team of design progress and issues as efficiently and clearly as possible. This was enabled by using a web based historical project log that could be searched, read and contributed to at all times.

The system was developed at Aston University, Littlehales et al. (2002), as a simple database driven web-site based on ASP technologies. A balance was achieved to extract as much process information as possible without over-burdening the participant, they used the system to:

- browse details of the design
- evaluate previous work
- communicate with each other
- read and contribute to discussion threads in a forum
- add project resources: websites, documents, diagrams and written comments
- add critical comment and guidance for other members of the research team

As students experience of using the environment increased they relied less and less on face to face meetings (although these continued to be an important part of the process).

Discussion threads were created to organise the research effort, stimulate debate and encourage investigation. These threads contained information on project activities including its management and particular resources and debates. The project group individuals decided what to create and who else to invite into the discussions, eg. receiving critical comment from outside persons in industry which are consequently available for the group to analyse and comment on.

The process of logging is illustrated in figures 1a-d.

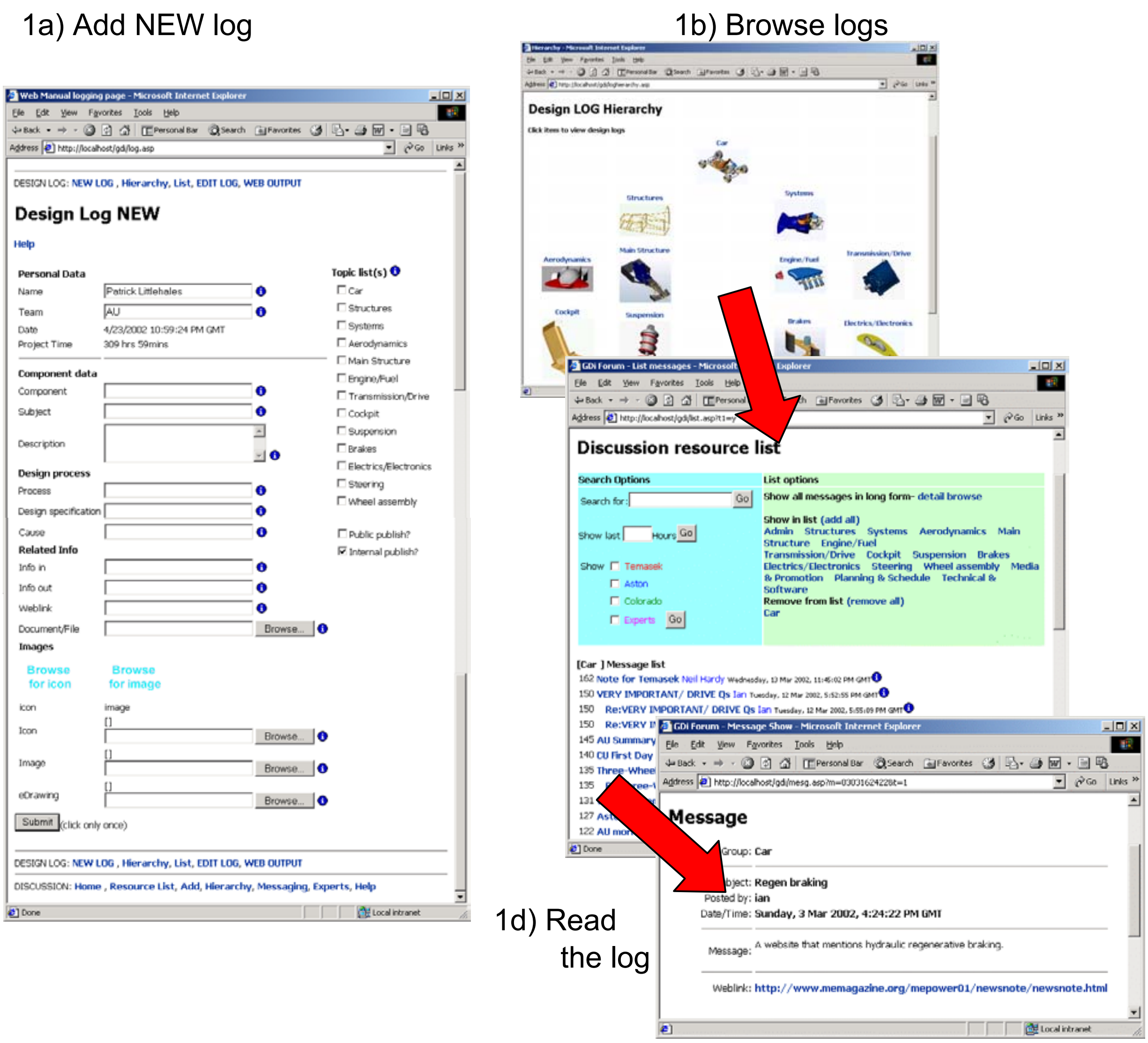


Figure 1

The 'add NEW log' page (Figure 1a) was split into three broad sections:

- Personal user data – a section to encourage individuals to take ownership of their contributions.
- Component and process information – additional information necessary to explain design reasoning and unusual project decisions.
- Related document and image resources – visual and written media relating to the design.

The car design structure was split into working sub groups. A visual hierarchy (Figure 1b) was provided including views of the components at that particular point in time. The project resources and progress logs were also navigated by list forum. This threaded presentation (Figure 1c) identical to common newsgroup and discussion forums would allow access to each message page (Figure 1d) which contains the comments and links to resources.

The process logger was technically simple in design. It provided a channel for recording of the design process, progress and reasoning. Web database access is simple to create with current technologies. The real challenge was capturing the right information to allow the project to flourish extending the confidence of participants in design and use of the technology.

Solid modelling

The 3D, solid modelling tool, SolidWorks, formed part of the inspiration for the project. The manufacturers claim that the tool was easy to learn and had integrated collaborative design tools set the challenge for GDi. The software provided a platform for an effective design process with quick sketch prototyping through to detailed design.

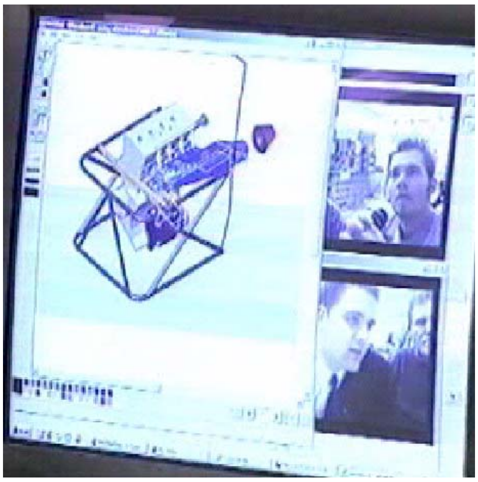
To enable multiple persons to develop the same project files without undoing each others work a part data management tool (PDM) was required. DBWorks provided an integrated tool that did just that, a simple set of macros were developed to integrate the CAD and PDM data with the process logger. A solid model design was linked into the appropriate section in the logger, capturing descriptive and visual information forming the initial part of a new log.

Collaborative meetings

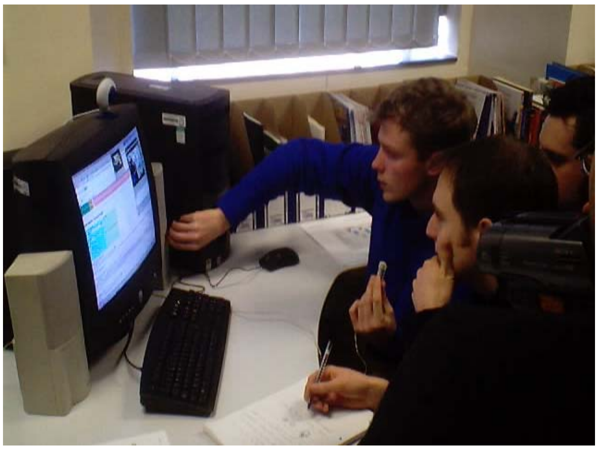
The project used NetMeeting (available with MS Windows operating systems) to enable group to group discussion at handover sessions. This component was easy to use and configure and provided audio, web-cam video and text communication between networked computers. An application sharing function allowed SolidWorks parts and assemblies to be explored collaboratively. This proved an extremely valuable collaborative tool particularly when used alongside the SolidWorks design software.

NetMeeting provided early integration of the project communities where individuals got to see and speak to their counterparts in the other teams. Nervous initial conversations were soon replaced by confident, focussed sessions where the teams explained their design decisions and project direction. It was also extremely valuable to share a design image or model and debate issues amongst the groups. An additional function allowing sketching onto a shared illustrative space facilitated discussion on design specifics. The

Teams in UK and USA discuss project plan via web conference



Two teams interactively discuss suspension mount issues meetings were vital to back up written and illustrative progress provided by the recording system and took place between pairs of students working on particular aspects of the project. The other team members watched the progress via a projected image on the wall of the design studio. Comments were relayed from team to team via the pair of students at the controls. The meetings had agendas and minutes that were included in the process log to enhance the record of discussion.



UK team participate in web conference

Information transfer

The individual ICT tools described integrated to facilitate the project goal, design of a car. The project as a whole discouraged email as a communication mechanism as it was external to the recorded communication process. It was important to create a complete history of all decisions and design aspects. The process forum and logger, NetMeeting and the CAD tools with integrated part data management (PDM) provided everything required to transfer the project information. During the run up to the project a website was created to provide a portal for the general public to view the project and watch the design progress. This now provides a narrative description of the project for further learning activities http://www.GDiCar.com

During a ‘shift' a team would have ownership of the data and design files. Other teams could browse these files but generally used the process logger to identify the current status of the design, particularly aspects that had been developed over night during other team sessions. Ownership was transferred during handover periods.

Outcomes

GDi was a complex project however the teams adapted particularly well to the problems of concept design, technical drawing and communication with their team peers. Student understanding of the technology progressed considerably and they also learnt much about the physical process of design and project management. Their confidence and motivation grew exponentially during the week. This was evident from the early starts and enthusiasm towards the conclusion of the design.

Substantial time was invested in the creation and testing of the recording system software. This was worthwhile as the system proved invaluable and worked due to its simplicity and structure and ability to submit research, designs and ideas.

Initially it was difficult to get participants engaged because the feedback they strived for their own contribution was missing until the end of day one, however as the project developed the design process became efficient and streamlined. In future projects include a short prior exercise is planned to demonstrate the logging and feedback mechanism in action.

The software tools created have formed part of a valuable suite of tools for collaborative design, appropriate for local university projects and more ambitious overseas events ensuring that the project was very successful. The work has since been nominated by the University for the Queens Anniversary prize for Higher and Further Education, 2002.

Project Benefit of Using ICT for Staff and Students

The GDi project delivered a unique blend of enhanced technology, design process and social experiment. The exposure to modern tools and techniques via a global project requiring such levels of focussed information management and communication provided a real world learning experience rarely seen in academia. All the participating students and staff benefited tremendously. The fast pace of the project required concentration on using technology effectively and appropriately to get the message across. To have any influence on the ultimate creation, that students became so attached to, they had to put their case strongly in the logger and during web conference meetings. The technology provided the opportunity to quickly prototype, sketch and annotate key components that would eventually be seen in the final design. The logger provided an historical narrative and the web conferences a forum for the global team to accept or reject aspects of design. There was no doubt that the technology enabled the development of expertise and a confidence to share experience and skill where necessary, even across continents via the web.

Implementing Global Collaborative Projects

The GDi project was an ambitious extra curricular experiment that succeeded due to the generous enthusiasm offered by all participants and sponsors. It demonstrated the potential for creating exciting learning opportunities with little preparation. The level of outcomes and achievement were not taken for granted and curriculum based collaborations in the future may benefit from further trials and experiments before a similar project is attempted. In GDi, students were left to draw their own conclusions and appreciation. The motivation of the team that created the project was to explore an idea and some technologies that boasted the ability to support such ventures. Technically the tools were all very simple. Netmeeting and its alter ego, MSN messenger, are the champion of young internet communicators of this generation. These tools are freely available and provide a valuable backbone to the exploits of learning via collaborative project whether in the locale or on a truly global basis.

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2.3 Learning Outcomes and their Assessment in Independent Studies

Author(s)	M.J.Dodridge		
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Faculty / School	School of Computing and Technology		
Department	Division of Electronics, Media Technology and Mathematics		
Programme(s)	BSc/BSc (Hons) Electrical &Electronic Engineering BSc/BSc (Hons) Music Technology and Audio System Design		
Title of Module(s)	Project		
Award(s)	BSc and BSc (Hons)	Year(s) of study	3
Module Credits	30	% project assessment	25
Assessment Outputs	4 Learning outcomes		
Industrial/ Professional Participation	Yes (in the case of part-time students)		
Group Project	No		

Synopsis of Case Study

This case study considers intended student learning achievements for a major independent project carried out in the final year of an honours degree programmes in engineering/technology. The focus is on the writing of learning outcomes, prioritising these into categories, the writing of appropriate assessment criteria and choosing the most appropriate assessment methods. Examples of typical outcomes are given together with an assessment matrix. The tracing of outcomes in the Programme Specification to module level using mapping techniques is also illustrated. The study concludes with some reflections on experiences relating to the student/tutor interface associated with learning and assessment.

Introduction

The final year of the majority of three-year undergraduate programmes of study in engineering contain a substantial project in the form of independent study. In the case of the University of Derby this is a double module amounting to 25% of the final phase. The project therefore attracts 30 credits at level 6 (UG level 3). This is somewhat lower than in many universities where the trend has been to increase the weighting, in some cases to as much as 50% (60 credits). Independent study in the form of a major project is designed to integrate much of the knowledge and skills developed by the student in the first two years of the programme. Because of the nature of the work it is expected to develop further skills and enhance existing ones. In particular, the project is a useful vehicle for promoting the intellectual, practical and transferable skills defined in the Programme Specification.

Learning Outcomes

It is quite possible to specify a large number of learning outcomes for most modules of study, and the project is no exception. However, setting too many outcomes can lead to over-assessment, which in turn can result in student underperformance. Where learning outcomes are to be formally assessed they need to be measurable by the tutor, achievable by the student and essential to the aims of the module. The University of Derby has produced a set of guidelines for the assessment of learning outcomes, the 3rd edition of which was published in September 1999. These guidelines were written in light of the experience gained in employing outcomes-based assessment over a number of years. The guidelines recommend that no more than four learning outcomes per module should be formally assessed. Each outcome statement should describe a learning achievement, which is considered fundamental to the purpose of the module. This sense of intrinsic importance for each designated learning outcome leads to what might be described as the acid test for a prospective learning outcome. In testing a prospective outcome, it is necessary to ask whether a situation could be envisaged where there may be a wish to recommend that the student should gain the credit for the item of assessed work despite not having satisfied the prospective learning outcome. If the answer is positive then the learning outcome is clearly not fundamental to the module and is unnecessary; if the answer is negative then the learning outcome has passed the test and is demonstrably fundamental to the module. Where possible, a single assessment should have one learning outcome attached to it. This has been achieved in the case of the project module, although it is recognised that this is not possible in all cases. Table 1 shows typical outcomes that might be expected in a project module; those in bold text are considered of fundamental importance and therefore are the only ones formally assessed.

Skill Area	P, A
A Knowledge and Understanding	
Have knowledge and an understanding in the subject area of the project.	P
B Intellectual Skills	
Execute a long-term investigation, which involves a structured approach to in-depth problem solving, planning, progress reporting and project management with regard to constraints of time, budget and available resources. Formulate a design in hardware and/or software to a given specification making use of ICT tools where appropriate. *Assess and manage risks.*	P,A P P
C Practical Skills	
Constructs prototype hardware and/or computer programmes to the design. Selects and demonstrates the use of laboratory and measurement for testing the prototype.	P P

D Transferable Skills	
Retrieve relevant information and organise this to assess the feasibility of a project and provide a realistic plan of execution to deliver the project within a time and budget constrained period.	P,A
Write an analytical technical report containing an extensive critical evaluation of the given problem and make recommendations and conclusions based on a sound body of knowledge.	P,A
Present and discuss a technical project in depth and clearly communicate the critical issues and key features of the project.	P,A

Table 1: Project Module Outcomes Key: P – Practised A – Assessed

Assessment Criteria and Assessment Methods

Learning outcomes are identifiable goals that students must achieve in order to pass. They are the basis for the learning and assessment strategy in a module and, unlike learning objectives, are systematically tested through assessment. There should be strong links between learning outcomes, assessment criteria and the assessment method. Having written a set of learning outcomes, tutors need to think about the best method for achieving each of them and the criteria that will be used to judge the standard of work. Table 2 shows the assessment matrix for the project module.

Assessment	Weighting (%)		Learning Outcome	Assessment Criteria	Assessment Method
1	10	Autumn Week 3	LO1 Retrieve relevant information and organise this to assess the feasibility of a project and provide a realistic plan of execution to deliver the project outcomes within a time and budget constrained period.	Students must demonstrate they are able to systematically retrieve and organise relevant information taken from published sources in order to assess the feasibility of the project. Students must provide a realistic plan of execution covering the project duration so that the outcomes can be delivered within a budget and constrained period. Also they must demonstrate that they can negotiate their findings with the project tutor in order to agree the best plan of action.	An assignment requiring the student to negotiate and successfully agree a plan of work with appropriate aims, objectives and outcomes for the project, culminating in a written proposal.
			LO2 Execute a long-term investigation, which involves a structured approach to in-depth problem solving, planning, progress reporting and project	Students must demonstrate that they are able to execute a project within given time and budget constraints and maintain a record of their progress and achievements in line with the project requirements. Students must manage all aspects of the project and report its progress on a regular basis to the project tutor. The student is required to submit the	A written logbook in which the student will maintain a continuous record detailing analysis, calculations and methodology of work conducted throughout the year.

2	10	Autumn/ Spring Weeks 8, 19 & 31	management with regard to the constraints of time, budget and available resources.	logbook to the tutor for formative assessment on two occasions, prior to final submission with the project report.	
3	60	Spring Week 31	LO3 Write an analytical technical report containing an extensive critical evaluation of the given problem and make recommendations and conclusions based on a sound body of work.	Students must demonstrate the ability to provide clearly structured and concise written evidence of a literature survey, the application of sound working practices, relevant technical theory and the ability to present in depth technical issues, making recommendations and conclusions based on a sound body of work. The report is strictly limited to 50 A4 sides and no more than 10,000 words, material submitted beyond this limit will not be considered for assessment.	A written technical report incorporating concise evidence of a literature survey, application of professional practices, relevant technical theory and the ability to discuss in depth technical issues.
4	20	Spring Week 36	LO4 Present and discuss a technical project in-depth and clearly communicate the critical issues and key features of the project	Students must demonstrate the ability to present and discuss their project in depth and communicate the critical issues and key factors of the project. The viva will be an opportunity for an in-depth discussion about critical issues and key features of the project. Also they must be able communicate a summary of their work in poster form and discuss it with their peers including the project tutor in the poster session.	A project viva and poster session attended by academic staff and the student. The student will be expected to provide an overview of the project in the form of a short presentation at the start of the viva and via an A3 poster.

Table 2: Project Module Assessment Matrix

The Programme Specification and Generic Outcomes

Since the independent project is an excellent vehicle for developing so many skills it is important that these are reflected in the programme generic outcomes. Table 3 shows generic outcomes for two programmes of study, which are BSc (Hons) Electrical and Electronic Engineering and BSc (Hons) Music Technology and Audio System Design. The skills map column has been selected from the Programme Skills Map and indicates how the overall project learning outcomes map to the programme outcomes. The next four columns show how the programme outcomes can be traced to individual module learning outcomes. It is all too easy to tick many more boxes than shown. This has been avoided by only mapping outcomes where the corresponding assessment provides the strongest opportunity for evidencing learning.

Programme Generic Learning Outcomes	Skills Map	Module Learning Outcomes			
		LO 1	LO 2	LO 3	LO 4
(A) Knowledge and Understanding (Electrical and Electronic Engineering)					
1. Basic mathematics to underpin electrical and electronic engineering (E)					
2. Basic principles used in analogue/digital electronic and electrical power circuits and systems (E)					
3. Technology supporting electronic and power circuits and systems					
4. Application of advanced and new technologies employed in the electrical and electronic industries	✓	✓	✓	✓	
5. Management of business relevant to the commerce and industry (E)					
6. Engineering practice and regulatory frameworks in the electrical and electronic industries (E)	✓	✓		✓	
(A) Knowledge and Understanding (Music Technology & Audio Syst. Design)					
1. Basic mathematics to underpin electronic and audio engineering (E)					
2. Basic Principles used in analogue/digital electronic circuits and systems in the communication and audio industries (E)					
3. Technology supporting audio circuits and systems					
4. Application of advanced and new technologies employed in the music industry	✓	✓	✓	✓	
5. Business and management relevant to the music industry (E)					
6. Engineering practice and regulatory frameworks applicable to the electronic, communication and music industries (E)	✓	✓		✓	
(B) Intellectual Skills (both programmes)					
1. Apply engineering principles and analytical thinking to problems and determine effective solutions (E)	✓		✓	✓	
2. Select and develop appropriate technology (E)	✓	✓	✓		
3. Employ computer software for simulation and analysis of circuits and systems (E)					
4. Design, develop and operate systems, products and processes and evaluate options (E)	✓	✓	✓	✓	
5. Exercise professional judgement with respect to commercial and technical risks (E)	✓	✓	✓	✓	
(C) Practical & Subject-specific Skills (both programmes)					
1. Use laboratory scientific equipment and instrumentation competently and safely in conducting experimental laboratory work and making measurements (E)					
2. Demonstrate the use of computer key board skills (E)					
3. Demonstrate the ability to configure computer programmes (E)					
4. Demonstrate the process of prototype build, manufacture and testing (E)	✓		✓	✓	
5. Plan and execute project work including the preparation of descriptive and interpretative technical reports (E)	✓	✓	✓	✓	

(D) Transferable Skills (both programmes)					
1. Apply numerical skills in the collection, recording, interpreting and presentation of data in a variety of forms (E)	✔			✔	
2. Utilise information and communication technology (ITC) in the preparation, process and presentation of information (E)	✔				✔
3. Demonstrate creativity in problem solving and design (E)	✔		✔	✔	
4. Utilise communication skills effectively in a variety of forms and for different audiences (E)	✔			✔	✔
5. Manage own roles, responsibilities and time in achieving objectives, learning performance, new and changing situations and contexts (E)	✔				✔
6. Assume responsibility as an individual or as a member of a team in a variety of situations (E)	✔				✔

Table 3: Tracing Programme Outcomes to Module Level
Key (E) – Engineering Benchmark

Reflections on experiences

An internal verification process for module coursework and examination assessments has been in place for some time, but in the case of the project module requires revision because of the differing expectations of project tutors. All academic staff undertake the verification role and deal with projects from both full-time and part-time students studying primarily on HNC/D and BSc/BSc(Hons) programmes. Problems exist with respect to the module learning outcomes, level and notional learning time. In formal assessment it is important that a consistent approach is taken to ensuring outcomes are in fact achievable by students and in measuring success/failure. There needs to be a process to check that for each project the student learning experience matches the intended outcomes. Module outcomes in many cases give a hint as to the level but in the case of the project they could be equally appropriate at levels 5, 6 and even 7. It can therefore be quite difficult to ensure that the appropriate level is set. The notional learning time for all undergraduate projects is 300 hours, and again it is necessary to ensure that the work demands the required effort whilst remaining manageable. Part-time projects are quite difficult to assess in all of these respects due to the fact that they are often group-based in nature.

A full achievement model is used in the project module as in all others. Outcomes-based models can sometimes be over complex, with too many hurdles for students leading to the need for compensation. The model used here is simple to employ and easily understood by academic staff and students alike, though there has been some criticism from students of over- assessment. The model differs from the traditional two-component approach - examination and coursework – as there are three or four assessments in each module with a greater weighting towards coursework. In the case of the project module the requirement to complete four assessments, each carrying one learning outcome, ensures that students engage fully in all parts of the work. Despite input to students on assessment during the induction week there have been a small number of cases where students have been referred, typically for not satisfactorily completing a logbook or failing to undertake the viva/presentation, expecting instead to pass with a good report and compensation. Other cases involve failure in the project proposal. If such a failure is formally recorded then under the University's regulations the student is required to wait for formal ratification at the Assessment Board before being offered a referral opportunity.

Referral is clearly not possible in the case of the project module, as it would prevent engagement with the rest of the work. Students in this category are asked to re-submit and are given a lower grade as a result of not meeting the time requirement. Since the assessments utilise criterion-based referencing, the stated criteria for each assessment represent the threshold to achieve the learning outcome warranting the minimum pass grade. For each assessment performance indicators are given for bands, from the lowest fail to the highest pass grade. Despite this mechanism second marking of the project work, and particularly the report, has thrown up a few cases showing wide variation in the recommended mark to be awarded. This finding suggests the need for more rigorous inspection of all project reports at a particular level. To achieve this goal efficiently where a large number of projects are involved is never easy, but it is a challenge that must be met to ensure the integrity of the grading process.

2.4 Fostering Progressive Learning Through Scenario-Based Assessment

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Department	Design, Technology and the Built Environment

Programme(s)	BSc(Hons) Architectural Technology, BSc(Hons) Construction Management, HNC/D Civil Engineering, HNC/D Construction, HNC Architectural Studies
Title of Module(s)	Scenario 1: Computer Aided Design I, Construction Technology I, Environmental Design, Design Studio I, Organisation and Procedures, Principles of Structural Behaviour, Project Planning and Control, Soil Mechanic 1, Structural Design, Surveying I Scenario 2: Business Environment, Construction Engineering Principles and Practice, Construction Services, Construction Technology II, Highway Design and Construction, Management of the Construction Process, Project Management, Refurbishment and Future Use, Strategic Management, Traffic Engineering
Award(s)	BSc(Hons), HNC/D Year(s) of study 1, 2 and 3
Module Credits 15	% project assessment 20 – 30% depending on programme
Assessment Outputs	Reports, presentations, portfolios, design calculations, working drawings, fieldwork

Industrial/ Professional Participation No

Group Project: Mixed   Group Size: 3 to 5   Group Selection: Tutor/self selected

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Synopsis of Case Study

This case study describes a project-based learning strategy, fostering the integration of the curriculum and encouraging students to appreciate the holistic nature of the construction environment. The use of two scenarios is discussed, one for first year students and the other for students at years two and three. While experience has shown that a project-based learning strategy requires a greater reliance on a team-focused concept approach, the benefits gained through students being able to progressively develop their knowledge and relate this to the working environment are significant.

Integrating the curriculum

As knowledge is not discrete, subject areas within a discipline need to be harnessed to enable students to develop an integrative approach to their studies. It is necessary to encourage a problem solving approach to reflect experiences in the working environment. However, the structure and design of the assignments have to be carefully considered so that an appropriate assessment strategy can be developed to foster a progressive learning environment. This relies on a team approach to ensure that all pieces of the assessment 'jigsaw' are in place at the outset.

It is important for students to realise that the processes connected with their current or future job function in the construction industry are based on decision making, self-awareness, self-criticism, sound judgement and the ability to adapt technical information. The assimilation of new information and experience, with sufficient thoroughness to permit purposeful use is essential. Central to this concept is the importance of students developing their problem solving skills from an early stage so that they are capable of enhancing their knowledge as their studies progress. To facilitate this, students have to be exposed to an assessment strategy that not only carefully considers the inter-relationship between the curriculum at each level, but also explores mechanisms for promoting this so that students become increasingly aware of subject integration. Project-based learning can be used to develop this approach.

In the mid-1990s, construction staff at the University recognised that the teaching, learning and assessment strategy was fragmented and that a new methodology was required that would enable students to develop a much deeper, more integrated understanding of the built environment. After considering a number of options, it was agreed that an enhanced student experience could only be developed through a team approach to learning. This would encourage a cross-fertilisation of ideas and promote a collective ownership by the team of the curriculum at each level of study.

Project-based learning through scenario-based assessment

In re-designing the strategy, the team took as their starting point the notion that students need to develop an integrated approach to problem solving from the commencement of their studies. Hitherto, it was only at the final stage of a programme that students were required to engage with a problem solving, group-based integrated project that drew together the knowledge gained from other modules. Using the integrated project as a springboard, the team considered that students' knowledge and learning experience could be substantially enhanced by adopting an incremental approach to problem solving commencing in the first year of their study.

Using project-based learning as the central focus, it was decided that wherever possible module assignments would utilise a common scenario for each level of study. In this way, students would be able to link the majority of their assignments to this scenario, thus providing the opportunity for a range of subject related problems to be tackled. While the assignments for each module are self-contained so that they are accessible to students studying individual modules, links and references to other modules may be included in such a way that thematic threads can be developed. For example, a structural analysis assignment may require a student to determine the forces in one or more structural elements identified in a scenario. To achieve this, the student has to consider the construction of the building so as to identify the load paths and determine the loads from first principles. In parallel, other conceptual ideas can be introduced that link with associated modules, for example structural design. Conversely, the assignments set for structural design can be developed in such a way as to extend those topics explored in the structural analysis module. Throughout this process the scenario acts as the focal point around which project-based assignments are positioned and connected by their subject associations.

The project-based assignments integrate the subject areas within a programme and illustrate realistic construction problems. In developing projects around the scenarios the following core themes were considered:

- Encouraging students' awareness of construction and its impact on the environment
- Developing students' design skills
- Promoting students' ability to recognise their role as members of a team
- Encouraging students' to develop a systems thinking approach
- Improving students' ability to collect and critically analyse information in order to make sound judgements

In addition to these core themes, the project-based learning approach was developed in such a way as to promote, via the assignments, the acquisition of individual programme learning outcomes. These outcomes, which are articulated in terms of knowledge and understanding, intellectual skills, practical and subject-specific skills and transferable skills, are well suited to being promoted through project-based learning.

The scenarios

Two scenarios were developed as the assessment vehicle for use across the undergraduate and BTEC programme portfolio. First year modules are intended to introduce students to concepts and principles that underpin their later studies, and as such there would be merit in providing an introductory scenario designed to enable students from diverse backgrounds to assimilate knowledge to achieve the required learning outcomes. To encourage ownership of the scenario by students, it was decided this should focus on a site within the University campus that would be easily accessible to the students. To foster awareness in students that modules studied in the second and third year of a programme are increasingly inter-related, it was considered that there would be merit in designing a single scenario that would act as a vehicle for this.

Scenario One provides students with comprehensive information for the construction of a two-storey maintenance workshop. The sketch design provided enables students to develop a basic understanding of the fundamental concepts, principles and techniques of subjects in the first year and apply them through a project-based learning environment to practical problems in varying degrees of complexity. Students are then able to acquire knowledge, skills and competencies on an incremental basis and apply them to a broad range of subject areas including construction technology, environmental science, structural analysis and design, surveying, soil mechanics and project planning. At the same time they are able to develop and apply key skills at an early stage.

In contrast, Scenario Two is used for more complex projects in years two and three. It incorporates the development of a large urban site for a variety of uses including commercial, industrial, residential and leisure. In addition to technical data, students are provided with a topographical survey, detailed site investigation and typical outline planning approval. This scenario is designed to enable students to enhance their learning by applying the principles and concepts contextually, using the tests of feasibility, suitability and acceptability, to a range of options. Students are encouraged to carry out option appraisal and cost benefit analysis. In Year 2, the projects are designed to develop a substantial body of knowledge and extend the student's experience as an independent learner. In Year 3, the projects are designed to be intellectually stimulating, challenging and demanding so that students can develop their imaginative, creative and analytical skills, fostering the development of a more critical, creative and innovative approach to their studies.

While scenario-based assessment is the main vehicle for coursework, there are instances when this approach is inappropriate and other methods of assessment are used - for example, field studies, laboratory exercises, etc. To date, these scenarios have not been used for assessment by examination, but it would be possible to extend the current arrangements. At postgraduate level, for instance, pre-seen scenarios are used for all modules subject to examination.

Designing the assignments

Experience has shown that for project-based learning to be successful, it is essential for all assignments to conform to a standard template that includes:

1. The submission date.
2. An overview of the assignment, locating it within the subject area and defining its relationship with other topics within the module and the programme as a whole.
3. Those learning outcomes to be achieved on completion of the assignment.
4. A brief specifying the nature and content of the assignment.
5. A clear statement of what the student is required to undertake in order to complete the assignment.
6. Recommended reference material that may be helpful as a starting point when undertaking the assignment.
7. Performance criteria specifying what is expected at the different levels of performance. For example, at final stage honours degree performance criteria were specified for first class, upper second, lower second, third, pass and fail.
8. The assessment weighting.

To assist staff in designing their assignments, samples were prepared for each year of study and circulated to the team. In parallel with these developments, additional student support material was prepared including detailed *Module Study Packs* for each programme, and guidance notes on report writing, making presentations and undertaking laboratory work. The scenarios and the support material were given to students at induction to encourage them to begin the process of planning their studies and taking greater ownership of the management of their learning at the earliest opportunity.

To provide an effective assessment strategy, a scrutiny panel was established to review the assignments prior to commencement of the academic year, in order to ensure validity, appropriateness of level and consistency in terms of style and layout. While a core team of experienced lecturers is involved in the review, the meetings are open to all staff and their input is welcomed. This process is very successful, albeit demanding, with team members exchanging views and contributing ideas to each other's assignments. Areas of overlap are identified and some assignments are modified in light of the review. An added bonus is the increased awareness of colleagues' subject areas, that in some cases results in a realignment of responsibility for delivering certain topics and an adjustment in lecture plans to improve the continuity and flow of the curriculum.

Learning and teaching

Experience of project-based learning has led to the need to review the learning and teaching. More emphasis is now placed on tutorials, seminars and workshops to enable students, particularly at Years 2 and 3, to become more responsible for their own learning. For example, in the modules *Highway Design and Construction,* and *Construction Engineering Principles and Practice,* the tutor acts as facilitator providing support and advice to students as they progress through the assignment. The modules are studio-based to simulate a design office environment. Encouragement is given to students to expand their knowledge through greater use of independent study and lateral thinking. This approach allows students to develop key milestones and to manage their own learning within a set time frame.

The success of project-based learning is dependent on a team approach and forward planning. One of the tangible benefits to emerge is that staff are far more aware of how the whole curriculum is being delivered, and when key topics are to be taught, allowing them to cross-reference and cite other examples when covering similar aspects. This reinforces for students the integrated nature of the curriculum, and emphasises the academic team's approach to the management of learning.

2.5 Intended Learning Outcomes and Assessment Criteria

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Department	Engineering
Title of Programme(s)	Electronic/Civil/Mechanical Engineering and Engineering & Management
Title of Module(s)	Group Project
Award(s)	MEng — Year(s) of study 4
Module Credits	60 — % project assessment 60%
Assessment Outputs	Individual report / evidence of learning for 20 credit Independent learning section, final group and individual reports, log books, minute book, supervisor's and examiner's observation of weekly meetings, peer assessment, group presentation and individual viva.

Industrial/ Professional Participation YES (where possible)

Group Project: YES Group Size 7-10 Group Selection: TUTOR/ STUDENT

Synopsis of Case Study

Projects offer an important means of addressing a wide variety of learning outcomes, many of which are very difficult to develop and assess in conventionally taught modules. In this case study, a wide range of programme Intended Learning Outcomes (ILOs) are addressed in a group project module. This 60-credit final year MEng group project is seen as the culmination of the whole degree programme and, as will be shown, its ILOs correspond very closely to those of the degree programme as a whole as expressed in the programme specification. The 60 credits of project is split 20/40 between an individual research/ independent study element and a 40-credit group element. Detailed assessment criteria for the group project element have been developed by drawing together inputs from all staff and these are given to students for guidance. ILOs and assessment criteria have been developed through different routes and are yet to be fully aligned with each other.

The following table shows the programme ILOs, taken from the programme specification, and the project ILOs alongside for comparison

Programme ILOs (from Programme Specification)	Project ILOs
On successfully completing the programme, a graduate will be able to demonstrate: A Subject knowledge and understanding of: 1. mathematical and computational methods and their use for modelling, analysis, design and communication in engineering. 2. a broad base of scientific principles underpinning electronic, mechanical and civil engineering. 3. the characteristics and uses of a broad range of engineering materials and components. 4. a broad range of principles and design methods relating to the chosen engineering discipline in general, with knowledge and understanding in several specialist areas at the forefront of the discipline. 5. management and business practices, including finance, law, marketing, personnel and quality. 6. ethical and social issues related to engineering and professional responsibilities. B Intellectual (thinking) skills – able to: 1. demonstrate an analytical, systematic and creative approach to problem solving 2. select and apply appropriate mathematical methods, scientific principles and computer based methods for the modelling and analysis of engineering problems, and apply them creatively and realistically in practical situations. 3. create a complete design, product or service to meet a customer need, starting from negotiation of specifications, to a professional standard, showing creativity and justifying all decisions. 4. take a holistic approach to design and problem solving. 5. assess and manage a wide range of risks (e.g.: commercial, safety, environmental etc.). 6. take personal responsibility for acting in a professional and ethical manner.	1. Subject Specific Skills. At the end of this module the students should: (a) demonstrate knowledge and understanding in the subject area of the project, at the forefront of the chosen discipline. (b) have used formal project planning methods to plan and manage the progress of a substantial (400 hours work) engineering group project 2. Core Academic Skills. At the end of this module the students should: *as appropriate to the project chosen:* (c) have demonstrated an analytical, systematic and creative approach to problem solving (d) have selected and applied appropriate mathematical methods, scientific principles or computer based methods for the modelling and analysis of an engineering problem and applied them creatively and realistically in a practical application. (e) have created a complete design, product or service to meet a customer need, starting from negotiation of specifications, to a professional standard, showing creativity and justifying all decisions. (f) have taken a holistic approach to design and problem solving (cost, life cycle, sustainability issues, etc.) (g) have assessed and managed all relevant risks (h) have taken personal responsibility for acting in a professional and ethical manner (i) have selected and used appropriate ICT based tools for analysis, design and communication of designs. (j) have selected and used laboratory instrumentation appropriately and correctly (k) have constructed prototypes or experimental apparatus to design specifications (l) have worked safely in laboratory, workshop environments etc., and promoted safe practice 3. Personal and Key skills. At the end of this module the students should: (m) have acquired extensive experience of working in a team from a major (400-hour) group project (n) have adopted different roles within a team including leadership

C Practical skills – able to: 1. select and use appropriate ICT based tools for analysis, design and communication of designs. 2. select and use laboratory instrumentation appropriately and correctly 3. construct prototype products, systems, experimental apparatus etc. 4. work safely in laboratory, workshop environments etc., and promote safe practice. D Personal and key skills – able to: 1. communicate effectively using the full range of currently available methods. 2. manage resources and time. 3. work in a team, which may be multi-disciplinary, adopting any required role within that team, including leadership. 4. evaluate the strengths and weaknesses of other team members and help them to contribute effectively 5. learn independently, identifying own personal development needs and goals, reflecting on own performance and manage own personal development 6. obtain and process information from a wide range of sources, analyse it critically and apply this information in engineering applications 7. sort, manipulate and present data in a way that facilitates effective analysis and decision making	(o) have demonstrated an ability to work constructively and supportively with others, taking and giving constructive feedback, identifying the strengths and weaknesses of others and helping them to contribute to a team effort (p) have taken part in formal, professional style, project management meetings, in roles including those of chair and secretary (q) have developed written communication skills to the extent of producing substantial formal reports of various types and length which conform to specified formats and communicate the outcomes of 600 hours of work effectively and accurately. (r) have contributed to formal team presentations of a professional standard (s) have managed resources and time with little need for advice (t) have learnt independently, acquiring skills at the forefront of current knowledge unaided, identifying own personal development needs and goals, reflecting on own performance and managing own personal development. (u) have obtained and processed information from a wide range of sources, which may have been conflicting, analysed it critically and applied this information in an a practical engineering application. (v) have sorted, manipulated and presented data in a way that facilitated effective analysis and decision making.

As can be seen from the previous table, the project ILOs have been derived largely from those in the programme specification, particularly those relating to intellectual (thinking) skills, practical skills and personal and key skills. This close alignment between project and programme ILOs might suggest that there is little need for students to demonstrate achievement of programme ILOs through other assessments. It should be noted, however, that outcomes are selected as appropriate to the specified project. Projects vary enormously, requiring different things from students, and it is almost inconceivable that any given project, even within this framework, would succeed in fully encompassing the full range of programme learning outcomes. Thus it is necessary to assess at least some of the programme ILOs through other pieces of assessed work.

Below is a further extract from the internal project module description, describing how the project is managed and assessed.

LEARNING / TEACHING METHODS

All the learning is by independent study carried out in part individually and in part within a group. The individual component will comprise one third of the work and will be carried out and assessed entirely as an individual. The group component will comprise two thirds of the work in which the assessment will be of the individual contribution to the group achievement. The whole module extends over 2 semesters, but the individual component will be completed in the first semester.

The final goal will be the completion of a group project, producing a product, design or service to an agreed specification, normally for a genuine industrial sponsor/customer.

After an initial meeting of the whole student group with academic supervisors and industrial sponsor/customer, the expertise required to complete the project will be identified and the required learning apportioned to group members. Individual students will then negotiate an independent learning and assessment contract with the project supervisor or, if more appropriate, other members of teaching staff. This learning must not have any significant overlap with other modules. An internal review panel will moderate all learning contracts to ensure that the work and assessment are appropriate for 20 credits at masters level, and learning contracts will subsequently be sent to external examiners. Individual students will then undertake the agreed programme of independent learning, amounting nominally to 200 hours work, aimed at acquiring an expertise in the subject which is significantly broader than that simply required to contribute towards completion of the group project and at the forefront of the chosen discipline. This learning will normally be supported by weekly meetings with a supervisor and assessed by portfolio/dissertation and viva with two examiners, at the end of the first semester. The portfolio/dissertation and examiners' notes from the viva will, of course, be made available to external examiners.

Alongside the above, during the first semester, the group will meet regularly and formally with academic staff and as appropriate with the industrial sponsor/customer, the meetings being chaired and minuted by members of the group. By the end of the first semester specifications, an outline design and a detailed project plan will have been agreed and will be presented in a progress report. At this stage members of the group will also complete peer and self-assessment forms. Throughout the second semester the practical group project work will continue, with weekly formal progress meetings. Each individual is expected to give approximately 400 hours to this group project part of the module. Students are expected to work as a group, supporting each other, and taking personal responsibility for completion of the project to the agreed specifications, with the academic supervisors acting as expert advisors. A wide range of support facilities are available, in the form of both physical resources and advice, which will be familiar to the students from previous project work, and the students are expected to negotiate and manage the use of these facilities themselves.

ASSESSMENT

33.33% - Individual component: assessment of individual independent learning carried out in preparation for the project, based on portfolio/dissertation and viva (with two examiners)

66.67% - Group component: based on logbooks, records (minutes) of weekly meetings, progress reports, interim peer and self assessment forms, final report, final group presentation, final peer and self-assessment forms

Assessment of the group component is undertaken by two project supervisors and a moderator, based on continual observation of work throughout the project, formal reports submitted by students independently and as a group, and taking peer and self assessment into account. Each student is assessed individually on the contribution made to group achievement. For this project examiners are looking for a high level of professionalism in the execution of all aspects of the work. The examiners consider a number of criteria, set out in detail in the Department's 'Project Assessment Criteria'.

Note: The assessment of the individual component is of learning carried out in preparation for the project, based on portfolio/dissertation and viva (with two examiners). The assessment is of the student's general knowledge and understanding of the chosen subject, not the specific use to which this expertise is applied in the project. Conversely, the assessment of the group component (i.e. of the individual contribution to group achievement) includes the use to which this expertise is put, but not the original broader knowledge and understanding, as this is then considered to be prior learning.

The assessment criteria for the project are presented below. These were developed by merging the contributions from many staff, drawing on their years of experience in supervising projects, and it would be foolish to throw this experience away. The programme ILOs were also developed using input from the same staff as well as from the Subject Benchmark Statement, SARTOR etc. But, having been developed through two separate processes, the alignment between ILOs and assessment criteria is not clear. It has been very valuable to look at the project from two angles, but at present, the message given to students is mixed. The essential next step is to look closely at both to resolve any differences and rewrite/rephrase as necessary to ensure full alignment.

Project Assessment Criteria. The following is a description of the attributes to be expected of projects being awarded particular ranges of marks. It provides a guide to the completion of the assessment table on the Supervisor's Report Form. The phrases offered are intended to cover a wide range of different styles of project, and will not all apply.

Mark out of 10:	0-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
General	Completely unsatisfactory. Almost nothing to show for any work that has been put in.	Unsatisfactory. Aims not met. No evidence of any real progress. Nothing worthwhile produced, although evidence of some work, albeit unsuccessful.	Satisfactory. Progress towards meeting most aims. No evidence of independent thought or much initiative. Could readily be completed by any student.	Good. Aims mostly met. A competent technician could have done most of the work.	Very good. Reasonably ambitious aims met fully or less ambitious aims exceeded. Required both ability and application to complete.	Excellent. Only a few students could have completed. Contains "something extra". Ambitious aims met fully or reasonably ambitious aims exceeded.	Outstanding. A member of staff could be proud of this work. No student could reasonably be expected to achieve much more or present it better with the time and resources available.	
							In the top 5% of projects.	Clear candidate for best project of the year.
Preliminary report, preparation and literature review (progress report for group projects)	Unsatisfactory report		Satisfactory report			Good report		
	Little or no evidence of any research whatsoever.	One or two sources (probably books or magazine articles) read.	Several sources of information used, but research not systematic.	Systematic literature survey attempted, but incomplete or inconsistent.	Competent literature survey carried out.	Comprehensive literature survey, sound base for project and further work.	Literature survey very systematic and comprehensive, student able to talk with confidence about other work in the field.	
Project management, contact with supervisor(s) and progress, financial awareness.	Complete failure in relationship between student and supervisor, likely that the student has effectively dropped out of the course. Shows no financial awareness whatsoever.	Contact with supervisor sporadic. Despite best efforts of supervisor to encourage student, amount of work insufficient. Supervisor has given very clear guidance but student has failed to follow it. Only vaguely aware of costs.	Contact maintained with supervisor, but generally not worked as hard as required. Student needed very clear guidance from supervisor, and has taken advantage of most, but not all, of this guidance. Shows some awareness of cost.	Fairly regular contact maintained with supervisor. Student worked hard. Clear guidance from the supervisor necessary for progress to be made. Could be relied on to keep track of costs.	Regular contact with supervisor. Needed some advice, but worked hard, and demonstrated ability to manage own work. Maintained sound financial record and provided realistic estimate of total development cost.	Maintained regular contact with the supervisor, but needed very little guidance (except in overcoming unusually difficult problems), worked very hard, almost totally self- motivating and self-managing. Meetings with the supervisor very productive and involved a two-way exchange of ideas. Rigorous record of all costs maintained, carefully justified estimate of total development costs provided and, where appropriate, a realistic prediction of further development costs, production costs, product retail price etc.		

Mark out of 10:	0-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Theoretical understanding shown and analytical content	Little or no understanding demonstrated.	Shows little understanding, and cannot relate any of the work to underpinning theory.	Shows understanding of some aspects, at a fairly superficial depth. Unable to present theoretical basis for work, though may, in interview, be able to identify some relation between the work and underpinning theory.	Shows understanding of what has been done, though may not be able to give comprehensive answers to more searching equations. Theory applied but report fails to demonstrate understanding of theory.	Good understanding of what has been done, and can describe theoretical basis, albeit with understanding of theory limited to that used directly.	Thorough understanding of the subject and can apply this understanding to the solution of unfamiliar problems.	Deep and comprehensive understanding of the subject, can answer all questions put accurately and with confidence and apply understanding to the solution of unfamiliar and difficult problems.	The student has evident mastery of difficult material, is able to explain it fluently, and has demonstrated significant original thought.
Design Requirements analysis, specification, consideration of possible designs, detailed design, verification that specs met, etc.	Little or no evidence of any design whatsoever.	No evidence that the design process is understood.	Design carried out in a way that makes sense, but process has many flaws.	Logical design process followed, but design decisions not justified.	Clear understanding of the design process shown. Proceeded in a logical manner and justified most decisions.	Clear understanding of the design process shown. Proceeded in a logical manner and justified all decisions. Design shows flair and innovation.	Very clear understanding of the design process shown. Proceeded in a logical manner, considering all options and fully justifying all decisions. Design shows considerable flair and innovation.	
Experimental work including experimental design, procedure, recording and presentation of results/data, error analysis, data analysis.	Little or no evidence of any experiments (where experiments were required).	No evidence of any data from experiments.	Some appropriate experiments carried out, but with very poor results. Almost no attempt to analyse the results.	Some success with experiments, but reliability uncertain and little attempt to account for errors. Problems, that could have been solved, not overcome.	Work properly planned, carried out carefully and fully documented. Data reliable or unreliability discussed adequately. New techniques applied. Problems overcome by developing equipment or method.	Experiments replicated and errors estimated. Theory developed and applied. Experimental data compared with theory and deviations examined and explained.	As 7-8 plus: experiments very carefully *designed*, and ingenuity demonstrated in this design. Every reasonable step has been taken to verify the results, and a thorough error analysis has been completed. Results may be publishable.	

Mark out of 10:	0-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Software development, including design and coding.	Little or no functioning software has been produced.	Some code produced and it does do something but does not work properly and there is no documentation or evidence of any thought given to a proper design process.	Some working code produced but poorly documented, not particularly reliable and a proper design process has not been followed. User interface difficult to understand and use.	Working code produced and documented. It does most of what it is supposed to do most of the time. Some evidence of a proper design process. User interface can be used with just a little guidance from the student.	Working code produced and thoroughly documented. It meets most specifications reliably. A proper design process has been clearly followed and documented. User interface usable without help from the student.	Working code produced and thoroughly documented. It meets all specs reliably. Proper design process rigorously followed and fully documented. Issues of maintainability, portability etc. addressed. User interface user friendly.	A good example of software engineering carried out properly. A rigorous design process has preceded the writing of an impressive piece of software that is robust and reliable and fully meets or exceeds demanding specifications. Full documentation, issues of maintainability, portability etc. fully addressed and the user interface is very clear and easy to use. In the top 5% of projects.	Clear candidate for best project of the year.
Practical (construction)	Little or nothing recognisable has been made.	If the project involves making something, it may be recognisable but it doesn't work.	If the project involves making something, it is unlikely to work very well.	If the project involves making something, it works satisfactorily.	If the project involves making something, it works well.	If the project involves making something, it works well/perfectly and shows real care and craftsmanship.		
Presentation of Final report: adherence to regulations, structure, grammar, spelling, typographical correctness, presentation of graphs, tables, etc., references, clarity of exposition etc.	Little or nothing handed in which could be accepted as representing a report.	Quality is low, with little or no structure. Reads like an expanded poor second-year lab report. Report is a rewrite of earlier reports without additional material.	Required components present in recognisable form. Possible to see what has been done from the report. Flawed, but has some results, some explanations and description of work which indicates that, with some additional application something worthwhile could be produced.	The report is properly structured and the required components are properly presented, but there are significant flaws. E.g.: references, diagrams, and calculations show errors or omissions.	The layout of the report follows the guidance given strictly. It is easy to read with few grammatical or spelling mistakes and gives a clear account of the project.	The report is coherent, follows the guidance given strictly, well structured, easy to read, and few corrections are required. It gives a very clear account of the work that has been done and sets this in the context of other work.	The report is excellent in every way. It needs no corrections, or only a few very minor corrections and in some cases could be of publishable quality.	

Mark out of 10:	0-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Logbook	Little or no evidence that one has been kept.	The presented "logbook" shows no evidence of being used properly.	A "logbook" has been kept, but inconsistently and has many omissions.	The student is developing a professional approach to keeping a logbook.	The logbook has been kept in a systematic way and represents a true and useful record of the work carried out.			
Group functioning (Group projects only) Group as a whole	No evidence of any communication between group members, or interactions entirely destructive.	Little evidence of communication between members of the group or attempts to work towards any common aim.	Clear evidence of communication, albeit poor, between members and of work being directed roughly in the direction of some commonly perceived aim.	Regular communication between group members. Work directed towards a commonly defined aim, though group planning may be inconsistent. Some systematic and appropriate division of roles and responsibilities.	Group worked together well. Few minor problems. Meetings organised with all members of the group contributing. Sense of a team effort rather than a collection of individual efforts, and a clear common aim established.	Group worked together well/extremely well. Meetings were well organised and purposeful. All members of the group contributed and supported the others; they had clearly defined roles but also showed a clear and constant understanding of the overall aims of the project and of the needs of the other group members. Very clear sense of team effort rather than just a collection of individual efforts. All members of the team working to the same plan, and same aims.		
Individual contribution to Group functioning (Group projects only)	No evidence of any communication with other members of the group, or behaviour towards rest of group entirely destructive	Little evidence of communication with other members of the group, or little positive contribution to group discussions	Some positive contribution to group discussions, and vaguely aware of fulfilling a specific role within the group.	Some understanding of own group role adopted within the. Some evidence of conscious support given to other group members, though this may be technical rather than personal.	Clear understanding of own group role, and aware of own strengths and weaknesses. Aware of the group roles taken by other members. Evidence of conscious support given to other group members. Can talk sensibly about the group dynamics.	Deep understanding and self-assessment of own group role. Can describe the group roles of other group members and assess performance. Consciously modifies own behaviour to support other group members in order to maintain or improve group function.	A deep understanding of the group roles, strengths and weaknesses of all group members including self. Can use this analysis to modify own behaviour appropriately and support all other group members so as optimise both their performance and that of the group as a whole. Aware of the personal development of other group members and can give them constructive guidance.	
	0-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
	(< 30 %)	(30 – 40%)	(40 – 50%)	(50 – 60%)	(60 – 70%)	(70 – 80%)	(80 – 90%)	(> 90%)

2.6 Running Team Projects in Co-operation with Industry

Author(s)	Dr Peter Willmot
Institution	Loughborough University
Faculty	Engineering
Department/ School	Mechanical and Manufacturing Engineering
Programme(s)	Mechanical Engineering.
Title of Module(s)	Application of Engineering Design (year 2) Project Engineering (year 4)
Award(s)	M.Eng (DIS) Year(s) of study 4 (or 5)
Module Credits	15 of 120 (2nd year) % project assessment 100% 30 of 120 (4th year M.Eng) % project assessment 100%
Assessment Outputs	2nd year: Written Reports (2) Oral Presentation 4th year . Written Reports (3) Individual assignment, Conference Presentation, Exhibition,

Industrial/ Professional Participation Yes

Group Project: Yes	Group Size	2nd year - 4	Group Selection:	Seeded
Group Project: Yes	Group Size	4th year - 5	Group Selection	Tutor

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Synopsis of Case Study

The Loughborough Teaching Contract is a scheme that guarantees industrially based projects to all mechanical engineering students at Loughborough University. The scheme has developed over a period of twenty years and currently offers the benefits of close cooperation between the university and fourteen engineering enterprises.

Small teams of students tackle real problems set by the companies through the academic year and engage in a number of factory visits and progress meetings. The companies pay a small fee to cover expenses and are presented with a full report of the students' findings. The industrialists take part in tutoring and assessing the project work as it develops and can exert influence on the practices and procedures used. Companies report frequent positive outcomes and generally welcome the opportunity to work with prospective placement students and graduate recruits.

The students benefit by developing an understanding of working in industry, gain context to their degree programme and improving their process and communication skills.

Introduction

This case study describes how we have embedded a significant industrial input into a Mechanical Engineering degree programme through a formal scheme known as the "Teaching Contract". SARTOR3(1) and Institutional accrediting panels place a greater emphasis than ever on the provision of industrial liaison in academia and the benefits are widely accepted but difficult to quantify. The QAA(2) require engineering students to have an “ability to operate in commerce and industry in a variety of situations”: how is this to be achieved if not through working with industry?

Clearly, all institutions set and supervise project work and in many cases, industrially derived projects are set on an ad hoc basis through a lecturer’s personal contact or by speculative approaches from industry. While this all very positive and those students who happen to land an interesting industry-based project are often well served, it was realised that a more formal arrangement was needed if we were to guarantee a similar quality of experience to all students and generate a robust and adequately moderated assessment regime.

The Loughborough Teaching Contract

The Teaching Contract is a consortium of companies who agree to provide projects for a number of students and give continuity of industrial support at the heart of the curriculum. The scheme guarantees industrially based project work for all our second year students (B.Eng/M.Eng) and final year masters students. We recently extended the scope to include Product design finalists. In 2002/3 there are approximately 200 students taking part. The conduct of the projects and the administration of the system is constantly monitored and improved by an annual advisory meeting of the consortium. The companies pay a small fee to the university that allows us to fund the necessary industrial visits, hospitality, cover basic project costs and maintain a high standard of report presentation. Over the years the scheme has involved a large number of engineering companies: currently there are fourteen companies involved that range from major household names to small local enterprises.

Recruiting the Industry Partners

The primary task of the Teaching Contract Director is to ensure that there is sufficient capacity within the scheme for the student numbers. There is a natural turnover of companies and an effort must be made to recruit new companies at every opportunity. Industrialists are usually keen to talk about working with a university but less eager to make a time commitment. An information pack is sent to interested parties but face-to-face discussions are undoubtedly the most effective recruiting tool. We also invite any company managers who express interest during the year to the summer exhibition of students work. Much of the recruiting activity takes place during the summer vacation. When a company joins the scheme, it agrees to the conditions and a modus operandi set out in an agreement document. Fortunately, to a certain extent, the scheme is self-perpetuating.

Setting up projects with industry

Considerable prior planning is involved. Companies express a preference for working with either second year students or finalists. Some prefer second year because of the reduced commitment and the possibility of recruiting future sandwich placement students while other prefer the more advanced level of the final year work. A batch of between fifteen and twenty students are allocated to each participant company; we find few companies will accept more than this. We also select an academic tutor to work with each company.

The companies prepare an initial statement of their project ideas. For finalist we insist on a different topic for each team but for second years it works just as well when student teams compete on the same topic. In some cases, this is more rewarding for the company as they get a better breadth of concepts and investigations. Tutors visit their company during the summer vacation to discuss the suitability of the ideas and offer advice on how the task should be set. We prefer that students are not provided with a detailed written brief as the first task is for the team to get to grips with the problem and generate their own detailed specification. Tutors also arrange an initial factory visit during the early weeks of term and provide advance notice of meeting dates etc.

Suitable project topics

The subject of the project may be almost any aspect of mechanical or manufacturing engineering, provided there is scope for some original conceptual work.

At second year level, the project is an open ended problem set by the company and the students work as consultants with the support of the academic tutor, a student-mentor (see Case Study 9) and an Industrial Tutor. The primary intention of these projects is to develop team working, creativity, commercial awareness, project planning and associated transferable skills rather than completely detailed designs. Working in teams of four, students are encouraged to research the field of study, present a number of well considered ideas or schemes, and develop the most promising of them into a design scheme together with a full evaluation of its merits. This often involves laboratory testing, modelling or simulation. A formal written report is prepared together with a formal oral presentation to the company and the peer group.

In final year, the topics a naturally more complex and studied to a greater depth but are similarly open-ended. Having already gained experience of team working with a company in their second year, finalists become effective much quicker and are ready to take a project from initial research through to a detailed solution that often includes a demonstration model or prototype. These students are also ready to tackle more advanced methodologies such as risk and failure mode analysis with maturity. Once again, students are introduced to the projects at the factory site and an academic supervisor works with all the teams allocated to any one company. Finalists work in teams of five and have a number of substantive assessment tasks.

Examples of Past Project Titles

- Developing a method to measure the crunchiness of a popular confectionery
- Non Destructive Testing (NDT) for rust in lagged pipes on the continental shelf
- A device to check for leakage in the seals on polythene milk bottles on the production line
- Rail Carriage conversion for freight
- A Supermarket checkout design for the disabled.
- In situ strength testing of corroded pipe flange bolts
- Hydraulic digger functionality improvements
- Intelligent pipeline pig
- Variable power steering
- An Improved hand-pump manufacturing cell
- A hydrodynamic bearing test cell
- Testing the longevity of pipe joints in a vehicle air conditioning system
- Measuring torque on a racing motorcycle

Typical Project Schedule

The module leader generates the project schedule. The outline schedule remains unchanged from year-to-year with all activities related to the module happening on a fixed half -day every week. The projects run from mid October to early May with a break during the examination period in January. When the university first introduced the semester system, we compacted the second year project into a single semester with similar time allocations but this was unpopular and the resulted in a distinct drop in the quality of student's work.

A generic lecture programme dealing with design processes, methods, researching and reporting methods supports the second year work. Finalists take a parallel module in engineering design management.

Example schedule (Final Year)

Week 1	Introduction to the scheme, team and company allocation
Week 2	Factory Visits
Week 3-5	Tutorials with academic supervisor
Week 6	Progress Meeting with company tutor
Week 7-11	Tutorials with academic supervisor
Week 12	Intermediate report handed in
Week 13-15	Examination Period
Week 16	Progress Meeting with company tutor
Weeks 17-24	Tutorials with academic supervisor
Week 25	Hand in Final Report
Week 26	Preparations for week 27
Week 27	Conference (am) and Exhibition (pm) with industrialists, also Teaching Contract AGM

Student - Industry Interaction Through the Project

Students have an early visit to the factory to see the environment at first hand. This means we need to arrange up to eight busses on the allocated visit days and we are happy to travel up to about 150 miles. The staff tutors accompany their teams but always allows the company to introduce the problems to be studied. Where more than one topic is on offer we allow teams to take their choice. This visit, that normally includes a tour of the site is crucial for the students to understand the context of the project and is a considerable motivator.

There are a number of essential follow-up visits to the university by the Industrial Tutor and the teams maintain additional contact throughout by email and telephone. We require students to generate their own agenda and chair these progress meetings where they report progress and seek further advice and direction. The primary purpose of the first university meeting is to agree the specification for the' contract'.

Quite apart from meeting with students, the visits offer the opportunity for industrialists to share their experiences with university staff and with other company representatives. We consider this a valuable networking opportunity and several developments such as research contracts have arisen directly from this interaction. To encourage this we arrange to meet together over lunch.

Finalists typically make one further visit to the factory or other associated industry by arrangement with their tutor. This is usually unaccompanied but we pay travelling expenses through the scheme. Secondary visits are less common for second year students. We encourage all students to contact other organisations in connection with their project work and we reward initiative. Students, for example, sometimes arrange for sales representatives to visit the university and demonstrate their products.

Space Needs

An important consideration in setting up such a scheme is the need to provide meeting space for a large number of teams at the same time. We provide a large studio with separate project areas and have a number of small study rooms for team meetings. Motivation is soon lost if suitable accommodation is not available. Coping with this demand has proved difficult however the income from the scheme has enabled us to gradually bring in additional presentation equipment etc.

Assessment

Assessment is conducted by the academic supervisor through staged reporting and the projects finish with a formal presentation at the University to the peer group. Individual finalists are allocated an additional assignment within the scope of the project and the oral presentations take the form of a conference followed by a large exhibition to which industrialists, academic staff and fellow students are invited. Students prepare copies of all reports and drawings for the company to keep and industrialists assist and countersign each stage of the assessment process. We use a series of pro-forma marking sheets with objective marking criteria to moderate each assessment stage. Finally, we apply a peer assessment routine to reward individuals appropriately.

Benefits

For students

- Knowledge and understanding of specialist engineering topics.
- Awareness of industry and commercial realism.
- Research techniques, teamworking and communication skills, problem solving, written and oral presentational skills.
- Prototyping and model making.
- Structured project management practice.
- Motivation.
- Enhanced employment prospects (students report that these experiences usually form the centrepiece of subsequent job interviews).

For industry partners

- Many of the ideas put forward by the students that have been taken up and developed by the participating companies.
- Many more companies have told how they benefit from the unrestrained basic research done with fresh and open minds and how this often leads to novel and otherwise ignored conceptual solutions to longstanding problems.
- Allows companies to tackle problems which the company would like to solve but which are perhaps not critical to daily production and which they would not usually resource.
- Access to university research using tools not available in the company.
- Excellent publicity for the company.
- Access to placement students and potential employees.
- Potential access to more extensive research projects.
- Industry staff involved usually enjoy the experience, that is considered as a diversion.

For the university

- Good industry links enhance a department's reputation with potential students
- A positive and powerful feature at professional accreditation.
- Contact with industry keeps staff up-to-date.
- Small income stream covers expenses.

Conclusions

Industry projects offer a wide range of benefits to all three parties involved in them. Above all, students are seen to noticeably develop in confidence and professional stature through this work. They begin rather slowly and hesitantly when faced with an unfamiliar open-ended problem at year 2 but end the scheme with confidence and commitment.

Industry projects provide an excellent vehicle to apply engineering science in context and practice key transferable skills that are so valuable to employers. Furthermore, industrial companies appear keener than ever to work with universities who they consider will provide them a source of high calibre graduate employees. Universities involved in engineering can only gain from such liaisons but they must weigh the benefits against the administrative complexity and the considerable time and space demands.

References

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2. Academic Standards – Engineering, Benchmark Statement, Quality Assurance Agency for Higher Education, 2000.

2.7 Widening the Project Based Learning Experience with Student Mentors

Author(s)	Dr Peter Willmot
Institution	Loughborough University
Faculty	Engineering
Department/ School	Mechanical and Manufacturing Engineering
Programme(s)	M.Eng Mechanical Engineering.
Title of Module(s)	Project Engineering
Award(s)	M.Eng (DIS) Year(s) of study 4 (or 5-sandwich version)
Module Credits	10 of 120 % project assessment – 100% Coursework
Assessment Outputs	*Individual assessments:* Mentoring Report 40%, Tutor Appraisal 20%, Project Management Essay 20% *Team assessment:* Case Study 20%.

Industrial/ Professional Participation Yes (indirect)

This is an individual activity that supports a 2nd year team project

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Synopsis of Case Study

This case study describes the arrangements and procedures for a successful final year student experience in project supervision. Fourth year M.Eng students are appointed 'mentors' to a team of second year students undertaking a year long project module. The mentors gain practical experience of aspects of project management and leadership in a controlled environment, and are encouraged to reflect and build on their performance through an appraisal procedure similar to that used by the professional engineering institutions.

Introduction

Surveys show that engineering employers seek virtues such as willingness, drive and self-determination, along with strong commercial and communication skills, ahead of traditional technical expertise. In short, companies look for young graduates with potential, who can perform from day one. This study describes how the introduction of the degree of Master of Engineering provided the inspiration to further develop an existing university/industry project scheme known as the 'Teaching Contract' to enhance the leadership and entrepreneurial potential of high-flying students: preparing them better for the world of work.

Finalist M.Eng students are appointed as mentors to a team of four younger students engaged in an industry based research and design project. Through this, they gain first-hand experience of project management and leadership. The experience is built into a module offering practical support and opportunities for self-reflection.

The Teaching Contract

For a full description of this project scheme please refer to Case Study 6 (p 2-41).

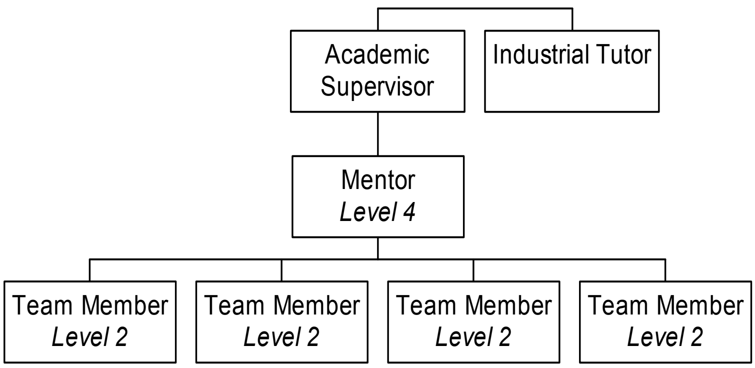
Rationale for introducing student-mentors

The widespread introduction of the degree of Master of Engineering (M.Eng) in the late 1990's required institutions to add breadth and depth to degree programmes. Along with this came a requirement to consider the professional competences of graduates and key transferable skills appropriate at master's level. The IMechE state that the degree should "enable the M.Eng graduate to progress rapidly to a position of responsibility." The aim of extending our Teaching Contract was to prepare our most able students more specifically for leadership and entrepreneurial roles.

How student-mentoring works

Early in the year, all our second year (level 2) students are introduced to an industrially derived problem from within the Teaching Contract consortium and a finalist works as 'mentor' to each team of four. Each consortium company sets problems to four or five teams (16-20 students in all) and an academic supervisor takes charge of the activities of the company group. In 2002/3 there are eight company groups operating. Projects run from mid October to early May on one afternoon per week, with a four week break during the mid year examination period.

The mentoring experience forms the major part of a final year module 'Project Leadership'. This is a 10 credit module that, crucially, takes place at the same time as the mentors are themselves participating in a level 4 (30 credit) industry based team project, hence there are



Company Group Structure

opportunities for the role of team-player to inform the task of leading a team through a smaller but similar style project. Students are encouraged, for example, to pass on their final year level experience at project planning and control to the second year team they are mentoring.

The module leader draws up a schedule of events for the duration of the project that includes weekly team meetings, observed team meetings where the supervisor sits in and two progress reports where the industrial sponsor is also present.

The mentor is expected to chair team meetings that last about an hour; (s)he must produce an agenda in advance and work to it. Teams record their meetings through minutes that are copied to the supervisor via email. The mentor must ensure this is done but may choose precisely how. They most commonly rotate the secretarial duties amongst the team members, though some mentors prefer to prepare their own minutes.

Monitoring and Appraisal

Roughly every third week the supervisors observe team meetings and conduct an appraisal of the mentor's performance using a reporting technique based upon the Engineering Council's Monitored Professional Development Scheme (MPDS). At the same time (s)he checks the progress of the project team but only intervenes if problems or difficulties are apparent. The supervisor and mentor meet in private shortly afterwards to discuss the appraisal, with the purpose of identifying the mentor's strengths and weaknesses. Both supervisor and mentor sign the appraisal record.

Once each semester, supervisors host an informal management meeting with all the mentors in their company group. Mentors are encouraged to exchange ideas on what they perceive as being effective and what has not worked so well for them. They identify problems and discuss how best to tackle them. These sessions are particularly useful and universally welcomed by the mentors.

In recognising the usefulness of an appraisal system, we also incorporate intermediate feedback on the mentors' performance by the mentees. We wrote a simple anonymous questionnaire for this purpose that mentors distribute amongst their teams. Information received through this does not directly affect module marks but helps the mentors identify their strengths and weaknesses.

Roles and Responsibilities

The mentor's primary role is that of project manager, who deals with project planning, gives advice and guidance, allocates duties to team members and encourages effective progress. While it is perfectly permissible for mentors to assist with the promotion and development of ideas, and to offer sound assistance with analysis and evaluation, they are asked to refrain from directly generating solutions or actually performing the technical tasks. Mentors are also required to give leadership and encouragement through which they quickly learn the effects of different styles of working with teams.

The academic supervisor is ultimately responsible for the mentor and the student teams within his/her company group, and for assessment of the performance of both.

Student Support and Context

The mentoring activity is, of course, central to this module, but if level 4 students are to realise the maximum benefit from it they should take time to reflect on their actions and the reactions of their subordinates: engineers are not noted for their sociological prowess.

The taught element of the module has three functions.

1. To support the mentoring activities.
2. We deliver a number of lectures and training workshops on subjects like project planning, team building, motivation and leadership, and how to conduct and record meetings.
3. To place the mentoring activity in an appropriate context.
4. We remind students of contemporary project management theory (studied in depth at level 3). In particular, we look at team dynamics and psychometric testing, and how personality factors influence the effectiveness of different management and leadership styles.
5. To consider, through case study, different types of projects, large and small, and tease out the common skills and expertise needed by those who lead them.

At first, we tried to teach these topics through conventional lectures but soon realised that the relatively small group size and the seniority of these high calibre students lends itself to participative workshop style teaching. Some of the material we employ was intended originally for staff development.

Module Assessment

Assessment is by coursework only and comprises three elements. The project supervisors mark assignment 1 against pre-defined criteria but assignments 2 & 3 are marked by the module leader.

1. Mentors write up their experiences including a reflective critique of their performance and the responses of their mentees. The report is informed by the appraisal system that identifies strengths, weaknesses and growth from the perspective of both supervisor and subordinates. Students must report how they reacted to the issues raised. The appraisal forms are appended to the reports and their numerical scores (staff appraisal only) contribute a small percentage of the report mark.
2. A short essay based on a reading assignment is set midway through the year to encourage students to research project management techniques for themselves.
3. A two-week case study assignment, delivered by a company director, widens the scope of the module by challenging students to consider how they might initiate and manage a major venture capital project. This interactive team exercise uses role-play to demonstrate the different views of interested parties and considers the obstacles to overcome. Assessment is part oral, part written.

Benefits

This module is quite a departure from our usual diet of engineering science, laboratory investigations and lecture-based tuition. The potential benefits in the students' personal development, however, are obvious. The leadership scheme is a self-building experience: mentors recall their own experiences in year 2 and this, added to the experience many have gained in industry during our optional sandwich placement year, seems to make the whole experience come to life. What is most noticeable is the mature attitude the finalists invariably bring to this work. The motivation not to let their charges down is very high, but the acquired responsibility of mentoring a team also influences the attitude to the parallel final year project work where we now see an unprecedented degree of professionalism.

It is particularly pleasing when we contrast this with the initial approach of the level 2 project students. Here, we often find the mark-driven, minimalist effort that is so common in early years work. Many would argue that the introduction of peer mentors improves this situation through the course of the year as the influence of the mentor is injected into the teams. It appears that students respond more readily and attentively to instructions and suggestions from peer mentors than from academic staff. Perhaps they relate in a manner that seems more relevant.

When compared with directly supervised level 2 projects the main benefit for supervisory staff is the reduced number of tutorial meetings that they need to attend; many of the weekly meetings are now taken by the mentor. Weighed against this, however, is the additional marking (mentoring reports and appraisal), management meetings with mentors and the obligation to monitor and take responsibility for project teams at arms length. On balance, there is no real time saving for staff.

Reflections

A lot of administrative work goes into providing the leadership experience for students but the result is a stimulating experience. We have not yet attempted any scientific analysis of the outcomes but module feedback is consistently good. Occasional comments like “the most useful module I did at Loughborough” are gratifying and show that at least some students gain from it. A number of finalists also reported that they discussed this experience during job interviews and that employers were keen to hear more. Their signed appraisal record is used to provide evidence.

The professionalism and maturity, referred to earlier, is probably the product of finalist mentors working ‘with’ academic staff rather than ‘for’ them to assist and motivate their project teams. Team leadership comes more easily to some than to others and some candidates are surprisingly ill at ease in this situation in the first instance. They are usually self-critical when asked (more critical, in fact, than their appraisers) and noticeably improve as they gain experience.

This module represents a modern and novel approach to appropriate vocational training.

2.8 Teaching Engineering through Problem Based Learning

Author(s)	Barry Lennox		
Institution	University of Manchester		
Faculty / School	Faculty of Science and Engineering		
Department	School of Engineering		
Title of Programme(s)	BEng (Hons) and MEng (Hons) in Mechanical Engineering, Aerospace Engineering and Avionics		
Title of Module(s)	The majority of first and second year modules		
Award(s)	BEng and MEng	Years of study	1st and 2nd
Module Credits	60 in Yr 1 and 80 in Yr 2	% project assessment	50-100%
Assessment Outputs	Reports, presentations, posters, tests, demonstrations		
Industrial/ Professional Participation	No		
Group Project: YES	Group Size 5 to 8	Group Selection: TUTOR	

Synopsis of Case Study

In September 2001, Problem based learning (PBL) was introduced as the primary teaching method for undergraduate engineering programmes at the University of Manchester. The introduction of PBL has brought with it many benefits and rewards for staff and students and has also raised a number of challenges and issues. Whilst it is premature to declare the overall initiative a success, an initial review of the programmes, conducted by an independent analyst, are encouraging. In addition, observations from staff indicate that after completing the first year of PBL, the students are more confident of their own abilities, better able to work in a team, keener to learn and have a greater understanding of the practical aspects of engineering. We also found that there were decreased re-sits and end of year failures, that is likely to have a positive impact on retention rates.

Many of the benefits and lessons learned from implementing a problem based approach are also applicable, within traditional engineering courses, to projects consisting of a problem based scenario. For example, the benefit of using learning logs, the initial resistance of staff, and the subsequent motivation and satisfaction of students and staff in undertaking engineering problem solving activities.

Background

It was recognised for a number of years that there was a need to conduct a thorough review of the content and delivery of the engineering programmes offered by the University of Manchester. The necessity to review the programmes was driven by two principal factors. The first is that the changing nature of 6^{th} form education means school leavers are increasingly mismatched with the traditional requirements of undergraduate engineering programmes, particularly in mathematics. The second factor reflects the changing needs of industry, who look for graduate students who not only possess a solid understanding of the fundamental science of engineering, but also have a practical and confident approach to problem solving, can function well in a team and have excellent communication skills.

To address these factors, the decision was made in 1998 that the Manchester School of Engineering (MSE) would create a series of new undergraduate engineering programmes that would adopt PBL as the primary method of learning and teaching.

Programme Development

In 1998 a team of four people were assigned to develop the structure and content of the PBL based programmes with the intention that the programmes should take their first cohort of students in the academic year beginning September 2001. The early stages in this development involved identifying how PBL should be integrated into the undergraduate programme, what form PBL should take and the amount of PBL that should be contained within the programme.

There have been many PBL methods proposed for undergraduate education and the one adopted by MSE involved dividing the class into groups of eight and having each group work on a problem for 1-2 weeks (this PBL implementation could be analogous to an intensive project implemented in a traditional course). A problem scenario is handed out to each group, the make up of which is selected at random at the beginning of each semester, on a Monday morning. Over the next 1-2 weeks, the students are encouraged to follow a set procedure that involves the recalling of knowledge, formulation of questions, discussion of what has been learnt and finally reflection. To ensure that this happens, each group is assigned a member of staff who facilitates for two 1-hour periods on Monday and Thursday mornings.

Continual self-evaluation is encouraged throughout the programmes, and the students keep a reflective log known as a learning journal as part of their Personal and Academic Development Plan (PADP). For the duration of the PBL exercise, the student keeps a record of his/her own notes, teaching materials received from other group members, and a reflective commentary on his/her own progress. This commentary includes personal skills acquired through team working and may also include the roles played by individuals in the group, how well the group stuck to the task, time management, and how the group resolved differences.

Assessment is managed using a range of group and individual tasks. These include tests, presentations, web page design, report writing and demonstrations (see later for credit ratings).

Before each PBL activity was introduced into the programme it was piloted extensively with the help of school children and third and fourth year students. This testing phase proved invaluable as the test students would often focus on unexpected aspects of the problem, rather than the desired engineering topics. Significant changes were made to the problem scenarios at this stage to ensure that the correct learning outcomes could be achieved.

A major problem facing the programme development team was that there was significant resistance from many academic staff to the transfer to a PBL based programme. To encourage staff to support the transition to PBL, a series of away-days and training courses were scheduled between 1998 and 2001. These courses proved very valuable and did change the opinions of some academic staff, although others remained very much against the change, citing increased workload as their primary concern.

Programme Structure

It was decided at an early stage in the planning that PBL would be used extensively in years 1 and 2 with the format of year 3 and 4 units being left to the discretion of unit leaders. The reason for this is that the students tended to be well motivated in years 3 and 4 of the traditional programmes at MSE and were happy with the structure and content of these years. This decision was later found to have a significant benefit with the engineering institutions, who have now given provisional accreditation to the programmes. The Institutes were encouraged by the PBL approach, but at the same time were pleased to see that years 3 and 4 were comparable with those offered at other universities.

The initial plan for year 1 (which both Mechanical and Aerospace engineers take jointly) was that PBL would be used as the only method of delivery of course material. Unfortunately it quickly became apparent that this would not be suitable as there was insufficient time available in the year for the students to complete the necessary number of problems that would ensure that the first year syllabus was covered. It was therefore decided that year 1 would be split between PBL activities and taught courses. The PBL activities would cover the majority of the core engineering science with the taught courses providing theoretical underpinning and filling in any gaps in the syllabus not covered in the PBL activities. A further benefit of the taught courses was that they provided some risk limitation for students and staff. Although PBL has been implemented in engineering programmes elsewhere in the world, the scale of its integration in the programmes offered by MSE far exceeds any of these implementations. There was therefore some concern that on such a large scale, PBL would be unsuitable in an engineering programme. Care was taken to ensure that the taught courses did not take the form of traditional lectures, as this did not exploit the skills that the students were learning through PBL and was seen as the primary cause for students becoming disengaged with engineering in the past. Consequently the taught courses took the form of 2-4 hour sessions, during which the students would receive several short 15 minute presentations, interspersed with several individual and group based problem solving activities.

The basic structure of year 1 is that the year is divided into 12 two-week blocks. In each two-week block the students undertake PBL activities in the morning and engage in more structured teaching in the afternoons. There is an exception to this structure for the first 5 weeks of the programme when the students complete a series of 1-week PBL activities. The purpose of these sessions is for the students to get to know the other members of their group and to learn about PBL and to discover how to get the most out of it.

The theme for year 2 is *Design as an Integrator* and the content of the year was such that the engineering science was introduced in the context of its purpose in the design aspects of engineering. Year 2 is the first year in which the engineering disciplines are divided into degree specific streams, Aerospace Engineering and Mechanical Engineering.

The second year is divided into four, 6-week periods. In each of these periods the course focuses on particular aspects of the degree programme, for Mechanical Engineering students these are ‘Statics and Dynamics’, ‘Thermofluids’, ‘Instrumentation and Control’ and an ‘Integrating Module’. The purpose of the integrating module is to bring all the various engineering sciences together to solve a particular problem, in this case the re-design of a reciprocating compressor. This approach equates to the 'integrating projects' which are sometimes adopted in traditional programmes.

As with year 1 the teaching methods employed in year 2 comprise a mixture of PBL and taught courses. However, unlike year 1 where there is only a loose relationship between the PBL and taught courses, the two teaching methods are closely linked in year 2.

Credit Ratings

Years 1 and 2 of the programme are structured as follows:

Year 1 modules		Assessment		
	Credits	*Exam %*	*Unit tests %*	*Coursework % (individual & group)*
PBL taught modules				
Mechatronics	10	60	20	20
Statics and Dynamics	10	60	20	20
Thermofluids	10	60	20	20
Design	10	0	0	100
Professional Engineer	10	0	0	100
Mathematics	10	60	20	20
PBL modules				
Group Work	20			100

Personal Studies	20		100	
Personal Development	20			100
Year 2 modules		Assessment		
	Credits	*Exam %*	*Unit tests %*	*Coursework % (individual & group)*
Taught modules				
Design 2	10	80	0	20
Materials	10	80	0	20
Accounting and Law	10	80	0	20
Management	10	80	0	20
PBL taught modules				
Taught PBL 1	10	80	0	20
Taught PBL 2	10	80	0	20
Taught PBL 3	10	80	0	20
Taught PBL 4	10	80	0	20
PBL modules				
Group Work	20			100
Personal Studies	10		100	
Personal Development	10			100

In years 1 and 2 the 'Group Work' mark is based upon the group based reports, presentations etc, that are completed. The 'Personal Studies' mark is an average of all the tests that are undertaken during each PBL activity. The 'Personal Development' mark is an accumulation of the personal and academic development plan report marks that are assessed by the tutors. In year 2 the management and design are more traditional in structure.

Passenger Problem and Peer Review

The single, largest problem that has been encountered with the PBL programme is that associated with ‘passengers’. Each group contains 1 or 2 students that provide little or no contribution. In the first year that the programme ran, this problem was, perhaps naively, unexpected and students who had failed to contribute to the PBL activities continued to receive high group marks. This caused major resentment with hard working students, both towards PBL and their peers. To address the problem a peer review scheme has now been introduced. At the end of each PBL activity the students provide a grade, out of 5, for the contribution that each member of the group has made. These figures are then processed and the group work mark for each student is moderated accordingly. Students can appeal if they believe that they have been unfairly treated by their peers but must provide factual evidence to confirm that they have contributed. This evidence typically takes the form of minutes and attendance from the meetings that are routinely held during the PBL activities. Although there have been some practical problems with the peer review system, these are beginning to be ironed out and the students are becoming appeased with the procedure.

Reflection

Following the completion of the first year of the programme an independent analysis was conducted. This analysis questioned, through interviews and feedback forms 79 students and 17 staff. The main conclusions from this analysis were that:

1. Desirable learning outcomes can be successfully achieved through PBL.
2. A group size of 5-8 works well.
3. Whilst initially there was some resistance from members of staff to PBL, those that have been acting as facilitators during the first year have found the experience rewarding, despite a slight increase in their work-load.
4. PBL motivates the majority of students to attend and engage, however there are still some problems with *passengers* and non-attendance which needs to be addressed.
5. The taught courses have been particularly successful with many students surprisingly rating Mathematics as their favourite unit.
6. The number of students who were required to re-sit units reduced from 40% in 2001 to 27% following the introduction of PBL and the number of students failing the year dropped from 30% to 16%. The reason for these reductions is believed to be because the students are enjoying the course more than in previous years and through PBL facilitation, members of staff have much closer contact with students during the year. This closer contact means that it is possible for members of staff to identify and respond to *at risk students*.

2.9 Learning Through Competition

Author(s) Dave Easterbrook (Colin Southcombe and Ken Bird)

Institution University of Plymouth

Faculty / School Faculty of Technology

Department School of Civil and Structural Engineering

Programme BEng / MEng Civil Engineering

Title of Module(s) Design Option

Award(s) BEng / MEng Year(s) of study 3

Module Credits 20 % project assessment 50%

Assessment Outputs: Project philosophy, poster display, project submission

Industrial/ Professional Participation YES, Industrialists

Group Project YES Group Size 4 or 5 Group Selection: STUDENT

Synopsis of Case Study

This case study describes how undergraduate design projects forming 50% of a 20 credit module are integrated with National Steelwork Design competitions run by the Steel Construction Institute and sponsored by CORUS.

Currently there are three competitions run each year by the Steel Construction Institute (SCI) and each participating university may enter a team (or even an individual) for all three competitions. High quality competition briefs are developed by a team of industry professionals and academics. The briefs contain real world problems that ensure that the students are stretched to their limits to come up with an appropriate design.

At Plymouth we also involve industrialists in judging the design projects. They are involved in attending student presentations and in determining which of the designs will go forward to the national competitions. The competition is between each other as well as with other UK universitites.

Staff, students and industrialists want the teams to perform well, are motivated by the competitive element, and are excited by the difficult briefs set. The competitions have clear criteria for judging covering the key elements of good design, as a result the competition criteria align well with module specification, learning outcomes and assessment methods for the design module.

Background to the competition

The Steel Construction Institute started running design competitions for undergraduates in 1995, and these have been run to cover four steel construction areas: Structural Steelwork Design, Steel Bridge Design, Tubular Steelwork Design and Steel Piling Design Awards, sponsored by Corus Construction Centre

The competition design briefs are set by a panel of industrialists and academics. The industrialists often provide a real design problem that is based on examples from their own design experiences. The design problem is then discussed at a panel meeting in order to produce a design brief which the academics feel is challenging but achievable and which the industrialists feel is a good test of structural engineering. As the problems are real this usually means that for the students to come up with solutions they must use and extend their structural engineering knowledge to larger and more innovative structures. The problems encourage students to really look at structures and explore new ideas and concepts.

Each University may only submit one team per competition, so there is also competition between the teams within each institution to be the team selected. This ensures a focussed approach to the competition which drives the students to succeed.

The brief is compiled by a panel of academics and industry professionals and is then assessed by a 2nd panel of academics and industry professionals. The only common membership of these panels is the Chairperson and a representative from both CORUS and SCI.

All of the teams selected from each university for the national design project receive a £250 prize and the winners of each competition receive prizes totalling £2,500

The group size for the competition entry is also determined by each university. In the past there have been winners with group sizes from 5 to 2 and even individuals winning prizes.

The competition briefs are available at the start of each academic year with a submission date in June the following year. This allows for each university to embed the competition into its own academic structure and unique learning and teaching methodology.

The SCI hosts a web site for the competition with a facility for students to post questions regarding the design brief, the answers to which are available for all competitors.

The entries to the National Design Competition are judged at the SCI Headquarters in Ascot, by a separate judging panel as described above. The judging takes place over one full day and involves healthy debate based around the design brief but particularly with respect to each judges own appreciation of the students final design. The competition culminates in a national award ceremony held at a location within the UK. All entrants, both staff and students, are invited to attend, and are able to view other competitors submissions which are on display at the location. This enables the best students from each University to learn from/judge each others' work.

The project is intended to engender competition but it is primarily a learning process albeit a sharp, focussed experience. The ceremony is very professionally organised and includes a formal lunch, following which the awards are announced. Despite the fierce competition which exists between the universities, both students and staff are generous in their appreciation of the winners.

Running the competition at the University of Plymouth

The students compete up to three times within the module:

1. to select an initial brief - within the university
2. against each other to go forward within the competition
3. the final competition - national

The design briefs are presented to the students at the start of their final year on the BEng/MEng (Hons) degree programme. The students then form into teams based on the design brief which interests them and an association from previous project work. This selection is indicative of the design team creation in industry and is often focussed on winning.

At Plymouth the students put in "bids" to determine which of the competitions they will enter. They produce sketch outlines for two of the competition briefs which they would like to undertake. The students submit their proposals, stating which is their preferred option of the two. The allocation of the project titles is determined by the quality of the submission and is intended to ensure an even distribution of teams for each project. This "bidding" for project titles ensures that a competitive spirit is created within the groups.

It is up to each University entering the competition as to how the project work is timetabled. At Plymouth, this is typically three hours contact time per week for 10 weeks in the second semester, largely delivered in an informal group based tutorial format with the module leader acting as a mentor to each team, asking more questions of the team rather than just giving answers.

In order to determine which group will be submitted to the national competition, students are requested to produce a presentation of their design work to industrialists and academics. The presentations are assessed by an equal number of industrialists and academics, to determine which projects will be put forward to the final national competition. There is often healthy debate between industrialists and academics over which project should be put forward. When the students present their work to the industrialists they also receive feedback which allows them to fine tune their design before submission to the National Competition (1 week later).

The presentations take the form of a poster display, computer based images and discussion. The students explain their design proposals to both the industrialists and academics who then question them much in the same as one would in practice. Other groups are encouraged to listen and learn from each “grilling”, as the process proceeds.

The competition is also an important element for the Industrialists involved at an institutional level. They are keen to see the teams progress and perform well in the competition and enjoy the judging process. This is usually arranged between 5-8 pm in the evening to make it easy for them to attend after work (food is provided).

The use of the competition design brief provides academics with an appropriate pre-written brief. Students and staff are all motivated by the competition and the Industrialists are very keen to learn of success in the competition.
There has been a good distribution of winners nationally from the competing Universities over the years that the competition has been run. For example at Plymouth they have won first prize in the tubular steelwork design competition three times, first prize in the steel plates design competition once and first prize in the steel piling design competition once, collecting a total of 7 prizes, including second and third place, since the start of the competition in 1995. This helps motivate the students as they want to out perform the previous year.

Integrating the competition with the module

The work that is carried out is undertaken both for the design competition and assessment in the module. The work counts for 35% of the module marks. As the competition briefs are written by both professionals from industry and academics the outcomes align appropriately to core module objectives.

The design brief is never prescriptive and has a broad range of solutions, which encourages the students to ‘think out of the box’ and to be creative in their design.

As the marking scheme is not prescriptive and cannot be prescriptive for such an open brief, the students are not so assessment driven and get their motivation from the competition.

The module is intended to introduce the students to real large and innovative structures. The students find the module daunting at the start but it becomes increasingly popular as they become more involved in the SCI competition in the second semester.

The competition integrates all of the knowledge, which can be expected from an undergraduate. It encourages aspects of structural design, buildability, maintenance, sustainability, economics and other aspects of a sound engineering degree course. This is the main reason why students initially find the module daunting. However with the realisation of the knowledge that they possess, which is generated by such a demanding brief they become increasingly more confident and “professional” in their approach.

The student design work is assessed based upon a criteria based marking scheme, relating to the key aspects of good design which naturally align with the competition judging criteria, e.g. that it must be elegant, safe, economic, well communicated and comply with the brief.

Benefits

The whole competition is run very professionally. The design brief is well constructed, there is a good panel and it is judged to appropriate criteria. The competition provides the industry with the opportunity to demonstrate the versatility and best use of steelwork in construction and to develop links with undergraduates.

There are a number of benefits from adopting a competition within a design project:

- The design brief is varied open and taxing
- The design brief is very professional as it is developed by an experienced team
- It is motivating for students:
- Financial reward
- Kudos and good evidence of success
- Motivating of staff and local industrialists, who want their students to be well represented
- Staff can't wait for the new design briefs for the year to come out
- Pride for the students in reaching the final of the competition and being awarded a National prize and satisfaction for staff in seeing these students developing into the designers of the future.

For more information on these competitions see:
http://www.steel-sci.org/education/competitions.shtm

2.10 Enhancing Teamwork in Group Projects through Pre-project Training Exercises

Author	Dr Colin Smith
Institution	University of Sheffield
Faculty / School	Engineering
Department	Civil and Structural Engineering
Programme(s)	M.Eng in Civil Engineering, M.Eng in Civil and Structural Engineering, M.Eng in Civil Engineering with a Modern Language, M.Eng in Civil Engineering with Architecture
Title of Module(s)	Stadium Design Project

Award(s)	M.Eng	Year of study	3
Module Credits	10	% project assessment	100

Assessment Outputs Group Presentation, Critical Session, Management of Meetings, Enterprise, Participation in Group Skills Workshop and Debrief:

Industrial/ Professional Participation Yes

Group Project: Yes Group Size: 8 Group Selection: Tutor

Synopsis of Case Study

Students are often expected to work effectively as teams in group projects without any formal guidance. This case study describes an approach where explicit team training was integrated closely with an existing engineering design group project. Three main aspects of the project are discussed: modification of the existing project structure to enhance the teamworking element, incorporation of an upfront team training session and incorporation of a final debriefing and reflection session. Student enthusiasm for this approach has been very positive.

Background

The ability to teamwork effectively is widely seen as an important skill in industry. Even before graduation, such a skill should assist students to gain more out of project work. Students may be introduced to teamworking in a variety of ways, for example through short stand alone teamworking courses, perhaps with an outward bound element. This case study presents an alternative approach that integrates the teaching of teamworking skills directly with an existing credit bearing engineering design project. This gives the teamworking training an immediate relevance, which is often a key issue in getting students to engage with the material.

An existing third year group design project, bearing 10 out of 120 credits for the year, was chosen as a suitable vehicle for this approach. The project had worked well in previous years, but had scope for restructuring to maximise the teamworking element, while retaining the original learning objectives. This case study describes how teamworking training and practice was built into the project as an integral component. A brief overview of the actual project is also given to set the context.

Project Development Rationale

The existing group project had, in previous years, run continuously through the first part of the Semester in parallel with conventional lecture courses. While this approach permitted students to get well immersed in the technicalities of the project, it did in many cases lead to students devoting too much of their time to it.

The timetable was subsequently revised to block the project into a concentrated intensive 2 week period on its own. As well as limiting the time spent on the project by students, this requires students to work efficiently as teams, and to manage their time wisely. There is no 'spare' time for inefficiencies in the project work, as the students are constantly under time pressure.

Rather than expect students to develop team skills indirectly as part of the process of working in a group, it was felt that they would get more from the exercise if they were given some initial teamworking training. Mistakes made in the training could be learnt from, enabling students to approach their project more confidently and see the direct benefit of the skills that they had learnt.

To give the project a clear high profile end, each team is required to make a presentation to industry participants. The project then finishes with a debriefing session covering both the technical and teamworking aspects of the work.

Project Content and Structure

The project revolves around the design of a new football stadium for a local football club, with the brief to redevelop the existing site. The entire project, including the team training element, lasts two weeks. Teams are given a wealth of background technical data and, within a day of starting, are required to interview the club architect, the club commercial director and tour the existing site. All these activities are run in parallel to promote teamworking. Following a formal mid-project progress meeting, students have to present their designs to the commercial director and architect in a formal meeting at the project end. The timing, arrangement and nature of the activities are set to require a significant amount of planning, co-ordination, leadership, and time management on the part of the students.

Teamworking training

At the start of the project, students are told that they will be undertaking an intensive piece of work with short deadlines and will require good teamworking to get through it successfully. This sets the scene for the training. To be useful, it was felt that a one and a half day teambuilding course was required, consisting of eight exercises interspersed with short lectures. The repetition of exercises allows mistakes to be made and learnt from, and new skills applied again. Students tend to repeat some mistakes even after 3 or 4 exercises, so it is important to have sufficient rehearsal and opportunities for self-evaluation to allow the principles to be appreciated and absorbed.

Suitable materials and exercises are available from a variety of sources, commercial and non- commercial. For this project, material inspired by TRANSEND* was used. It is not within the scope of this case study to provide details of all the team exercises, but the overall format is set out below:

- Eight team exercises are run over one and half days, with each exercise taking ~30-60 minutes. Each exercise builds on the previous one.
- We use the same teams (of 8) as for the main exercise. The aim of the exercises is as much to promote teambuilding in preparation for the main project as to teaching teamworking skills. Each team has a staff or postgraduate tutor.
- Each student takes a turn at leading and also a turn at observing. It may be necessary for the tutor to steer the more challenging team exercises to the students who are most likely to cope best with them.
- Each exercise is preceded by a short presentation (15-20 minutes) from an industry speaker on teamworking and related topics.
- Each exercise is followed by a detailed debrief (10-15 minutes) facilitated by the team tutor, including comments from the student observer for that exercise. This is followed up by an overall class debrief (5-10 minutes). Key points are written up on flip charts.

The debriefing is not only a vital component of the teamworking training, but also works well in providing a model format for the final end of project debrief. Other useful pointers are listed below:

- It is important to define the learning objectives of the teamworking activities in the context of the main project and its overall learning objectives. In the project described here, the main objectives include teamworking, communication, time management and planning, introduction to leadership, and problem solving. These objectives need to be set at a suitable level for the students. It may be necessary to edit or simplify some teamworking activities where they assume significant prior experience, or cover advanced topics.
- A mix of generic and engineering based exercises can be used. The latter are often more challenging for the students, as they tend to become engrossed in the engineering aspects to the detriment of the overall task.
- It is useful to use a venue with which students are unfamiliar, and that is perhaps slightly more formal, to give the training a different atmosphere to their conventional teaching.

- Organisation and timing are critical - everything must be planned to the minute. It is advisable to run a training session for tutors before the main event, and to carry out a dry run of some or all of the material. To work well, it is essential that the tutors are clear on their role and have the aptitude for the debriefing sessions. In particular, this may involve dealing with students who tend to be reticent and reluctant to participate.
- Due to the intense nature of the project and the training exercises, there is little contingency either for the students or the academics. It thus requires academics to ensure that everything is guaranteed to work first time!
- Finally, external assistance with many aspects of the training can be invaluable, perhaps from the University's Staff Development Department.

Final debrief

The final project debrief is considered to be a vital component of the project. Following the final presentations to the 'client', the class debrief (with students sitting in their team groups) is carried out in two parts:

Academic debrief

This allows staff and industry participants to feed back on the technical aspect of the design work.

Skills debrief

Teams are asked first to discuss what individual skills they felt they had picked up during the project. This can link into PDP (Personal Development Planning) issues. They are then asked to consider how they had worked and developed as a team during the main project. Finally, they are asked to consider how their team functioned in the context of Belbin's classifications. Prior to the project students are given some input on teamworking and asked to complete a Belbin questionnaire. The questionnaire results are held back until the debrief stage. Comparison of their pre-project responses to Belbin with post-project discussions on how things went in practice can lead to some interesting insights, in particular on how the way students operate in a team depends very much on the context.

The skills debriefing is run in a similar format to the teamworking training, setting the activities as mini team exercises, with tutors facilitating the discussions. At this final stage, there was some concern that students would be too fatigued to participate. However, this has proved not to be the case. They seem to enjoy the debrief as a way to wind down after the project - and the provision of some prizes at the end also assists!

Resources

The resource implications for a project such as this are significant over a short period, but not necessarily large when averaged out. The team training and final debriefing requires substantial staff time, with one member of staff per group for a total of 2 days. However, suitably skilled postgraduates or research assistants can also be used. The upside for staff is that tutoring on the training exercises is both enjoyable and a valuable opportunity to get to know the students better.

The financial outlay required will vary depending on the nature of the materials required for the teambuilding exercises. The ability to run the project as an intensive 2 week exercise is important to its success, but does require careful negotiation over timetabling.

Student Response

The project has run in this format for one year. Overall, the project received very positive student feedback and the team training was extremely well regarded. Based on the end of project debrief, students felt that they had improved a range of skills. The skills most improved (among a large list) were delivering presentations, time management, teamworking and problem solving. The development of presentation skills was an existing learning outcome of the project.

A more detailed survey is currently in progress to investigate how well what was learnt in this project has been carried over into group projects later in years 3 and 4. At present, students are briefly reminded at the start of subsequent projects of what they have learnt, what they did well and what proved more difficult It may be that there is a need to incorporate more in depth revision and recapping to reinforce the message. Anecdotal evidence to date would indicate that teamworking skills significantly improved during the group project, and that these skills have been carried forwards into later project work.

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* Acknowledgements to TRANSEND, and in particular Dr Dave Faraday and colleagues at the University of Surrey, for their help and advice. They have many years experience in running teamworking courses, which are scheduled as a precursor to a sandwich year in industry. The TRANSEND web site may be found at: http://transend.cpe.surrey.ac.uk

2.11 Introducing Business and Enterprise to Civil Engineering Students

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Programme(s)	MEng in Civil Engineering, MEng in Civil and Structural Engineering, MEng in Civil Engineering with a Modern Language
Title of Module(s)	Project Management Group Project

Award(s) Year(s) of study 4

Module Credits 20 % project assessment 100

Assessment Outputs Group Project Report (60%), 3 Assessed meetings (individual assessment, 30%), individual report on development of commercial enterprise (10%)

Industrial/ Professional Participation Yes

Group Project: Yes Group Size: 3-5 Group Selection: Tutor

Synopsis of Case Study

This group design project has been developed to introduce civil engineering students to the concepts and skills required in commercial organisations to allow informed decisions to be made on the economic feasibility of large infrastructure investments. The project introduces concepts of economic evaluation, project planning to optimise resources utilisation, the role of the capital markets and the importance of marketing and sales for many commercial projects. It was recognised that these concepts, and the skills required to apply them, are of little interest to many civil engineering students. It was therefore considered essential that in order to teach these business concepts and skills, an environment would have to be created with a strong engineering content. The environment that was used was a group design project in which students play the role of consultants hired by a large European stainless steel manufacturer to evaluate the economic viability of the construction of a new stainless steel cold rolling mill in Sheffield.

Background

In 1997 the Engineering Council produced a report “Standards and Routes to Registration – SARTOR”. This report outlined the new standards required in the education and training of engineers wishing to achieve chartered status in the UK. The new guidelines stated that the MEng. degree would now become the “expected” route for delivery of the academic education for Chartered Engineers. They also stated that MEng. graduates will need “an understanding of the construction industry, its role in wealth creation, the social and political context within which engineering is practised, the role of civil engineering in shaping the physical and social environment and its diverse contribution to the quality of life including the profitable management of industrial and commercial enterprises”. For the first time there is a stated requirement that students must receive some teaching in commercial awareness and business skills in civil engineering degree courses.

This new environment has created a number of challenges for all Civil Engineering departments. Departments now need to provide teaching in the curriculum that will develop commercial skills in a meaningful way, so as to enhance employability or comply with the requirements of accreditation. This area of teaching is often seen as particularly troublesome for some Departments given the limited personal experience of staff of working in commercial environments. Students also tend to select civil engineering courses because of their personal interest in the technical aspects of construction, not because of the management challenges found in the construction industry. Hence student interest in subjects that are not purely technical can be extremely limited. It was therefore decided that any teaching would have to occur in an environment with a strong civil engineering context if students were to successfully develop the desired commercial and business skills. A structured group design project was chosen to meet this requirement.

This case study describes the development of such a project. Teaching materials were created, with the aid of industrial collaborators, to encourage students to challenge existing ideas, generate new ones and logically evaluate them in an environment that would reward innovation as well as the acquisition of knowledge and performance of individual skills. The project presented students with an identified potential commercial opportunity, they then had to collect and interpret the available background data, evaluate its commercial potential and then propose a realistic implementation plan. This was thought to be the most effective method of developing commercial skills and awareness amongst the students, given the need to make the learning as relevant as possible to the tasks within the design process inherent in any Civil Engineering project.

Project Development Rationale

In developing the content of the project it was the intention to give students the opportunity to experience a number of different commercial aspects common to many civil engineering projects. The aim was for the students to be given the opportunity to:

- Evaluate the desirability of a proposed scheme, its economic potential and the financial risks involved.

- Organise the resources required to exploit the proposed scheme in terms of the financial, managerial and technical resources required.
- Show an appreciation of the importance of creating value for society by large-scale commercial investments.

The project was only loosely based on an existing case study example. This was deliberately done so that there was never seen to be a “correct” solution. This can be a problem when using an existing project in design work. There is a tendency for students and tutors to tend towards the “conventional” accepted solution, that is the solution the industrial collaborator originally selected. The project constraints were framed so that the project was barely economically viable. This format was thought to give the students groups more opportunity and incentive to develop novel, more economically viable solutions.

Project Structure

The project involves student teams examining the feasibility of constructing a stainless steel rolling mill in the UK. The students act as consultants contracted to examine the feasibility of constructing a new cold rolling stainless steel plant in Sheffield. The clients have requested that the plant be able to roll 80000 tonnes per annum of a particular product mix (austenic/ferritic, different thickness and surface finishes). The project is split into three stages: outline plant design, project planning and implementation, and economic evaluation including studying the stainless steel market to discover whether the production mix of the plant could be altered to optimise investment returns (see table 1). The aim of this structure is to introduce students to the more engineering based elements of the project early on, in order to engage their interest and to persuade them of its relevance to Civil Engineering. The focus on the economic evaluation is introduced in the later part of the project, when the students are familiar with the engineering aspects of their solution and aware of the potential avenues they could explore to optimise the engineering performance of the plant or the construction phase to enhance economic value for their clients. This structure also has the advantage of leading students from detailed plant design first, then to construction planning and costing, then to the more generic ideas and techniques of economic project evaluation, and finally to concepts of enhancing value by consideration of the commercial market place for rolled stainless steel products.

At the end of each of these three stages the students attend an assessed meeting at which they present their ideas and their analysis of those ideas to the project tutors. The students are given feedback on their performance. This progressive type of assessment is considered to be very helpful in guiding students as to the performance expected of them in terms of the level and depth of ideas and analysis. At the end of the project the groups put together a final feasibility study report. This is a written document in which each group reports on the activities in each of the three stages.

Phase 1	Project Briefing – Introduce client requirements Introduction to stainless steel manufacturing process and plant design 1st Assessed meeting – Presentation of outline designs of plant layout and manufacturing capacity, selection of optimum building and plant layout

Phase 2	Project planning techniques workshop (provided by industrial collaborator) Introduction to cost evaluation models 2nd Assessed meeting – Construction implementation, programme and costs of recommended building and plant layout.
Phase 3	Marketing of stainless steel workshop (provided by industrial collaborator) 3rd Assessed meeting – economic evaluation of recommended scheme, examination of options (e.g. product mix, new products and markets) to enhance profitability Submission of group based feasibility study report

Table 1 – Programme of student teaching and assessment activities.

Teaching Materials

The teaching materials used fall into two groups; the first group contains materials with information specific to this project. Some of the documents are data-based, others are based on real documents supplied by our industrial collaborators but abridged for student use. It is the intention to supply the student design teams with too much data so that one set of skills they have to develop is that of data selection, interpretation and, if suitable data has not been supplied, data acquisition from external sources. The second group of documents is more generic in nature in that they provide students with information on skills (mainly commercial) that they need to develop in order to be able to complete the project. These skills - e.g. project planning, resource allocation and optimisation, and economic evaluation techniques (net present value, internal rate of return, return on capital) - are introduced during 2-hour workshops using examples relating to the project. Students are then expected to use the documents produced as reference materials as they try to apply the economic evaluation concepts using their design as a source of data. Each design team is expected to construct their own economic model of the proposed scheme (usually using Excel) so that various construction, manufacturing and marketing options can be investigated and subjectively compared. Most Civil Engineering students encounter concepts such as net present value and internal rate of return only in the formal lecture environment, and so have little experience in applying these economic evaluation methods to real data. Only when students have the opportunity to apply these techniques to realistic data do they start to appreciate the importance of such commercial methods in the decision making process. The opportunity to manipulate the input data to their economic model - e.g. plant layout/performance, construction sequences and product mix - clearly demonstrates to engineering students the impact of what seem to be purely “engineering” decisions on the commercial viability of a project.

One last aspect that enhances this appreciation is that the initial design criteria (80000tpa capacity, the performance of the available plant and anticipated costs and sales income) mean that the project is on the limit of economic viability. This is very useful as it emphasises the fact that all projects have to compete for capital resources, either internally within a large organisation or against other investment opportunities available on the open market. Students learn that detailed feasibility studies, even for a well-engineered solution, may not suffice to ensure that a project runs. Equally, more able students are also able to appreciate and demonstrate that engineers can, given some innovative ideas, turn a barely viable scheme into a much more financially robust project by changing their design solution to enhance income or cut costs.

Student Response

This project has been running for two years in its present format. In general most student teams have proved able to provide an economically viable solution, with many teams (over 70%) providing enhanced solutions examining the potential of different products or product mixes, and reducing manufacturing or construction costs to significantly enhance the economic viability of their schemes. All teams are able to collate and interpret the large amounts of data supplied, learn new engineering skills - e.g. basic rolling plant design - and build an economic model of their scheme so that objective economic decisions can be made.

Given the innovative nature of this project, structured questionnaires were completed anonymously by students in order to examine student attainment of skills and knowledge specifically related to the business learning aspects of the project. This data indicated significant increases in student awareness of business and enterprise and the role of "added value" to large engineering projects. Complex commercial skills also improved, with over 80% of students claiming they now had the confidence to commercially evaluate an engineering scheme and two thirds stating that they now had sufficient skills and knowledge to formulate a business plan and present it to potential investors. These were significant improvements on the pre-project data.

Outcomes

This project has shown it is possible to successfully teach commercial skills and business awareness to Civil Engineering students. However it is vital that these skills are taught in an environment that is clearly relevant to the students' interests and motivation. It is also important that students are given the opportunity to continually use the taught commercial evaluation techniques with realistic data so that their relevance to the students is made very obvious. It must be remembered that to engineering students much economic analysis is analytically trivial, it is the importance of its application that needs to be demonstrated. If this is not done teaching commercial skills to engineers will be a thankless task.

2.12 An Innovative Design Class for First Year Mechanical Engineers

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Programme(s)	Mechanical Engineering
Title of Module(s)	16187: Design and Engineering Applications
Award(s)	B. Eng. , M.Eng Year(s) of study One
Module Credits	Three % project assessment 100%
Assessment Outputs	Group poster and oral presentation, group design portfolio

Industrial/ Professional Participation No

Group Project: Yes Group Size: 4 Group Selection: Tutor

Synopsis of Case Study

First year engineering students need support in the transition from school to university study. The new class "Design and Engineering Applications 1", which accounts for 25% of the credit load for first year Mechanical Engineers, seeks to provide this support while giving an introduction to engineering design. The class aims to illustrate the relevance of the students' engineering science classes to the design process, to build the students' confidence in their own abilities and motivate them to research and discover things for themselves. Largely taught in groups of four, the students are also encouraged to develop group-working and presentational skills.

Introduction

The Department of Mechanical Engineering at the University of Strathclyde, Glasgow, has introduced a new class for all first year students. Entitled, "Design and Engineering Applications 1", it replaces former taught credits in Engineering Materials, Mechanical Engineering Production and Engineering Applications. This class, which accounts for 25% of the students' credits in first year, is innovative in approach, and relies heavily on group work, problem based and student centred learning.

Ethos and Context

The transition from school to university is often a large step for students, who must adapt quickly to the new learning environment and develop a whole range of skills while adjusting to unfamiliar surroundings. The first year study programme at the Department of Mechanical Engineering at the University of Strathclyde is designed to support students in making this transition, with four main goals:

1. To establish firmly and reinforce the basic concepts of mathematics and engineering science, that will form the foundation for study and learning in later years
2. To allow for differences in background between students
3. To build confidence, enthusiasm and responsibility
4. To nurture, support and encourage the students in their studies

Design and Engineering Applications 1 is an integral component of the first year curriculum, and subscribes to the basic goals listed above. The specific aims of the class are to give an introduction to the concepts and processes of engineering design, and to illustrate the relevance of the engineering science curriculum to the design process. In addition, the class strives to build the students' confidence in their own abilities. The department is fortunate in having relatively high entry standards, and all the students have achieved good grades at school. This being the case, students are shown that their understanding of school level physics and maths is sufficient as a starting point for understanding the concepts of engineering design. They are encouraged to study and find things out for themselves, and to estimate, simplify and approximate. The class is largely taught and assessed in groups of four students, which develops team working and presentation skills.

Activities

The class, which currently numbers some 130 students, is divided into four teams, which cycle in sequence through four different activities, in blocks of either four or eight weeks throughout the year. The four activity blocks are as follows:

1. Design appreciation (8 weeks): Mechanical dissection of a motor car. Each student group selects and removes a component from the car. It is stripped and cleaned for analysis. The group's task is to describe the function, service conditions, materials and manufacturing of the component, and their interrelation, by the production of a poster and oral presentation. After initial removal and cleaning, each group spends approximately one hour discussing the component with staff, who give guidance on what analysis is appropriate and expected. The specific aim is for the group to

produce a convincing description of the factors that must be taken into consideration in the design process of their component. This should be quantitative, e.g. numerical estimates of forces, stresses, speeds, pressures, temperatures etc. should be produced. Specimens are selected for microstructural examination, to discover which materials and processing routes have been used in manufacture. The materials and processing choices are to be explained in the context of the service conditions expected, e.g. the magnitude and type of stresses, corrosion and temperature effects, wear resistance etc. The students are provided with initial input from staff, but must then research and read around the subject for themselves. After a few weeks, they produce a draft poster, which is discussed in detail with staff. At this time misunderstandings and mistakes can be ironed out, and areas that require deeper analysis can be identified. The posters are finally submitted at the end of the block, and oral presentations are made by each group to their peers and members of staff, with the opportunity for questions. This gives each group a view of issues that have been researched by other groups, which may not have been relevant to their component.

2. Design theory and practice (4 weeks): A series of exercises in group work, data gathering and communication, including an introduction to complex systems and their analysis. Examples of activities include group poster presentations of abstract ideas, literature searching on an engineering topic, analysis of the causes of a rail crash including technical failure and the human machine interface.

3. Design drawing and graphical communication (8 weeks): An introduction to the process of design including the use of sketching and drawing, presentation techniques, colour and data gathering. An individual design task based on a hand blender: this includes sourcing of components, ergonomics and aesthetics. A group design project on transportation including layout drawings, market research, advertisements and operating instructions.

4. Engineering applications laboratories (4 weeks): This fulfils the accreditation requirements for workshop appreciation training by giving each student practical experience of workshop processes (turning, drilling, milling), welding and metallographic preparation. The students attend five three hour labs and write up log books for each activity.

Teaching Learning and Assessment

The entire class is far from traditional in either teaching delivery or assessment. There are no formal lectures, and no examinations. The class (or part class) is occasionally addressed as a whole at the beginning of a set of activities, but the vast majority of staff input is through informal small group discussions. This has the great advantage that a relationship is built between staff and students based on support and shared learning. This can be challenging for staff, who act as partners in the learning process, and must be willing to admit to what they don't know. However, this is in itself a useful lesson, since real engineering problem solving often involves working from a starting point with less than perfect information.

All assessment is on the basis of “pass” or “not passed yet”, with the opportunity to re-work and re-submit posters, coursework etc. until they meet the required standard. An important element in this loop is the effective feedback by staff to students and groups of what is still required for satisfactory completion. This requires significant staff time and patience, coupled with a good relationship with the students.

The high level of group working necessitates some checks and balances to ensure that all group members have contributed equally to the group effort. This is achieved by confidential peer marking exercises, which are completed by students during the course. Peer marking sheets require each student to award a share of some arbitrary quantity of marks to each group member, including themselves, with some words of justification. This method quickly reveals “passengers”, and also shows up possible personality conflicts within groups. In either case, single members, or each member of the group can be given a brief individual oral examination to explore the problem, and remedial coursework can be set if required.

Resources and Logistics

The resource implications of such a class are significant. The intensive discussions with small groups of students, and the variety of activities that are involved, require substantial staff time if they are to have the maximum benefit for the students. As an example, in the mechanical dissection class four members of academic staff are on hand for six hours per week over 20 teaching weeks, during which time each group of four students will have individual discussions with at least two staff for in excess of two hours. However, given the goals of the class, and the high level of technical engagement which has been achieved by first year engineering students, this level of resource is deemed justified.

The monetary costs of the class are very small. For instance, the total cost of the cars and consumable materials for the dissection class work out at less than £5 per student. Some initial set-up costs were incurred, e.g. the purchase of a set of tools and overalls for the car labs, and a new digital camera for the metallurgical microscope.

The logistics and organisation of a class of this nature should not be under estimated. Highly complex timetabling issues have to be addressed, which involve staff from two departments and activities taking place in six locations. The schedule of events has evolved over the four years that the class has been run, so that sufficient capacity is built into the timetable to allow groups or individuals to catch up in the event of difficulties or illness. Simplicity in timetabling is vital so that each student and group know exactly where they should be and what they are doing at all times. Clear deadlines for completion of each element are detailed in advance. All timetables and scheduling information are given on the departmental web pages for ease of reference.

Further Issues

Provision of space for a class of this nature is important. We are fortunate in having a spacious lab with level access to the street, in which the car dissection takes place. In addition, suitable teaching rooms with facilities for poster production have to be made available, and equipped if necessary.

One criticism levelled at the class in the planning stage was that students would be unable to cope with the engineering and materials parts of the car dissection class, because they had not yet covered the relevant subject matter in lectures. This has not been our experience. On the contrary, we are frequently amazed by the depth of information the students present in their posters, most of which they have never been formally “taught”. It is easy to under-estimate the ability of students to find out and understand things for themselves, and it is our belief that things learned in this way are understood at a much deeper level than in traditional lecture and exam classes, where doing enough to pass the exam can become the overriding goal.

The students have generally enjoyed the class, particularly the informal atmosphere. Group-work forges relationships that in many cases last for years and help the students settle in. Many of our students come from the Glasgow area, but many do not, so being part of a group helps with integration. The pass rate in the class is about 98% due to the fact that students have the opportunity to iterate their submissions until satisfactory standards have been reached.

Conclusion

The new design class has proved a success with students and staff, with high levels of student engagement and technical output. The opportunity to show the relevance of engineering science to the design process, and enhance confidence and self learning for the students, are major benefits.

Section 3 Project Design

This section of the guide:

- Describes the benefits of using a project based approach to learning
- Considers different types of projects that can be used in engineering
- Explores the characteristics of individual and group projects
- Explores the characteristics of open and closed projects
- Explores the characteristics of incremental and innovative projects
- Considers the benefits of multi-disciplinary projects
- Considers the benefits of industry-based projects

3.1 What can projects offer?

There are many good reasons for using projects within engineering programmes. Well-designed and well-run projects can offer a number of benefits for students. In particular, project work can be useful for:

- providing a rounded, integrated and satisfying learning experience when used alongside other approaches to learning and teaching
- enhancing student motivation by virtue of being 'hands-on' and grounded in real-life engineering problems
- promoting greater understanding of the value – and limitations – of theoretical knowledge by virtue of its application to practical problems
- developing a range of specific engineering knowledge and skills, sometimes including experience in industrial settings
- developing a range of generic skills and abilities that will be of value in work and other life situations
- strengthening retention of knowledge and skills which have been acquired through experience and practical activity
- enhancing students' employment prospects because of the practical skills and experience they will have acquired
- enabling students to 'hit the ground running' in industry through their experience of linking theory to practice(1)

Project work can take many forms. In order to maximise the opportunities afforded by learning through projects it is important to identify the type of project that is best suited to the topic area and the intended learning outcomes. The rest of this section explores the characteristics and requirements of several different project types:

- Individual/group

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(1) For a useful overview of the benefits of a project-based approach to engineering education see Schachterle, L and Vinther, O (1996) "The role of projects in engineering education", *European Journal of Engineering Education 21,* 115-120

- Open/closed
- Incremental/innovative
- Multi-disciplinary
- Industry-based

3.2 Individual/group projects

Module learning outcomes will normally make it clear whether the project is to be individual or group-based. Some of the guidance the tutor will need to provide for students will vary depending on whether the project is individual or group-based.

3.2.1 Individual projects

With individual projects issues of equity and parity can arise. There is sometimes a perception amongst students that there are hard and easy projects. Lecturers might usefully employ a robust, transparent system of filtering and approval that ensures a minimum threshold level of difficulty. The issue then becomes one of emphasis – one project is more difficult and demanding in this area whilst another is more challenging in that. Any such system of approval needs to be explicit and shared with students from the outset.

This kind of approval system could be integrated into the project definition procedures operated by a number of departments, wherein the aims, objectives, scope and methodology of the project are described by students at an initial stage, and approval is sought before proceeding.

The value and limits of contact and communication between students doing individual projects need to be defined. Students will frequently seek to share information, ideas and problems with other students working on similar or related projects. This kind of discussion can properly be encouraged as it is the type of communication that takes place naturally between engineers in the real world.

However, lecturers need to stress that whilst discussion on technical and other issues is acceptable, the final design, product or report must be the work of the individual. Staff should ensure that students understand the nature and seriousness of plagiarism.

For individual projects the lecturer, in the role of project supervisor, should encourage the student to accept responsibility for managing the project and progressing it to a conclusion within the timescales agreed. To facilitate successful project management regular progress reviews between the lecturer and the student are important, monitoring progress against task and checking off milestones and deliverables. Both parties should keep records of these meetings.

Section 7 offers a fuller account of the planning and organisation skills essential to effective project work.

3.2.2 Group projects

When projects are to operate on a group basis the lecturer will need to consider a range of practical issues including:

- Group size – this will vary according to cohort numbers, the tasks involved and resources available, but as a general guide groups of 3 or 4 work well whilst larger groups can become unmanageable
- Group composition – there are a number of possible approaches to determining which students will work together, each of which has its merits and limitations (see Section 9 for a more detailed discussion)
- Team building – some input may be beneficial at the outset, since a team which operates cohesively and efficiently will enhance the learning experience, whilst a malfunctioning team can seriously impair it
- Team dynamics – the lecturer has an important role to play in encouraging the development of an efficient, harmonious team in which individuals communicate well, support each other and pursue both individual and group deliverables
- Team roles – there are different ways of ascribing roles to individual team members; for example, they could be allocated by the lecturer on a random basis, or on the basis of perceived strengths, or the group could be asked to decide for themselves
- Team meetings – regular meetings are important, especially at the outset and again towards the end when submission deadlines are looming; students need to keep records of attendance, progress against previously agreed actions, new action points for the next period and specific issues for the attention of the lecturer
- Group tutoring – as well as team meetings between students, provision for regular review and monitoring meetings between the lecturer and the group is important for tracking progress, checking records, dealing with problems and providing such additional support and advice as is needed[(2)]

Case Study 10 (Colin Smith, University of Sheffield) offers an example of a project, used across a range of third year MEng programmes in civil and structural engineering, designed specifically to foster skills in teamworking. Students report very favourably on a team training component delivered at the start of the project:

> *"Overall, the project received very positive student feedback and the team training was extremely well regarded…students felt that they had improved a range of skills…[including] delivering presentations, time management, teamworking and problem solving."*

Further guidance on the lecturer's role in supporting individual and group projects can be found in Section 9.

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(2) Some guidelines for lecturers using collaborative learning methods can be found in Chapter 7 of Wankat, P and Oreovicz, F (1993) *Teaching Engineering*, New York: McGraw Hill

3.3 Open/closed projects

The brief for a project will differ enormously depending upon the type of project envisaged and its intended learning outcomes. One important dimension is whether the project can be characterised as open or closed.

3.3.1 Closed projects

Closed projects are those that ask students to work within a defined knowledge base and/or to adopt a specific methodology. These projects usually require a detailed brief with facts, figures, formulae and data acquisition information. Examples of this type of project would be:

- the design of a component structure to meet given loading or performance criteria
- the design of a machine or mechanism to perform to a given torque, velocity or life criteria

From the point of view of the tutor, closed projects are often the most straightforward to implement and monitor. Tutors can prepare model answers or typical solutions that provide effective and easily delivered feedback at the end of the project.

Traditionally, closed projects have been used in the first year of a degree programme, based on the rationale that this is when students are more likely to need and benefit from tightly constrained project briefs with clearly identified deliverables. They are suitable for promoting a pre-determined set of skills but less useful for encouraging students to develop new ideas, innovative approaches or creative skills.

3.3.2 Open projects

By contrast, open projects are less constrained in nature. The student is set a ‘problem’ and the immediate task is to convert this into a ‘project’. The student may be required to assemble his/her own project strategy from a very general description of the problem. The necessary background information is for the student to discover through independent research. An example of this type of project might be:

- ‘A company is suffering intermittent breakages on a production line conveyor: investigate the cause and determine the most appropriate strategy for managing or eliminating the problem.’

Open projects are particularly useful for developing key skills or specialised knowledge. The student is required to display independent learning skills, using lecturers and others as a resource to access information and guidance. Appropriate preparation and support structures are important if students are to gain the most from such projects.

Open projects have often been used in the later stages of degree programmes, though increasingly are used at all stages within programmes embracing problem-based learning.(3)

Case Study 6 (Peter Willmot, Loughborough University) describes an open project, delivered in conjunction with industry as part of a mechanical engineering programme, in which the students' ability to work up a limited brief into a fully-fledged, deliverable project is integral to the process:

> *"We prefer that students are not provided with a detailed written brief as the first task is for the team to get to grips with the problem and generate their own detailed specification…working in teams of four, students are encouraged to research the field of study, present a number of well considered ideas or schemes, and develop the most promising of them into a design scheme together with a full evaluation of its merits."*

3.4 Incremental/innovative projects

Another dimension by which projects may be characterised is the extent to which they are incremental or innovative. An incremental project builds on the knowledge base of previous projects in the particular area of study. Many undergraduate projects will fall into this category.

Innovative projects may be 'new' for two reasons: either they are new concepts being introduced or they are new to the module type and have migrated from other areas.

3.4.1 Incremental projects

If a project is similar in structure or desired outcomes to work previously undertaken by comparable student groups, project design and implementation is comparatively straightforward. The provisos on this are that:

- feedback from project deliverers or students involved in precursor projects has been generally positive
- best practice from earlier projects has been identified and carried forward to future projects
- shortcomings in earlier projects have been addressed and the resulting improvements have informed the revised project brief

In short, the implication of this is that precursor projects need to be identified, and their strengths and limitations assessed, in order to inform the aims of the revised project and the manner in which it is to be implemented. Capturing this information in the module specification will promote the effective evolution of projects, and should enable the module team to implement a successful project. Ideally, information on precursor projects should be accessible within and across cognate departments and faculties.

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(3) A discussion of the trend toward greater use of problem-based projects in engineering can be found in Cawley, P (1997) "A problem-based module in mechanical engineering", in Boud, D and Feletti, G, *The Challenge of Problem-based Learning* (2nd Edition), London: Kogan Page

3.4.2 Innovative projects

When introducing an innovative project, it is helpful if there are opportunities for 'piloting' the new project. The principal reason for piloting is to test and improve the initial design of the project.

Two approaches to piloting novel projects are:

- Pilot in part - the key elements of the project are implemented as part of another project within the same subject area, but delivered before full implementation of the new project (essentially, adopting an incremental approach to an innovative project)
- Pilot as a whole - the whole project is run in full, but with a limited number of participants, and with particular attention paid to monitoring and feedback as part of the change control mechanism

Innovative projects can, on occasions, be implemented without being piloted either in part or in full. Sometimes this occurs when the project carries low weighting within a module, rendering the pilot an ineffective use of resources, or where there are time pressures to implement the project quickly. Whilst these reasons may be entirely valid, the lack of opportunity for reflective practice may result in the project being less successful than it could/should be.

One means of minimising this risk is for feedback to be gleaned from colleagues and students on the initial design. For example, the lecturer designing the project can generate a team discussion by 'walking the value-chain' with colleagues.

The aim here is for the team to think through the project as designed in a structured, systematic way, identifying possible difficulties and corrective strategies. The discussion will also aim to identify similarities and differences to existing models. Key points from the exercise are recorded and form the basis for review and revision of the project brief prior to implementation.

Innovative projects can and do have real spin-offs for staff and students. Case Study 2 (Patrick Littlehales, Aston University) describes an ambitious extra-curricular project, offered in a Mechanical Engineering Department, that involves student teams based on three continents working collaboratively in the design of a racing car. The project team reports significant benefits to students on a number of fronts:

> *"Student understanding of the technology progressed considerably and they also learnt much about the physical process of design and project management...the exposure to modern tools and techniques via a global project requiring such levels of focussed information management and communication provided a real-world learning experience rarely seen in academia. All the participating students and staff benefited tremendously."*

3.5 Multi-disciplinary projects

Multi-disciplinary project work involves students from different engineering disciplines, and/or from other subject or professional areas, coming together to work on a defined project brief. Working in multi-disciplinary teams simulates the real world environment, and helps undergraduate engineers develop a broad range of important transferable skills such as team working, communication and project planning.

Planning and implementing a successful multi-disciplinary project has much in common with all project based learning activities, but it also requires the lecturer to consider some issues in particular detail, and to take into account some factors unique to this type of work. This section of the guide aims to highlight and provide guidance on specific areas relevant to multi-disciplinary project work.(4)

3.5.1 Working across disciplines

The considerable scope that exists for multi-disciplinary project work in engineering stems from the fact that there are natural connections and linkages between various engineering disciplines (civil, mechanical, electrical, chemical and so on). There are also potential links between the engineering disciplines and a number of other academic disciplines and professional areas.
It is this inter-connectedness that leads to the formation of multidisciplinary teams in many sectors of industry, and which therefore needs to be considered in devising integrative project work.

Some examples may help to illustrate this point. Thus, mechanical engineering is very often aligned with materials and/or manufacturing in the design and manufacture of engineering equipment and products. Civil, on the other hand, aligns more closely with architecture, building environment engineering and again materials in the design of buildings and infrastructure projects. Electrical, which may include electronic engineering, can align with mechanical in such areas as drive systems and control, measurement and instrumentation but also aligns well with non-engineering disciplines such as computing and science in general.

Other non-engineering disciplines, which could form the basis of integrative projects, include mathematics and business/management. Multi-disciplinary projects including the latter are particularly appropriate for training engineering students to consider important practical matters such as costs of production, business plans and marketing aspects.

Case Study 11 (Simon Tait, University of Sheffield) provides an example of one approach to integrative project work, in which final year MEng students are required to develop and demonstrate business and enterprise skills through participation in a civil

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(4) For an example of how a project-based approach can be used over the course of a whole programme as a vehicle to integrate disparate subject material see Jarvis, P and Quick, N (1995) "Innovation in engineering education: the PAMS project", *Studies in Higher Education* 20, 173-185

engineering project. Case Study 4 (Norton Farrow and Colin Fryer, University of Derby), drawn from a Department of Design, Technology and the Built Environment, describes a project-based learning strategy that aims to promote student appreciation of how different strands of engineering mesh together in real-life construction activities.

3.5.2 Types of multi-disciplinary projects

Multi-disciplinary projects in engineering can vary in scope and complexity. For example, it may be decided that in the early stages of undergraduate study both individual and group project activities will be tightly defined, with clearly set deliverables. Integrative project work at this stage, therefore, might be fairly limited in nature, with students from a single discipline working individually, or in groups, on an activity primarily within their own discipline but with a multi-disciplinary element to it.

By contrast, in the final stages of degree programmes projects might embrace wider disciplinary content, thus broadening the students' horizons into other subject areas. Integrative group projects may require students to work in teams from different disciplines. This reflects the real world more closely and, although projects of this nature are more difficult to plan and implement for the lecturer(s), the learning experience for the students can be significantly enhanced.

3.5.3 Collaboration between staff

It is important for staff to work collaboratively to plan and administer multi-disciplinary projects. Whilst it is advisable for one lecturer to carry overall responsibility for coordination of the project, each member of the multi-disciplinary team will have a unique contribution to make. This may require the lead role in terms of learning and teaching to rotate at different points of the project.
Where a broad range of disciplines and multi-professional groupings are brought together, it needs to be recognised that each will bring its own traditions and cultures. An appreciation of the distinctive character and requirements of the various disciplines/professions should be acknowledged and reflected in staff input.

Consideration will also need to be given to the number and timings of joint staff meetings, bearing in mind the timetabling constraints impacting on each member of the team. A formal meeting of all participating staff should be held as early as possible, where actions can be agreed, tasks delegated and dates for future meeting booked. Potential difficulties caused by timetable clashes for students following different programmes also need to be resolved at this stage.(5)

3.5.4 Technical specification and resources

A key task for supervisors of project based learning activities, and particularly important for multi-disciplinary projects, is to define the project in the form of a detailed written technical specification. Particular consideration should be given to the breakdown

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(5) For further discussion of the implications for staff of running multi-disciplinary projects see Chapter 2 of Toohey, S (1999) *Designing Courses for Higher Education*, Buckingham: SRHE/Open University Press

between departments as regards responsibility for specifying, supervising and monitoring resources for each activity.

It is useful if the written technical specification contains the following sections:

- General outline/scope of the project – to include learning outcomes, relevance of the project to students from each discipline and the responsibilities of staff from participating departments
- Design requirements – broken down into separate lists for each of the engineering and non-engineering disciplines/professional groupings involved
- Availability of resources – related to design requirements, with an indication as to which team member/department is responsible for supplying the resource
- Budget costs – an accurate initial assessment of likely costs is particularly important for multi-disciplinary projects as costs can accumulate quickly in different departments; the pro forma below provides a useful means whereby the costs for individual items of equipment or activities can be calculated and assigned to the various participating departments
- Sources of funding – this might include support from industry, research project funds, earmarked departmental and/or University funds for specific initiatives or general teaching funds from participating departments; the critical factor is to ensure at the outset that adequate funds are available
- Control of expenditure – this is particularly important for multi-disciplinary projects where it is likely that there may be more than one supervisor for the project and work may be carried out in more than one department; careful recording and monitoring is essential; students should be made fully aware of budget constraints, required to maintain expenditure within budget limits, asked to obtain estimates and approval before incurring expenses and instructed to maintain full records of expenditure; it is advisable for regular budget/expenditure reviews to take place between supervisors and students.

Example Budget Costs Form

Project title		Students/ departments	
Session/ semester		Supervisors/ departments	

Component/ Activity Code	Description	Cost Item	Budget cost	Department responsible	Actual cost
		Materials			
		Consumables			
		Bought-in parts			
		Manufacturing			
		Equipment buy/hire			
		Travel/ subsistence			
		Other			
		Emergency			
		Total costs			

3.5.5 Communication

Regular meetings and other forms of interaction hold the key to good communication and effective teamwork, especially in projects that involve students from various disciplines. All team members should be encouraged to take part in discussions and decision-making on every aspect of the project.

It may be best to avoid asking individual students to work in isolation in areas of subject specialism, as it is often activity at the interfaces between disciplines that can dictate the rate of progress and the achievement of deliverables for the project as a whole. Involvement in shared decision-making processes will draw team members together at these intersections.

3.5.6 Monitoring progress

Because integrative projects require students to work across discipline/professional boundaries, and/or in teams drawn from different subject backgrounds on closely interrelated tasks, the lecturer needs to monitor progress particularly closely. Students should be encouraged to recognise the importance of regular communication within the team through scheduled team meetings, email exchanges and the like.

Additionally, project teams should be asked to draw up a project plan that incorporates interim milestones, deliverables, key target dates and a project budget. This plan should be reviewed on a regular basis, perhaps monthly, within student team meetings and at supervision sessions with the lecturer.

3.6 Industry-based projects

Arguably there is no better environment to assess the ability of a student of engineering than within the industry itself. No doubt this was at the heart of some of the recommendations made by the Dearing Report into Higher Education(6), subsequently endorsed by the government of the day, regarding the undergraduate experience of the world of work. The following recommendations are of particular interest:

> Recommendation 18: “We recommend that all institutions should, over the medium term, identify opportunities to increase the extent to which programmes help students to become familiar with work, and help them reflect on such experience.”
>
> Recommendation 19: “We recommend that the government, with immediate effect, works with representative employer and professional organisations to encourage employers to offer more work experience opportunities for students.”

The intention, clearly, is that all institutions should aim to increase the level of student learning centred on relevant vocational areas. In engineering, where the links between academic discipline and profession are particularly explicit, both SARTOR 3(7) and the QAA benchmark statement(8) have re-emphasised the value of providing students with opportunities to work with industry.

One type of learning activity that can achieve this goal is the industry-based project. It is useful, therefore, to identify the potential benefits that can accrue to students, universities and industrial partners from industry-based projects, and to explore a number of issues linked to the planning and implementation of such projects.

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(6) National Committee of Inquiry into Higher Education (1997) *Higher Education in the Learning Society* (Dearing Report), London: HMSO

(7) Engineering Council UK (1997) *SARTOR* (3rd Edition), London: Engineering Council

(8) Quality Assurance Agency for Higher Education (2000) *Subject Benchmark Statements: Engineering*, Gloucester: QAA

3.6.1 Benefits

For the student:

- working on company initiatives provides the opportunity to develop awareness of commercial and industrial imperatives
- the chance to work on 'real life' engineering problems that the company wants solved, rather than hypothetical problems created for academic purposes only
- experience of project work that is likely to be multi-disciplinary, reflecting the complex interlocking nature of the world of work
- the opportunity to meet with and impress prospective employers

For the company:

- students may deliver new ideas or solve long-standing problems at comparatively little cost to the industry
- the opportunity to observe and assess the work of prospective employees
- the chance to raise the company profile within universities, thereby increasing recruitment possibilities
- developmental experiences for company staff

For the department:

- direct contact with industry, enabling staff to stay up-to-date and deliver programmes grounded in modern practices, new technological developments etc
- research opportunities arising out of links with local industry
- the possibility of industrial sponsorship, eg for new equipment, student scholarships etc
- strong graduate recruitment performance through careful nurturing of industry contacts

Case Study 6 (Peter Willmot, Loughborough University) offers an example of a long-running industry-based project in mechanical engineering, the benefits of which for all involved are clearly appreciated by the programme team:

> *"Companies report frequent positive outcomes and generally welcome the opportunity to work with prospective placement students and graduate recruits. The students benefit by developing an understanding of working in industry, gain context to their degree programme and improving their process and communication skills…students are seen to noticeably develop in confidence and professional stature through this work…universities involved in engineering can only gain from such liaisons."*

3.6.2 Planning issues

In setting up projects with industry, a number of practical issues need to be taken into account by the programme team. These include the need to:

- invest considerable time and effort in identifying suitable partners, forging the necessary links and developing shared understandings about the purpose and mutual benefits of the scheme – this initial investment should promote continuity and avoid the need to recruit new partners too frequently
- engage in early discussions to achieve the right balance between the ambitions and aspirations of the company, the time constraints on students and the academic requirements of the institution
- clarify the arrangements in place for furnishing students with the necessary supplies and material support – eg access to telephone/fax/PC, stationery, secretarial support, purchasing procedures, budgets etc
- confirm the respective roles and responsibilities of the university and the company in terms of supervising and assessing the student's work – industrial involvement in student assessment seems right in principle, but careful moderation is needed since company personnel have no necessary expertise in academic assessment
- provide written agreements covering issues such as: contractual status, confidentiality, intellectual property rights, health and safety, equal opportunities, etc
- clarify funding arrangements – often participating companies will provide sponsorship of the project in one form or another, including cash contributions, equipment, personnel time or prizes
- ensure that contingency plans are in place in the event that the company withdraws its support for a project part way through – this may be a particular danger affecting projects with smaller, local companies who are more vulnerable to short-term staffing or cash-flow problems

Again, Case Study 6 (Peter Willmot, Loughborough University) reflects the importance of getting all of this right in the planning and development stage. The scheme takes the form of a Teaching Contract – essentially a consortium of companies committed to offering industry-based project work to students – and includes written documentation setting out the expectations and responsibilities of all parties. The need for clarity from the outset is paramount:

"An information pack is sent to interested companies but face-to-face discussions are undoubtedly the most effective recruiting tool…when a company joins the scheme, it agrees to the conditions and a modus operandi set out in an agreement document…considerable prior planning is involved…the companies prepare an initial statement of their project ideas…tutors visit their companies during the summer vacation to discuss the suitability of the ideas and offer advice on how the task should be set."

3.7 Summary

Project based learning takes many forms and offers many potential benefits to students on engineering programmes. The potential advantages of project work can best be realised by careful matching of project type to topic and intended learning outcomes.

The different types of projects that can be made available to engineering students include:

- individual/group projects
- open/closed projects
- incremental/innovative projects
- multi-disciplinary projects
- industry-based projects

Each project type holds particular advantages, as well as presenting some potential pitfalls. Each demands that the tutor pays attention to a range of practical and technical issues at the planning stage to ensure successful implementation.

3.8 Additional references

- Badiru, A (1996) *Project Management for Research: A Guide for Engineering and Science*, London: Chapman and Hall
- Howard, K and Sharp, J (1996) *The Management of a Student Research Project* (2nd Edition), Aldershot: Gower
- Lewis, V and Habeshaw, S (1997) *53 Interesting Ways of Supervising Student Projects, Dissertations and Theses*, Bristol: Technical and Educational Services
- Luck, M (1999) *Your Student Research Project*, Aldershot: Gower
- *Project Squared,* http://www.ncteam.ac.uk/projects/fdtl/fdtl3/project_descriptions/4-99.htm
- Rogerson, S (1989) *Project Skills Handbook,* Bromley: Chartwell-Bratt

Williams, R and Beaujean, D (1993) "Developing engineering competence through the medium of syndicate studies", *Engineering Science and Education Journal 19,* 35-39

Section 4 Learning Outcomes

This section of the guide:

- Explains what learning outcomes are.
- Indicates why they are important
- Offers a way of categorising learning outcomes
- Explores their relevance to curriculum design
- Shows how learning outcomes can be developed
- Describes how they can be achieved through project based learning
- Provides illustrative examples of learning outcomes in engineering

In determining whether to use project based learning, the starting point must be to decide if learning through projects supports the learning outcomes of the programme. This will frequently be the case in engineering, where many existing programmes already make effective use of projects to enable students to demonstrate learning achievement.

Programme learning outcomes need to take account of the requirements and expectations set by professional bodies and other relevant sources. External reference points include:

- The Quality Assurance Agency (QAA)
- SARTOR 3 (Standards and Routes to Registration, 3rd edition)
- The Engineering Professors Council (EPC)

The QAA engineering benchmark statement(1), published in 2000, establishes general expectations about the standards for Honours Degrees in engineering. In March 2003 the benchmark statement was extended to include MEng degrees(2). Both documents make particular reference to the value of project work as a means of developing many of the skills required by engineers.

See http://www.qaa.ac.uk/crntwork/benchmark/engineering.pdf and http://www.qaa.ac.uk/crntwork/benchmark/mast/MEngintro_textonly.htm

Project based learning also features in the standards and expectations for engineering programmes described in SARTOR 3(3). Here there are some general statements about the technical/non-technical content which should be present in all engineering courses. Project based learning has an important role to play in programme design in meeting the requirements of SARTOR 3.

The EPC Output Standard Project(4) has developed output standards for engineering graduates. Taking the form of 26 generic ability statements, the standards define what every graduate from a UK engineering degree can reasonably be expected to be able do on completion of their degree. Course providers need to interpret the generic “ability to" (A2) statements within their own disciplines, and then devise benchmark statements to describe the threshold level of achievement required. The EPC view their A2 statements as compatible with the QAA benchmark statement.

4.1 What are learning outcomes?

Learning outcomes are essentially about student achievement. They describe what it is critical for the learner to achieve, i.e. what the learner will know, understand and be able to do as a result of learning.

Learning outcomes need to be specified at programme and module level. Programme learning outcomes will be formulated in a more general way than those for modules, which need to be more specific.

Students must be able to satisfy the overall programme learning outcomes through meeting the learning outcomes of a set of modules. In modular programmes offering a high degree of flexibility in choice of modules, it is essential that the various combinations of modules available to students will enable them to meet programme learning outcomes.

4.1.1 Programme learning outcomes

These refer to the range of achievements learners will be expected to demonstrate on successful completion of the programme. Typically, programme learning outcomes will cover a range of achievements including knowledge acquisition, understanding, intellectual skills, generic or transferable skills, practical and subject-specific skills, etc. The learner must achieve the programme learning outcomes in order to pass the programme.

Appropriate programme learning outcomes will be defined by reference to a number of factors including:

- The purpose, nature and level of the programme
- The characteristics of the intended student group (see Section 4 of this guide)
- The requirements of professional bodies in engineering
- The QAA engineering subject benchmark statement

4.1.2 Module learning outcomes

These describe the intended learning to be acquired from specific modules. The student must demonstrate achievement of all the learning outcomes in order to pass the module and receive credit. Module learning outcomes should derive from, and contribute to fulfilment of, programme learning outcomes.

Case Study 3 (Melvyn Dodridge, University of Derby) provides an illustrative example, drawn from the third year of two BSc (Hons) programmes in the Division of Electronics, Media Technology and Mathematics, of mapping individual module learning outcomes from the generic programme learning outcomes. The mapping matrix is reproduced below. Full descriptions of the module learning outcomes can be found elsewhere in the case study.

Programme Generic Learning Outcomes	Skills Map	Module Learning Outcomes			
		LO 1	LO 2	LO 3	LO 4
(A) Knowledge and Understanding (Electrical and Electronic Engineering)					
7. Basic mathematics to underpin electrical and electronic engineering (E)					
8. Basic principles used in analogue/digital electronic and electrical power circuits and systems (E)					
9. Technology supporting electronic and power circuits and systems					
10. Application of advanced and new technologies employed in the electrical and electronic industries	✓	✓	✓	✓	
11. Management of business relevant to the commerce and industry (E)					
12. Engineering practice and regulatory frameworks in the electrical and electronic industries (E)	✓	✓		✓	
(A) Knowledge and Understanding (Music Technology & Audio Syst. Design)					
7. Basic mathematics to underpin electronic and audio engineering (E)					
8. Basic Principles used in analogue/digital electronic circuits and systems in the communication and audio industries (E)					
9. Technology supporting audio circuits and systems					
10. Application of advanced and new technologies employed in the music industry	✓	✓	✓	✓	
11. Business and management relevant to the music industry (E)					
12. Engineering practice and regulatory frameworks applicable to the electronic, communication and music industries (E)	✓	✓		✓	
(B) Intellectual Skills (both programmes)					
6. Apply engineering principles and analytical thinking to problems and determine effective solutions (E)	✓		✓	✓	
7. Select and develop appropriate technology (E)	✓	✓	✓		
8. Employ computer software for simulation and analysis of circuits and systems (E)					
9. Design, develop and operate systems, products and processes and evaluate options (E)	✓	✓	✓	✓	
10. Exercise professional judgement with respect to commercial and technical risks (E)	✓	✓	✓	✓	
(C) Practical & Subject-specific Skills (both programmes)					
6. Use laboratory scientific equipment and instrumentation competently and safely in conducting experimental laboratory work and making measurements (E)					
7. Demonstrate the use of computer key board skills (E)					
8. Demonstrate the ability to configure computer programmes (E)					
9. Demonstrate the process of prototype build, manufacture and testing (E)	✓		✓	✓	
10. Plan and execute project work including the preparation of descriptive and interpretative technical reports (E)	✓	✓	✓	✓	
(D) Transferable Skills (both programmes)					
7. Apply numerical skills in the collection, recording, interpreting and presentation of data in a variety of forms (E)	✓			✓	
8. Utilise information and communication technology (ITC) in the preparation, process and presentation of information (E)	✓				✓
9. Demonstrate creativity in problem solving and design (E)	✓		✓	✓	
10. Utilise communication skills effectively in a variety of forms and for different audiences (E)	✓			✓	✓
11. Manage own roles, responsibilities and time in achieving objectives, learning performance, new and changing situations and contexts (E)	✓				✓
12. Assume responsibility as an individual or as a member of a team in a variety of situations (E)	✓				✓

4.2 Why are learning outcomes important?

There are a number of reasons for using learning outcomes:

- They help to inform student choice – students will be able to match the programme/modules they choose with what it is they are seeking to achieve
- They increase public transparency – learning outcomes which clearly describe what successful students will have achieved are useful to employers and other external stakeholders
- They inform curriculum design and delivery – by focusing attention on achievement rather than input, learning outcomes encourage an approach to curriculum planning in which learning, teaching and assessment methods are appropriate to the outcomes sought
- They help define academic standards – in identifying precisely the learning to be achieved, learning outcomes play a major part in assuring the standards of university awards
- They are an important feature of current national developments – within HE the specification of learning outcomes for programmes and modules is an integral part of QAA Programme Specifications(5), Subject Benchmark Statements and the Code of Practice for the Assurance of Academic Quality and Standards in Higher Education(6)
- They are increasingly used by accrediting bodies in evaluating output standards

4.3 Categorising learning outcomes in engineering

There are many different ways of grouping learning outcomes. The model adopted in this guide is that used in the engineering benchmark statement. The document describes the skills, attributes and qualities required by engineers under the following headings:

- Knowledge and understanding
- Intellectual abilities
- Practical skills
- General transferable skills

More detailed descriptors of the types of skills, qualities and attributes grouped under each category are provided below.

4.3.1 Knowledge and understanding

- Key facts, concepts, principles and techniques
- Theories relevant to specialist engineering disciplines
- Grasp of science, mathematics and technology as relevant to discipline

- Business and management techniques as relevant to engineering

4.3.2 Intellectual abilities

- Problem solving
- Data gathering, analysis and interpretation
- Abilities in design and experimentation
- Evaluative skills in relation to design, processes and products

4.3.3 Practical skills

- Use of tools, techniques, equipment and relevant software
- Laboratory and workshop skills
- Ability to develop, promote and apply safe systems of work

4.3.4 General transferable skills

- Communication and presentation
- Use of ICT
- Time and resource management
- Multidisciplinary teamwork
- Creativity and innovative thinking

Broadly following this model, the following pages feature the programme learning outcomes from a BEng in Mechanical Engineering, together with a set of module learning outcomes for a second year module in Application of Engineering Design drawn from that programme.

Programme Learning Outcomes (BEng in Mechanical Engineering)

a) Knowledge and understanding
On successful completion of this programme, graduates should be able to demonstrate knowledge and understanding of:

- *Relevant mathematical methods and the principles of engineering science as applied to mechanical engineering systems*
- *A number of specialist engineering science disciplines*
- *The role of IT in providing support for mechanical engineers*
- *Engineering design principles and techniques*
- *Characteristics of engineering materials*
- *Management and business practices appropriate to engineering industry*
- *The professional and ethical responsibilities of engineers and engineering designers*

b) Subject-specific cognitive skills
On successful completion of this programme, students should be able to:

- *Interpret numerical data and apply mathematical methods to the analysis of engineering design problems*
- *Use the principles of engineering science in developing solutions to practical mechanical engineering problems*
- *Analyse systems, processes and components*
- *Solve mechanical engineering problems*
- *Select and apply appropriate IT tools to a variety of engineering problems*
- *Create new engineering components and processes through the synthesis of ideas from a range of sources*

c) Subject-specific practical skills
On successful completion of this programme, students should be able to:

- *Apply numerical modelling methods and/or appropriate computational techniques to engineering problems*
- *Use appropriate computer software and laboratory equipment*
- *Research for information*
- *Prepare engineering drawings, computer graphics and technical reports and give technically competent oral presentations*
- *Demonstrate basic organisational and project management skills*

d) Key transferable skills
On successful completion of this programme, students should be able to:

- *Demonstrate a high level of numeracy*
- *Apply creative and structured approaches to problem solving*
- *Communicate effectively through written, graphical, interpersonal and*

presentation skills

- *Design and implement basic computer based information systems*
- *Work independently and/or work in a team*
- *Organise and manage time and resources effectively*

Source: Loughborough University, Faculty of Engineering

Module learning outcomes (Application of Engineering Design)

a) Knowledge and understanding
On completion of this module, students should be able to demonstrate knowledge and understanding of:

- *Essential elements of the design process*
- *Essential design methodologies*
- *The professional responsibilities of an engineer associated with working in and contributing to a team*
- *The characteristics of engineering materials and components*

b) Cognitive
On completion of this module, students should be able to:

- *Design a system, component or process using routine design techniques*
- *Generate ideas to design new systems, components or processes*
- *Apply scientific principles in solving unfamiliar engineering problems*
- *Model and analyse routine engineering systems*
- *Appreciate commercial risk*
- *Understand the capabilities and limitations of computer based methods for engineering problem solving*

c) Practical
On completion of this module, students should be able to:

- *Use computer based engineering tools to solve problems, gather data and display the results*
- *Search for information related to a design solution and present it for discussion*
- *Participate in the planning and execution of practical or simulation tests of a design solution and present a report of its findings*

d) Transferable

- *On completion of this module, students should be able to:*
- *Select and analyse appropriate scientific evidence*
- *Effectively communicate, making extensive use of common IT tools including email and the web*
- *Assess information and make value judgments about it*
- *Make acceptable presentations of technical and business information in a variety of ways*
- *Work as part of a team*

Source: Loughborough University, Faculty of Engineering

4.4 Learning outcomes and curriculum design

Learning outcomes are central to curriculum design. Basic questions in curriculum planning are:

- What is to be learnt?
- How is it to be learnt?
- How is it to be assessed?

Programme learning outcomes therefore provide the starting point in programme planning and module design. Programme and module learning outcomes will have implications for the learning and teaching methods employed, and for how learning is assessed.

How learning and teaching is delivered will be influenced by what it is students are expected to learn. Different teaching methods are better suited to promoting different forms of learning and developing different types of skills. For example, lectures may be useful for the transmission of factual information but less so for the development of analytical skills; product performance testing is a suitable method for developing evaluative skills, but is unlikely to promote the development of creative design skills.

Similarly, the choice of assessment methods should be driven by the nature of the learning outcomes to be tested. For example, multiple choice questionnaires may well be suitable for testing knowledge acquisition, but not for assessing practical skills; laboratory reports may be effective in gauging the ability to analyse information and develop reasoned arguments, but not for judging teamwork or communication skills.

The matrix below shows one way of mapping the relationship between learning outcomes and assessment. The matrix is adapted from an individual design project module which forms part of the final year of a CEng accredited undergraduate programme.

	LO1	*LO2*	*LO3*	*LO4*	*LO5*
Self critique of design proposal	✓		✓		
Progress report	✓	✓	✓	✓	✓
Poster display/ demonstration		✓	✓		✓
Design report	✓	✓	✓	✓	✓
Critique and questioning				✓	✓

Learning Outcomes
LO1 *Produce a specification for a product or process*
LO2 *Apply design methodology, models and tools to identify alternative solutions and to select appropriately*
LO3 *Perform critical analysis and evaluation of the selected product or process*
LO4 *Validate and verify the selected product or process*
LO5 *Reflect on personal performance*

Source: Universities of Brighton and Central Lancashire
(ECP Output Standards Project)

4.5 Learning outcomes and project based learning

As noted in the introduction, how project based learning is used can take many different forms. It can vary in terms of scope, level and nature, as well as reflecting the specialist engineering discipline(s) within which it is applied.

Project based learning is also well suited to developing and assessing a wide range of generic skills and attributes relevant to the engineering graduate. These could include:

- Higher order cognitive skills – critical analysis, synthesis, evaluation
- Application of theoretical knowledge to practical situations
- Problem solving skills
- Abilities in self-directed study and autonomous learning
- Groupwork, teamwork and interpersonal skills
- Time management skills
- Decision making skills
- Practical workshop and laboratory skills
- Business and enterprise skills
- Presentation skills
- Information management skills

As this list suggests, project based learning is a powerful vehicle for moving students beyond ‘surface learning’ – concerned primarily with the gathering and memorising of facts and other forms of information – to ‘deep learning’, characterised by learners understanding material, seeking meaning, relating concepts to experience, critically evaluating ideas, and so on[(7)].

Projects are often well suited to applied topics, where different solutions may have equal validity. Students will be required to discover ‘new’ information for themselves, and to use that knowledge in finding solutions and answers. A project based approach is likely to promote deeper understanding of the new knowledge acquired, and to enable that knowledge and understanding to be retained rather than readily forgotten.

Project based learning can be used in different ways within a programme:

- As part of a single module to support learning in relation to specific outcomes
- As the learning and teaching approach for a whole module, covering all the module outcomes
- To support learning across a number of modules, meeting one or more learning outcomes from each module
- As the major means of learning and meeting the full range of programme outcomes

In whatever way it is used, learning acquired by students from project work in engineering will often touch on a great many programme learning outcomes. For the purposes of making assessment both valid and manageable it is important to focus on the key learning outcomes attached to the project. Be clear about what learning achievements you want students to demonstrate by virtue of completing the project.

Case Study 5 (Warren Houghton, University of Exeter), describing a final year group project used across several MEng programmes in the Engineering Department, highlights the potential of project work to cover a wide range of specific learning outcomes in support of the more general learning outcomes identified for the programme. The table below shows how this looks in practice.

Programme ILOs (from Programme Specification)	Project ILOs
On successfully completing the programme, a graduate will be able to demonstrate: A Subject knowledge and understanding of: 1. mathematical and computational methods and their use for modelling, analysis, design and communication in engineering. 2. a broad base of scientific principles underpinning electronic, mechanical and civil engineering. 3. the characteristics and uses of a broad range of engineering materials and components. 4. a broad range of principles and design methods relating to the chosen engineering discipline in general, with knowledge and understanding in several specialist areas at the forefront of the discipline. 5. management and business practices, including finance, law, marketing, personnel and quality. 6. ethical and social issues related to engineering and professional responsibilities. B Intellectual (thinking) skills – able to: 1. demonstrate an analytical, systematic and creative approach to problem solving 2. select and apply appropriate mathematical methods, scientific principles and computer based methods for the modelling and analysis of engineering problems, and apply them creatively and realistically in practical situations. 3. create a complete design, product or service to meet a customer need, starting from negotiation of specifications, to a professional standard, showing creativity and justifying all decisions	1 Subject Specific Skills At the end of this module the students should: a) demonstrate knowledge and understanding in the subject area of the project, at the forefront of the chosen discipline. b) have used formal project planning methods to plan and manage the progress of a substantial (400 hours work) engineering group project 2 Core Academic Skills At the end of this module the students should: *as appropriate to the project chosen:* c) have demonstrated an analytical, systematic and creative approach to problem solving d) have selected and applied appropriate mathematical methods, scientific principles or computer based methods for the modelling and analysis of an engineering problem and applied them creatively and realistically in a practical application. e) have created a complete design, product or service to meet a customer need, starting from negotiation of specifications, to a professional standard, showing creativity and justifying all decisions. f) have taken a holistic approach to design and problem solving (cost, life cycle, sustainability issues, etc.) g) have assessed and managed all relevant risks h) have taken personal responsibility for acting in a professional and ethical manner i) have selected and used appropriate ICT based tools for analysis, design and communication of designs. j) have selected and used laboratory instrumentation appropriately and correctly k) have constructed prototypes or experimental apparatus to design specifications l) have worked safely in laboratory, workshop

4. take a holistic approach to design and problem solving. 5. assess and manage a wide range of risks (e.g.: commercial, safety, environmental etc.). 6. take personal responsibility for acting in a professional and ethical manner. C Practical skills – able to: 1. select and use appropriate ICT based tools for analysis, design and communication of designs. 2. select and use laboratory instrumentation appropriately and correctly 3. construct prototype products, systems, experimental apparatus etc. 4. work safely in laboratory, workshop environments etc., and promote safe practice. D Personal and key skills – able to: 1. communicate effectively using the full range of currently available methods. 2. manage resources and time. 3. work in a team, which may be multi-disciplinary, adopting any required role within that team, including leadership. 4. evaluate the strengths and weaknesses of other team members and help them to contribute effectively 5. learn independently, identifying own personal development needs and goals, reflecting on own performance and manage own personal development 6. obtain and process information from a wide range of sources, analyse it critically and apply this information in engineering applications 7. sort, manipulate and present data in a way that facilitates effective analysis and decision making	environments etc., and promoted safe practice 3 Personal and Key skills At the end of this module the students should: m) have acquired extensive experience of working in a team from a major (400-hour) group project n) have adopted different roles within a team including leadership o) have demonstrated an ability to work constructively and supportively with others, taking and giving constructive feedback, identifying the strengths and weaknesses of others and helping them to contribute to a team effort p) have taken part in formal, professional style, project management meetings, in roles including those of chair and secretary q) have developed written communication skills to the extent of producing substantial formal reports of various types and length which conform to specified formats and communicate the outcomes of 600 hours of work effectively and accurately. r) have contributed to formal team presentations of a professional standard s) have managed resources and time with little need for advice t) have learnt independently, acquiring skills at the forefront of current knowledge unaided, identifying own personal development needs and goals, reflecting on own performance and managing own personal development. u) have obtained and processed information from a wide range of sources, which may have been conflicting, analysed it critically and applied this information in an a practical engineering application. v) have sorted, manipulated and presented data in a way that facilitated effective analysis and decision making.

4.6 Project based learning in engineering

Within engineering, project based learning is likely to be an effective means of teaching and assessing a range of relevant skills and qualities. The engineering benchmark statement specifically identifies extended project work as an important tool for the development of many of the skills needed by the graduate engineer. These include:

- Planning and management of work over an extended period of time
- Meeting deadlines and working within other externally defined constraints
- Tackling work which lacks a well-defined outcome or has a wide range of

possible answers
- Utilising practical applications of theoretical learning in real-life situations
- Thinking about different aspects of engineering – design, materials, manufacturing – as parts of an integrated process
- Presenting and interpreting technical information in various ways
- Working across discipline boundaries, often as part of a team, drawing on engineering, science, business, computer science etc as required
- Applying knowledge and skills in industry or other workplace settings, considering technological, environmental and commercial issues

The kinds of tasks that engineering students might undertake as part of a learning project could include:
- Design, build and test
- Technical evaluation of performance and upgrading of products/processes
- Reverse engineering
- Experimental laboratory testing and simulation
- Simulated public enquiry
- Review/survey of technical literature

4.7 Formulating learning outcomes

A number of taxonomies of learning have been developed that can help in devising learning outcomes that reflect the full range of skills and attributes that are to be developed and assessed. A taxonomy is a means of classifying things systematically – in this case, of classifying different levels of learning.

A widely used taxonomy in HE is Bloom's taxonomy of the cognitive domain[8]. Bloom identified six levels of learning. The most basic level of learning is factual knowledge, the highest order of learning is evaluating information.

In terms of writing learning outcomes, the taxonomy can guide you in thinking about the level of learning achievement(s) you are seeking. As the table below shows, each level of learning suggests a number of words to define a learning outcome at that level:

Level	Key question	Likely words
Knowledge	What do you know?	define/repeat/name/state/recall
Comprehension	How can you convey understanding?	explain/discuss/express/identify
Application	How can you apply knowledge?	demonstrate/apply/use/operate
Analysis	How can you analyse what you know?	test/calculate/categorise/infer

Synthesis	How can you synthesise what you know?	design/construct/create/propose
Evaluation	How can you evaluate what you know?	judge/appraise/evaluate/assess

The following list shows a set of learning outcomes, covering each cognitive level, drawn from a workshop-based design and build module in Mechanical Engineering.

1. *List the health and safety codes applicable to workshop practice*
2. *Discuss a number of different project management methods*
3. *Apply Newton's Laws to the design of an electrically powered mechanism*
4. *Test a working prototype*
5. *Design and create new components*
6. *Evaluate commercial risks attached to large-scale development*

Source: Loughborough University, Faculty of Engineering

4.8 Summary

Learning outcomes describe the essential learning that students must acquire. Programme learning outcomes reflect the learning achievements that students must evidence in order to successfully complete the programme. Module learning outcomes reflect the learning required to pass the module.

Learning outcomes will usually involve a combination of:

- Knowledge and understanding
- Intellectual abilities
- Practical, subject-specific skills
- Generic or transferable skills

Learning outcomes should always inform:

- The way the curriculum is designed
- The learning and teaching methods employed
- The types of assessment used

Project based learning is well suited to developing a wide range of learning outcomes. In the engineering context, it is particularly suitable for developing many of the specific skills and more generic attributes required of the graduate engineer. These skills and attributes reflect the standards described variously by SARTOR 3, the EPC and QAA.

4.9 Endnotes

(1) Quality Assurance Agency for Higher Education (2000) *Subject Benchmark Statements: Engineering*, Gloucester: QAA

(2) Quality Assurance Agency for Higher Education (2003) *Annex to Academic Standards – Engineering: MEng degrees*, Gloucester: QAA

(3) Engineering Council UK (1997) *SARTOR (3rd Edition),* London: Engineering Council

(4) Engineering Professors Council (2000) *The EPC Engineering Graduate Output Standard: Interim Report of the EPC Output Standards Project*, Coventry: EPC

(5) Quality Assurance Agency for Higher Education (2000) *Guidelines for Preparing Programme Specifications*, Gloucester: QAA

(6) Quality Assurance Agency for Higher Education (2000) *Code of Practice for the Assurance of Academic Quality and Standards in Higher Education: Section 6 Assessment of Students and Section 7 Programme Approval, Monitoring and Review*, Gloucester: QAA

(7) For an interesting discussion of deep and surface learning see Biggs, J (2003) *Teaching for Quality Learning at University (2nd Edition),* Buckingham: SRHE/Open University Press

(8) For a brief overview of Bloom's taxonomy and its application see D'Andrea, V (2003) "Organising teaching and learning: outcomes-based planning", in Fry, H et al *A Handbook for Teaching and Learning in Higher Education: Enhancing Academic Practice (2nd Edition),* London: Kogan Page

4.10 Additional references

- Biggs, J B (2002) *Aligning Teaching and Assessment to Curriculum Objectives,* LTSN Generic Centre at http://www.ltsn.ac.uk
- Carter, R (1985) "A taxonomy of objectives for professional education", *Studies in Higher Education 10,* 135-49
- Engineering Professors Council (2002) *Assessment of Complex Outcomes: Report of the Assessment Working Group,* London: EPC
- Jackson, N et al (2003) *Guide for Busy Academics: Using Learning Outcomes to Design a Course and Assess Learning,* LTSN Generic Centre at http://www.ltsn.ac.uk
- Moon, J (2002) The Module and Programme Development Handbook: A Practical Guide to Linking Levels, Outcomes and Assessment, London: Kogan Page

Section 5 Learners

This section of the guide:

- Explains how student characteristics can affect the learning process and learners' achievements
- Identifies a range of personal and social variables that can influence learner characteristics
- Identifies four key characteristics that individual learners bring to learning situations and explores their implications for the learning process.
- Provides examples of how lecturers can take account of the different characteristics and needs of students
- Offers a checklist of things to consider in seeking to ensure that project learning in engineering is responsive to student diversity

Learning and teaching, especially through projects, is a complex, dynamic process. The characteristics of individual learners, and of the student group as a whole, will impact on the learning experience. What learners bring with them interacts with the learning activities on offer in many ways, exercising a subtle yet powerful influence on the outcomes of the learning process.

5.1 Student characteristics

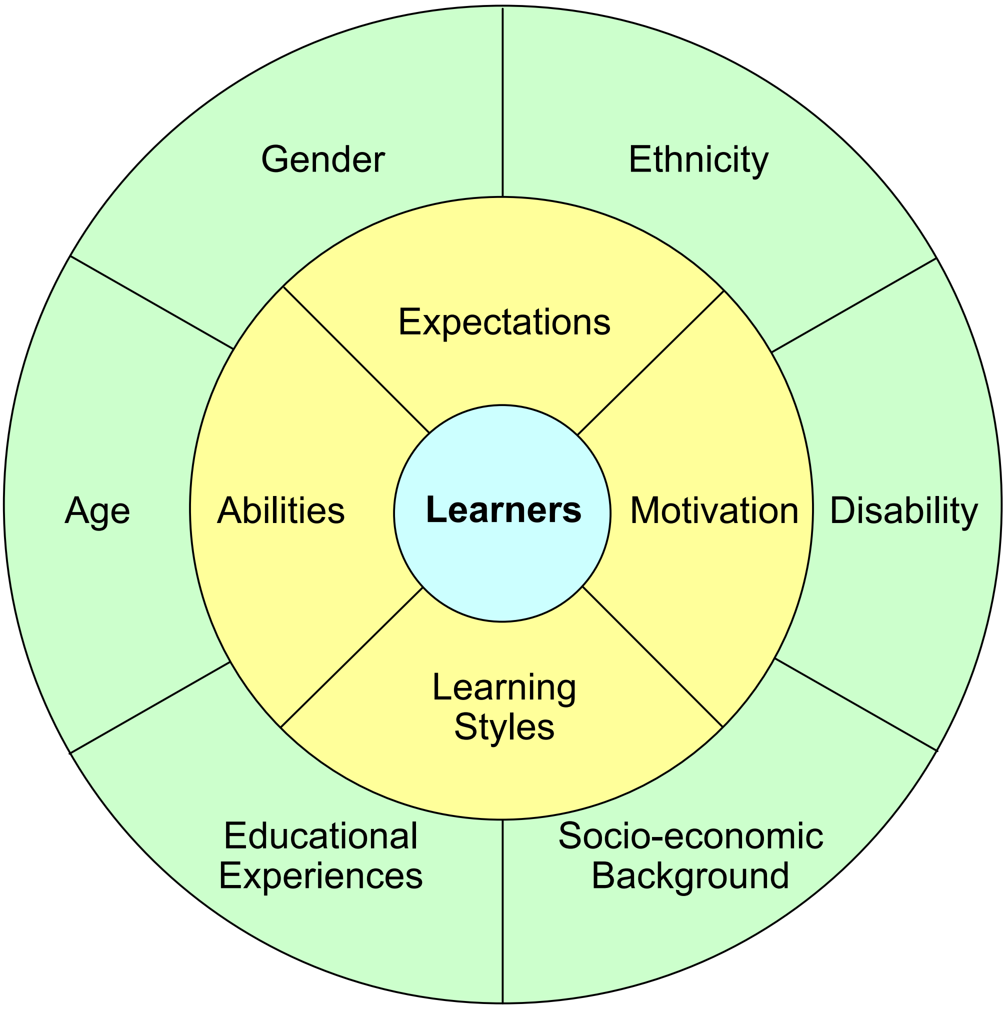
Significant characteristics that students bring to the learning situation include:

- Expectations about learning and teaching – their views and beliefs about what formal learning involves, the role of lecturers/students, etc
- Motivation – willingness to engage with the learning process and what they hope to get out of it
- Abilities – subject-based knowledge and skills, and also generic skills (eg communication, problem solving, teamworking, time management)
- Learning styles – individual preferences to learn in particular ways

These elements can help or hinder students' engagement with the learning process. Different learning, teaching and assessment methods will impact differentially on students depending on their expectations, motivation, abilities and preferred learning style.

The characteristics of individual students are, in turn, influenced by a range of personal and social variables including previous educational experiences, socio-economic background, ethnicity, gender, age and disability.

The interrelationship between individual learners, their personal characteristics and educational experience and social factors can be shown in diagrammatic form.



An important consideration in any learning and teaching context is how the teacher responds positively to the diverse characteristics and learning needs of students in ways that maximise the quality of the learning experience for every learner.

These issues are not peculiar to project based learning, but may be more prominent in this form of learning and place additional demands on lecturers. For project work in engineering to be successful, the teacher will need to consider, as far as is possible, the characteristics of their student group and their potential impact on the learning experience.

It is important to note that students' characteristics and needs may change as they progress through their time at university, partly influenced by the nature of the HE experience and its impact on them. This may make the task of running projects with first year students very different to working with finalists, some of whom at least will have been much changed by their time at university. The general point – that individual students will present a diverse range of characteristics and needs as learners – will still of course hold true.

In the remainder of this section, each of the four key elements – expectations, motivation, abilities, learning styles – is considered in turn, with reference to its implications for student learning and some pointers on how to address the issues positively. A final sub-section presents some key questions connected to curriculum planning and delivery in relation to issues of diversity in project based learning, and offers some ideas for responding to the particular needs that students may bring.

5.2 Expectations

Most students will arrive in HE with views about what learning involves, how it should be delivered and what their role is as learners. These views will be important determinants of how they respond to the learning experiences on offer.

For example, some students will believe that 'real' learning is about the transmission of knowledge by 'experts' and its assimilation by learners. Thus, the role of the lecturer is that of provider of facts, theories etc, and the role of student is as passive recipient. Didactic teaching methods (i.e. based on teacher input) and assessment through formal examinations are the obvious corollaries of this view of the learning process. Such students may have experienced a large proportion of their education in this mode and achieved high levels of success. Alternative approaches – such as the introduction of project based learning incorporating teamwork, self-directed study and elements of peer assessment – may well be treated with a degree of concern, particularly if project work is not introduced for the first time until a relatively late stage of the degree programme.

For other students, learning through projects may be part of their educational or other life experience. The extent to which they enjoyed the process, the amount and quality of support they received along the way and the success they achieved in it, will directly influence their initial attitude to this type of learning activity.

Numerous other examples could be given, perhaps two will suffice: mature students returning to formal education after a long break may find current approaches markedly different from their previous experiences; some international students may find wide variations between UK educational practices and the traditions within their own countries.

5.2.1 Implications

The lecturer's role is to enable all students to participate successfully in project work. To achieve this it is important to allay any concerns or anxieties they may bring with them about project based learning. This can be achieved in a number of ways, including:

- providing examples of previous project work by successful engineering students, through access to project reports, designs and working models or direct inputs from/discussions with former students
- regular review and feedback during the project, allowing students the opportunity to raise and resolve any areas of concern
- introducing learning through projects of different types, scope and complexity at various stages within engineering programmes of study

5.3 Motivation

Students coming to HE possess different types and levels of motivation. In terms of their desire to participate in the learning process, student motivation can be characterised as:

- predominantly extrinsic – tied in very much with external rewards such as good assessment results, approval of parents/significant others, maximising future career prospects etc. These students tend to adopt what is known as a 'strategic approach' to learning. They are driven by the need/desire to perform well in summative assessments. This can result in a surface approach to learning and a reluctance to engage with deep learning if it is perceived as unnecessary to achieve the minimum acceptable outcome.
- predominantly intrinsic – grounded in an interest in and commitment to the process of learning itself. It is not that these students are unconcerned with assessment results, but that they are driven more by the desire to maximise learning and personal development. They are more likely to engage with deep learning, and will find it difficult to adopt an instrumental approach to learning that sees satisfying the minimum assessment criteria as sufficient.(1)

These are theoretical characterisations, of course, and in reality many students will combine elements of extrinsic and intrinsic motivational factors. Nevertheless, an understanding of each individual's key drivers is important to enable the teacher to enhance student motivation. Factors influencing the motivation that students bring with them could include age, educational background and previous experience of projects.

Motivation may well vary at different stages of a degree. Students who are stimulated by the university experience may move from the extrinsic to the intrinsic during the course of the programme and this, of course, should be encouraged. A positive experience in project work can act as a powerful motivational driver. The rewards it can offer include not only high marks, but also enjoyment of the process, a sense of satisfaction at a challenging piece of work done well and a recognition that valuable learning has been acquired. The opposite, of course, is also true – a student who has a poor or badly supported experience is likely to be less motivated in the future.

A small number of students appear to lack any motivation at all. These 'amotivated' learners(2) are engaging in learning without any real identification with either the process or what they hope to get out of it. Again, recognising such students is important in order that lecturers can offer additional support and encouragement, and can take action to avoid negative attitudes impacting adversely on other students.

5.3.1 Implications

Project based learning is suitable for students regardless of the nature or intensity of their motivation. What may be required is a range of strategies to foster or enhance motivation in learners with different motivational drivers. These strategies could include:

- clarity about the rationale and purpose of learning through projects within engineering modules/programmes – students need to understand that some key learning outcomes (eg development of teamwork and problem-solving skills) rely on particular learning, teaching and assessment methods

- confirmation of the relevance of project based activity, stressing that many of the skills and abilities developed through this form of learning will be directly applicable to future 'real life' situations including many working environments
- emphasis on the student-led nature of project based learning – unlike other forms of learning (eg lecturing) students will only achieve their desired outcomes (be they high grades or maximum personal growth) by high levels of active participation in the project work
- creating a conducive learning environment including, for example, attention to appropriate space, computer access, laboratory materials, tutor support, and an ethos characterised by inclusivity
- the use of competitive project work, pitching one team against another, which can provide tremendous motivation, provided that care is taken to ensure that the less successful are not embarrassed or belittled in any way
- focusing project work on themes and topics likely to excite the imagination of engineering students – for example, projects about motor vehicles and cycles are more likely to be more attractive than those about static structural problems; an example of this is provided in Case Study 2 (Patrick Littlehales, Aston University), describing an extra-curricular project drawn from a Mechanical Engineering department, where the nature of the project work in itself generated unusually high levels of student commitment:

> *"Within the Global Design initiative (GDi), three student teams based in UK, Singapore and USA had to design a radical concept, formula racing car within 5 days. Each international team worked for an eight hour period, at the end of this period there was a hand over to the next team. GDi was designed so that the time zone differences meant that together the three teams worked around the clock. To ensure effective communication and transfer between international teams the project was facilitated using an interactive web based learning environment developed by the author…..[student] confidence and motivation grew exponentially during the week. This was evident from the early starts and enthusiasm towards the conclusion of the design."*

- devising project titles likely to be of immediate and obvious interest to students – an example, drawn from Loughborough University, saw an enormous increase in student interest when a project entitled 'The analysis of buckling in thin walled cylinders' was renamed 'Crushing soft drinks cans'
- structuring and sequencing project work so that the elements most likely to be appealing to students come first – for example, Case Study 11 (Simon Tait, University of Sheffield), drawn from the final year of the MEng programme in a Civil and Structural Engineering department, which describes how a project designed to develop business and enterprise skills in engineering students begins with a strong emphasis on the civil engineering component of the project in order to establish motivation and relevance; as the author notes:

"The aim of this structure is to introduce students to the more engineering based elements of the project early on, in order to engage their interest and to persuade them of its relevance to Civil Engineering. The focus on the economic evaluation is introduced in the later part of the project, when the students are familiar with the engineering aspects of their solution and aware of the potential avenues they could explore to optimise the engineering performance of the plant or the construction phase to enhance economic value for their clients."

5.4 Abilities

The increasingly diverse nature of the HE student population means that in any learning situation lecturers are likely to be faced with a broad range of abilities and skills. It is important that they know as much as possible about the abilities of their students to be able to respond most effectively to their learning needs.

Information about the knowledge and skills that students bring with them can be gleaned from a number of sources, including:

- student records – giving details of past educational experiences, on-course performance to date, additional needs etc
- colleagues – other lecturers who have already taught the student will have knowledge/information/insights not usually found in formal records
- students – themselves often a rich source of information about their own abilities, strengths and weaknesses, which can be gleaned through individual tutorials, group discussions, questionnaires
- personal development planning (PDP) – increasingly important in HE, and a requirement for all HE awards by 2005-06, PDP is a structured and supported process designed to involve students in review, reflection and planning for their own development needs[3]

Ability is an important factor in team selection for group projects. While stronger students can help and encourage the less confident, the presence of weaker members in a group can cause anxiety for the leaders who may feel they are not achieving their maximum potential. On the other hand, a team composed entirely of poor students is likely to achieve very little. Team selection is discussed in more detail in Section 9.

5.4.1 Implications

When embarking on project based learning, it is worth spending some time exploring the existing knowledge, abilities and skills of the students. This will enable the lecturer – and the students – to identify what strengths they are likely to bring to project work, and any areas of potential difficulty. Strategies for harnessing and developing students' strengths could include:

- provision of additional input/support in specific skill areas relevant to engineering project work (e.g. data analysis, time management)
- careful planning to ensure that the project activity relates to previous or current learning experiences in engineering or other disciplines
- making sure the project is pitched at a level that offers all students the

prospect of successful achievement

5.5 Learning styles

People tend to learn in different ways. Most of us have preferred learning styles that influence how successfully we interact with different forms of learning experience. A widely used inventory of learning styles, developed by Honey and Mumford[(4)], suggests that there are four broad learner types: activists, reflectors, theorists and pragmatists. The key characteristics of each group are summarised below.

5.5.1 Activists

- engage enthusiastically with new experiences/challenges
- respond to immediate problems/crises
- generate new ideas without reference to structures or feasibility
- enjoy teamwork/interactive/problem oriented learning experiences
- become bored with detailed planning/practise/implementation
- do not respond well to solitary/passive learning activities

5.5.2 Reflectors

- consider problems from many angles
- collect and analyse all available data thoroughly
- think carefully about consequences before acting
- enjoy highly structured learning experiences
- tend to postpone decision/action in favour of further investigation
- do not respond well to time limited learning activities

5.5.3 Theorists

- think problems through in a logical, step-by-step way
- assimilate disparate facts into coherent theories
- adopt a detached, analytical approach to tasks
- enjoy complex, intellectually stretching learning experiences
- struggle with ambiguity, uncertainty, subjective judgements
- do not respond well to open-ended learning activities

5.5.4 Pragmatists

- engage in practical testing of theories/techniques to see if they work
- seek out new ideas and experiment with their applications
- regard problems as challenges to be solved as quickly as possible
- enjoy learning experiences rooted in real life situations
- become impatient with discussions or obstacles to implementation

- do not respond well to theoretical/conceptual learning activities

In essence, learning styles can be seen as attitudes and behaviours that determine how we prefer to learn. No one style is most effective: different learning situations require different learning styles. The most successful learners are likely to be those who can employ whichever learning style(s) is best suited to the task.[5]

5.5.5 Implications

The lecturer's responsibility is to recognise that students will have different preferred learning styles, and to understand the significance of this for their participation in learning through projects in engineering.

There are a number of ways in which an awareness of different learning styles could help shape the nature of the project exercise, including:

- planning to ensure that the project offers the opportunity for different types of learning suited to different learning styles (eg generating hypotheses, data gathering and analysis, construction of theoretical explanations, active experimentation)
- formulation of assessment criteria that reward these different facets of learning
- building in opportunities for students to learn from each other's strengths and ways of learning

A carefully designed project, then, should enable all learners to participate and achieve success irrespective of their preferred learning styles. Well-constructed projects can offer:

- to activists, the opportunity to engage with new ideas and experiences as part of a team, with a 'here and now' focus
- to reflectors, the opportunity to investigate, assemble and analyse information within a structured learning framework
- to theorists, the opportunity to apply models and concepts help understand complex problems and situations
- to pragmatists, the opportunity to test out ideas and techniques by applying them in 'real life' contexts

Case Study 4 (Norton Farrow and Colin Fryer, University of Derby) offers an example of how a scenario-based approach to project work, used across a number of modules at different levels in a department of Design, Technology and the Built Environment, provides students with an integrated learning experience that would be suited to a range of learning styles. An extract from the study gives some idea of the range of activities in which students are required to engage, and the different approaches to learning that this will demand of them:

"The project-based assignments integrate the subject areas within a programme and illustrate realistic construction problems. In developing projects around the scenarios the following core themes were considered:

1 Encouraging students' awareness of construction and its impact on the environment
2 Developing students' design skills
3 Promoting students' ability to recognise their role as members of a team
4 Encouraging students' to develop a systems thinking approach
5 Improving students' ability to collect and critically analyse information in order to make sound judgements"

5.6 Responding to diversity

Being able to respond to the needs of a diverse student body is becoming increasingly important for lecturers. It allows all students to learn effectively, it aids student recruitment and widening participation, and it meets the requirements of legislation – in particular, the Special Educational Needs and Disability Act 2001 (SENDA), which places a statutory duty on institutions and departments to ensure that they do not discriminate against students with disabilities.(6)

What follows is a series of questions, connected to issues of diversity, that lecturers may need to consider in the planning and delivery of project based learning. Under each heading there are some ideas for responding to the particular needs that students may bring.

See also the LTSN ENG guide on *Working with Students with Disabilities*
http://www.ltsneng.ac.uk/er/dis/dispguide.asp

5.6.1 Are learning outcomes inclusive?

- Specifying written or oral reporting as a learning outcome may present difficulties for some dyslexic or international students respectively. Unless the format is essential to the desired learning the outcome could simply be to "report on findings using an appropriate medium".
- Some design and build outcomes may be problematic for learners with particular physical disabilities. Use of computer simulation may be an acceptable alternative.

5.6.2 Are learning materials appropriately representative and accessible?

- Learning materials should reflect the diversity of the wider community, i.e. they should present positive images of both sexes, people from different ethnic backgrounds, able bodied and disabled people. Visual images, case studies and role models shown in project based materials need to be representative.
- The use of language is an important aspect of making learning materials inclusive for all students. Language needs to be gender-neutral, sensitive to cultural variations, and free from colloquialisms that are likely to exclude some learners.
- Learning materials and resources should be accessible to students with

specific needs. Attention may need to be given to such factors as font style and size, the availability of audio/video format, compliance with Web Content Accessibility Guidelines, etc. Early availability of materials will be essential if reformatting is necessary.

5.6.3 Is the timetable accommodating?

- Mature students may have family responsibilities that limit their availability. This may be important in projects requiring out-of-class group meetings. The use of email and electronic discussion-based forums would provide greater flexibility.
- Staff and students undertaking a group based project activity should be sensitive to the range of festivals and days of significance relevant to various religious groups and faith communities.

5.6.4 Is the learning environment appropriate?

- Project based learning places a strong emphasis on information seeking and presentation of findings. Some disabled students may be helped by access to assistive technology, e.g. screen readers and voice recognition packages (for further guidance see the TechDis Accessibility Database www.techdis.ac.uk).
- In group based project work it is useful to establish a set of ground rules that encourage inclusivity. This may include attention to such things as seating arrangements, only one person speaking at once, opportunities for everyone to contribute, writing key points on a board, signalling your intention to speak etc. These practices may be particularly helpful, for example, to deaf/hearing impaired students, students whose first language is not English, dyslexic students, women students in predominantly male groups, etc.
- Students should be made aware of the services on offer to provide additional support for specific needs, e.g. institutional/departmental provision in English Language, Study Skills, Disability Support, Information Technology Skills, etc.

5.6.5 Are the learning, teaching and assessment methods inclusive?

- Peer-based discussion and challenge is often integral to project work in groups. However, it may be unfamiliar to some international students who could find it both confrontational and demanding of their English language skills. Appropriate briefing by the tutor, together with the development of protocols governing group conduct, should help ameliorate any difficulties.
- Some assessment methods may be less familiar to certain student groups (for example, international students or mature students returning to learning who may not have experienced peer assessment). It is important that the methods are explained clearly, the assessment criteria are explicit and students are adequately prepared.

It is worth noting that the strategies described here, whilst contextualised in terms of the needs of particular student groups, will often be of benefit to all learners. Thinking about how best to meet the needs of a diverse student group can help to improve learning through projects as a whole.

5.7 Summary

The characteristics of learners will impact on the learning process. Lecturers need to take account of student characteristics in planning and implementing learning through projects.

Characteristics that students bring to the learning situation will include:

- Differing expectations
- Varying levels of motivation
- A range of abilities
- A variety of preferred learning styles

An important feature of the HE learning process is the need to respond to an increasingly diverse set of learners. As a lecturer it is worth spending time finding out what learners bring with them, both in terms of the four key aspects noted above and a range of personal and social variables including educational experiences, socio-economic background, ethnicity, gender, age and disability. This will enhance your understanding of the student group and strengthen your ability to respond to their particular needs and qualities.

In planning to use project based learning, an appreciation of learner characteristics can help inform your approach to:

- Setting appropriate learning outcomes
- Choosing learning materials
- Timetabling
- Designing the learning environment
- Learning, teaching and assessment methods
- Determining the type and extent of tutorial support

5.8 Endnotes

(1) Newstead, S and Hoskins, S (2003) "Encouraging student motivation", in Fry, H et al *A Handbook for Teaching and Learning in Higher Education: Enhancing Academic Practice* (2nd Edition), London: Kogan Page

(2) Deci, E and Ryan, R (1985) *Intrinsic Motivation and Self-determination in Human Behaviour*, New York: Plenum

(3) Quality Assurance Agency for Higher Education (2001) *Guidelines for HE Progress Files*, Gloucester: QAA

(4) Honey, P and Mumford, A (1992) *The Manual of Learning Styles*, Maidenhead: Peter Honey Publications

(5) For a broader discussion of learning styles in the engineering context see Chapter 15 of Wankat, P and Oreovicz, F (1993) *Teaching Engineering*, New York: McGraw-Hill

(6) Two useful guidance documents for HE staff are: Skill - National Bureau for Students with Disabilities (2002) *A Guide to the DDA for Institutions of Further and Higher Education* (5th Edition), London: Skill; South West Network for Disability Support (2002) *SENDA Compliance in Higher Education*, Plymouth: University of Plymouth

5.9 Additional references

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- Powell, S (2003) *Special Teaching in Higher Education: Successful Strategies for Access and Inclusion,* London: Kogan Page
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Section 6 Knowledge Based Skills

This section of the guide:

- Highlights methods of developing knowledge and understanding in projects
- Investigates depth versus breadth issues for project work
- Describes prerequisite requirements for theoretical knowledge of the subject area
- Considers students learning independently
- Provides illustrative examples of developing theory within projects

Projects provide students with the opportunity to bring together knowledge based skills such as key concepts, principles and theoretical models from a number of different subject areas and apply them to real life problems. Projects provide a context to the theory that a student is learning; this can motivate the student so that they can deliver the project. This can also help to re-enforce existing knowledge and improve retention.

Case Study 2 by Patrick Littlehales, Aston University, describes the Global Design Initiative (GDi) where three student teams based in UK, Singapore and USA designed a racing car in 5 days working around the clock. This case study offers an example of how students were found to be well motivated for a voluntary extra-curricular project run alongside the standard lecture schedule.

> *Student understanding of the technology progressed considerably and they also learnt much about the physical process of design and project management. Their levels of confidence and motivation grew exponentially.*

6.1 Knowledge and understanding in projects

Within the QAA Subject Benchmark statement for engineering[i] the skills qualities and attributes of an engineer which are detailed first are for knowledge and understanding. The benchmark statement outlines that graduating engineering students should demonstrate knowledge and understanding of the following:

- discipline specific essential facts, principles and theories
- external constraints
- basic science, maths and technology for the specific discipline
- business and management techniques
- professional and ethical responsibilities
- the impact of engineering on society
- relevant contemporary issues

These knowledge based skills are usually delivered through lectures and tutorials, but may also be incorporated into projects, in fact there are often benefits to adopting a project based approach to develop these skills.

The Engineering Council report on "Standards and Routes to Registration - SARTOR[iii]" requires engineering students to receive some teaching in commercial awareness and business skills.

> “This area of teaching is often seen as particularly troublesome for some Departments given the limited personal experience of staff of working in commercial environments. Students also tend to select …. engineering courses because of their personal interest in the technical aspects”

Case Study 11 by Simon Tait at the University of Sheffield describes how he overcame these difficulties with civil engineering students using a project based approach. In a group design project the students learnt about; economic evaluation, project planning to optimise resources utilisation, the role of the capital markets and the importance of marketing and sales in an engineering environment. In the project students play the role of consultants evaluating the economic viability of a cold rolling mill.

Teaching this subject area through projects also provides context and relevance to the knowledge based material:

"Only when students have the opportunity to apply these techniques to realistic data do they start to appreciate the importance of such commercial methods in the decision making process."

This increased student awareness was substantiated by student questionnaires:

"This data indicated significant increases in student awareness of business and enterprise and the role of "added value" to large engineering projects. Complex commercial skills also improved, with over 80% of students claiming they now had the confidence to commercially evaluate an engineering scheme and two thirds stating that they now had sufficient skills and knowledge to formulate a business plan and present it to potential investors. These were significant improvements on the pre-project data."

Learners understand and retain information that has actually been sampled or experienced. If students, in projects, are required to ‘use’ their newly acquired theoretical knowledge they are much more likely to understand the reason for that knowledge and to commit it to long term memory.

Case Study 6, by Peter Willmot, Loughborough University,describes a teaching contract scheme that guarantees industrially based projects to all mechanical engineering students at Loughborough University. The scheme has developed over a period of twenty years and currently offers the benefits of close cooperation between the university and fourteen engineering enterprises.

Small teams of students tackle real problems set by the companies through the academic year and engage in a number of factory visits and progress meetings. The industrialists take part in tutoring and assessing the project work as it develops and can exert influence on the practices and procedures used. Willmot describes a second year project.

> *"The project is an open ended problem set by the company and the students work as consultants with the support of the academic tutor, a student-mentor (see Case Study 7) and an Industrial Tutor. The primary intention of these projects is to develop team working, creativity, commercial awareness, project planning and associated transferable skills rather than completely detailed designs.*
> *A formal written report is prepared together with a formal oral presentation to the company and the peer group."*

Final year students tackle more advanced methodologies:

> *"students are introduced to the projects at the factory site and an academic supervisor works with all the teams allocated to any one company. Finalists work in teams of five and have a number of substantive assessment tasks.*
> *The students benefit by developing an understanding of working in industry, gain context to their degree programme and improving their process and communication skills."*

Projects can also highlight the limitations of theoretical treatments and the simplifications that need to be made to adapt theory to practice. This gives practice in creating satisfactory theoretical models of complex practical systems and an appreciation of how to apply theory to real situations.

6.2 Depth versus breadth

There is often resistance to teaching too much of the curriculum through project based work, as academics feel that whilst students may solve an individual problem in some depth, there is not the same breadth of coverage as would be achieved through a traditional lecture course. For example in research based projects the depth of coverage of theory may be extended beyond that encountered in a traditionally taught course but in a narrower field.

Research studies within the medical profession, where learning through projects has been used in earnest for over twenty years, have shown that students undertaking a project based syllabus initially perform less well at traditional exams. However the students were found to have substantially better retention of the material and as time progressed their exam performance improved throughout the programme so that it reached the normal level. (Albanese & Mitchell 1993[iii], Farnsworth 1994[iv], Vernon 1995[v].)

If the intended project learning outcomes include a breadth of knowledge based skills then it is essential that the project brief needs to be well structured and sufficiently detailed for example incorporating facts, figures formulae and data collection information. Some subject areas align more easily with this type of project such as the design of a component structure to meet given loading or performance criteria.

Case Study 12 by Andrew McLaren, University of Strathclyde, describes how first year engineering students need support in the transition from school to university study. The new class "Design and Engineering Applications 1", which accounts for 25% of the credit load for first year Mechanical Engineers, seeks to provide this support while giving an introduction to engineering design. The class aims to illustrate the relevance of the students' engineering science classes to the design process, to build the students' confidence in their own abilities and motivate them to research and discover things for themselves. This case study provides an example of how knowledge based skills can be developed and re-enforced in a project to provide the breadth and depth of coverage by specifying how the information should be used and presented:

> *"Mechanical dissection of a motor car. Each student group selects and removes a component from the car. It is stripped and cleaned for analysis. The group's task is to describe the function, service conditions, materials and manufacturing of the component, and their interrelation…*
>
> *…The specific aim is for the group to produce a convincing description of the factors that must be taken into consideration in the design process of their component. This should be quantitative, e.g. numerical estimates of forces, stresses, speeds, pressures, temperatures etc. should be produced."*

The use of specific knowledge or learning points can help the students to cover knowledge based material gradually rather than becoming overawed or disheartened. The schedule of the introduction of learning points can be controlled by designating reporting dates or mileposts within the assessment structure and ensuring that supporting lectures are appropriately scheduled alongside. Setting appropriate project assessments is also critical to achieving a broad coverage. It is also important to ensure that students stay on track, if they do not receive appropriate feedback from their project staff and peers they may miss important content.

The project supervisors may need to offer support or guidance to the students in sourcing the information that is anticipated; to prevent them from becoming disillusioned by their not being able to find what is needed for themselves.

It should also be noted that exams are not usually the best method of assessing project work as they largely measure knowledge based skills. A much wider set of skills, such as problem-solving, communication, team working and independent learning, are usually developed by learning through projects. It is these skills that the students should also develop in order to meet the benchmarking statements of the professional engineering institutions and the needs of industry.

6.3 Prerequisites

When specifying a project the theoretically based learning outcomes are often the first to be defined, such as numerical skills, and application and retention of key principles and concepts.

In addition to learning new concepts within projects it is usually expected that students will be required to apply theory that has been learnt from a range of current and previous modules. To avoid overloading and de-motivating the students the tutor needs to distinguish between pre-requisite theory and knowledge based skills developed as part of the project and assess whether the students have realistically covered the relevant pre-requisite theory prior to undertaking a project. This can usually be checked from the programme and module timetables and specifications or from talking to the programme manager and the students.

6.4 Scheduled classes

Projects can be an inefficient method of covering a large amount of theory or factual work, but project based learning does not have to be an alternative to lectures; the two are frequently combined together with other teaching methods. Many institutions schedule traditional lectures and support classes to run alongside project work to provide a well-rounded, integrated and satisfying learning environment. It is also possible to adapt the way that the lectures are delivered so that they are more appropriate to developing project work.

Case Study 8 by Barry Lennox, University of Manchester, describes an alternative method of providing taught courses for group based problem solving work in the School of Engineering:

> *"Care was taken to ensure that the taught courses did not take the form of traditional lectures, as this did not exploit the skills that the students were learning through problem based learning and was seen as the primary cause for students becoming disengaged with engineering in the past. Consequently the taught courses took the form of 2-4 hour sessions, during which the students would receive several short 15 minute presentations, interspersed with several individual and group based problem solving activities."*

6.4.1 Traditional lectures

Lectures are often scheduled to provide the student with relevant information at the appropriate time within the project. The project helps provide context to the theory from the lectures and often improves lecture attendance.

These lectures can be made more interesting if the lecturer (and sometimes the students) adopt specific roles or stances within the project.

Engineering and technology degrees tend to be highly structured with programmes biased towards the acquisition of knowledge. Somehow more time needs to be devoted to enabling students to develop inquiring and creative minds, and a project based on a student centred learning approach with role play at its heart is one answer. Case Study 1 by Peter Hedges, Aston University, offers an example of how civil engineering students, staff and industry professionals adopt specific roles within a simulated public inquiry:

Throughout the inquiry the students gain practical experience of real life engineering problems. The project has a variety of learning outcomes beyond knowledge acquisition. These include: the development of teamwork, communication and decision making skills; generating an understanding of the role of the professional engineer within society; and raising awareness of the sociological and environmental effects of a major development.

"Within the inquiry the student groups are allocated roles such as the water companies promoting the scheme, the county council, or local residents . Each group presents their case at the inquiry from the perspective of their allocated role…

… Student motivation is rarely a problem. The pressures of meeting deadlines, and the different nature of the project to their normal learning experience, suffice to generate enthusiasm."

The main problem for the project supervisor associated with a project such as the Public Inquiry, is that it requires considerable investment of time and energy collecting data before it can even start. To enable an immediate response to the students' requests, the underlying information has to be at the supervisor's fingertips. The first few years are the most demanding, whilst the 'Additional Information' reports are prepared on the hoof, until the variety of possible questions have been largely addressed.

6.4.2 Support classes

These classes involve focused and structured student discussions, with both project tutors and peers. A substantial amount of theoretical knowledge can be transferred through the discussions. Within group work this is often the opportunity for peers to explain the theory behind a part of the project they are responsible for.

Within a project support class students may often be directed to find relevant and supporting theory through independent learning, which they will then report on during the next class.

For both support classes and traditional lectures there are clear time tabling issues which must be addressed by the project staff.

Case Study 8 by Barry Lennox, University of Manchester, School of Engineering, describes how a group problem is set to encourage the recalling of previously acquired knowledge at the start and that support classes are scheduled to make sure that this takes place:

> *"A problem scenario is handed out to each group, the make up of which is selected at random at the beginning of each semester, on a Monday morning. Over the next 1-2 weeks, the students are encouraged to follow a set procedure that involves the recalling of knowledge, formulation of questions, discussion of what has been learnt and finally reflection. To ensure that this happens, each group is assigned a member of staff who facilitates for two 1-hour periods on Monday and Thursday mornings"*

6.5 Independent learning

Learning through projects is an ideal method of allowing a student to independently develop knowledge and understanding of theory in order to complete specific parts of the project.

The structure of the project assessments and resulting outputs is critical if the project tutor wishes to ensure that specific engineering concepts, principles and mathematical skills are researched and applied.

Many undergraduate projects involve students gaining an understanding of new theory from prime sources and then applying it. It is this very need for knowledge that makes that theory more relevant and urgent.

When students learn through projects the need to subsequently apply the newly learnt theory provides the students with context and motivation, which students may sometimes lack in modules without project work.

A student cannot become an independent learner overnight. High-level skills are involved and students will need guidance and direction on how to:

- identify source materials
- extract relevant information
- analyse and interpret the information
- use the information for problem-solving
- apply the information within the project

The source of independent learning material may be varied and includes:

- texts
- journals or articles
- audio and video
- WWW, CD, or intranet software
- project support staff or peers

A wide range of support materials has been produced to help students develop their learning skills, that are described within the section on Support. For more detail on sources of material, including library and Information and Communication Technology (ICT) resources, see the Section 10 on Resources.

If a student is strongly motivated by a project then, as they seek a solution, they will gradually assume increased responsibility for their learning and develop their independent learning skills. These skills will be transferable both to future project work within their academic programme and subsequently to the workplace. Project work frequently provides useful material for discussion at interviews.

6.5.1 Group work

When students are working in teams they may split the tasks according to subject area. These case studies highlight the needs for teams to meet and communicate the relevant theory to each other in relation to their own task. Hence learning is through peers. It is particularly important in this case that there is effective communication within the group so that all students become aware of how to apply the theoretical background to the problem. The need to explain the theory to fellow students can help with communication skills and can provide further impetus to the student to ensure they have a good understanding.

The project assessments can be structured to test whether individual members of the group have learnt the relevant theory.

6.6 Summary

To elicit theory-based learning appropriate assessment methods and assessment outputs must be structured in to project work.

Within a well-structured project, information, concepts, principles and numerical skills are learnt and integrated with one another due to the context.

The resulting benefits of learning knowledge based skills through a project are :

- improved comprehension / understanding
- improved context and student motivation
- theory is learnt and applied in a situation resembling a work based scenario
- improved communication skills for theory based content
- ability to apply theory to a real application
- improved retention

6.7 Endnotes

(1) Quality Assurance Agency for Higher Education, 2000, *Subject Benchmark Statements: Engineering*
http://www.qaa.ac.uk

(2) Engineering Council UK, 1997, *SARTOR (3rd Edition)*, London: Engineering Council

(3) Albanese, M., & Mitchell, S., 1993, "Problem-based learning: A review of the literature on its outcomes and implementation issues", *Academic Medicine*, 68 (1), pp52-81.

(4) Farnsworth, C.C., 1994, "Using computer simulations in problem-based learning" *Proceedings of the Thirty-fifth ADCIS Conference*, Nashville, pp. 137-140 TN: Omni Press.

(5) Vernon, D.T., 1995, "Attitudes and opinions of faculty tutors about problem-based learning", *Academic Medicine*, 70 (3) pp216-223

6.8 Additional references

- Boud, D. and Feletti, G., 1998 *The challenge of problem based learning* London, Kogan Page 2nd Edition
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- Gibbs, G., 1992, *Improving the quality of student learning*, Bristol, Technical and Educational Services Ltd.
- Orma, E. and Stevens, G., 1995, *Managing Information for Research*, Buckingham, Open University Press
- Qin, Z. and Johnson, D. W., 1995, “Cooperative Versus Competitive Efforts and Problem Solving”. *Review of Educational Research*, 6 (2), pp129-143

Section 7 Process Skills

This section of the guide:

- Defines what process skills are
- Explains why they are important
- Indicates how project based learning can contribute to their acquisition
- Describes the role of the lecturer in developing them
- Explores in detail three sets of process skills with particular relevance to engineering
- Provides illustrative examples and case studies drawn from a number of engineering degree programmes

In undertaking learning through projects, there are a number of process skills that students will need to possess or acquire for successful completion of the project. There has been a growing recognition, reflected in the engineering benchmark statement[(1)], of the need for graduates to possess a range of process skills applicable to employment as a professional engineer and this is often a key driver for using projects.

7.1 Process skills and project based learning

Process skills are those generic, transferable skills that need to be developed alongside subject content and discipline-specific skills. Examples of process skills would include:

- Communication
- Applications of IT
- Decision-making
- Teamworking
- Time/resource management

Many of these skills are by no means unique to project based learning. They are required in other forms of learning. For effective learning through projects, however, students frequently need to acquire new, more complex or higher order process skills.

The nature of the project work will impact on the particular combination of skills needed, the level of competence/mastery required, and the patterns of staff-student and student-student interaction. Whilst all projects in engineering are likely to involve some level of enquiry and investigation, the characteristics of projects will vary in significant ways. These differences can be conceptualised along a continuum of project-based approaches to learning.

More constrained ◄──►	Less constrained
Lecturer led	Student led
Predetermined topic(s)	Student choice of topic(s)
Knowledge sources provided	Knowledge sources sought
Short-term	Longer-term
Individual or group based	Usually group based
Problem-solving curriculum	Problem-based curriculum

The skill-sets required by learners will differ according to the project's location on this continuum. For example, individual students asked to undertake a series of short problem-solving exercises on a weekly basis will need skills in:

- Application of knowledge derived from lectures and course handouts
- Tight time management
- Independent study skills

Conversely, a group of students asked to conduct a collaborative project running over a full academic year are more likely to need such skills as:

- Acquisition and analysis of new information
- Wider resource management skills
- Teamworking

A useful device to employ is a skills map, setting out the full range of skills to be developed within a programme and identifying which skills will be acquired through completion of particular modules.

An example of a modified skills map, drawn from the final year of an undergraduate degree programme in Electrical and Electronic Engineering, appears on the next page. The mapping chart identifies those programme learning outcomes related to transferable/key skills that are addressed through the double weighted project module. The chart reveals that the project module promotes the acquisition of four of the five transferable process skills relevant to that programme.

Transferable/Key Skills	*Module: Project (Double)*
D1	▪
D2	▪
D3	▪
D4	
D5	▪

Transferable/Key Skills

D1 *Assume responsibility, as an individual or as a member of a team, for the management of resources and/or guidance of technical staff*

D2 *Utilise effective communication skills and actively participate in human and industrial relations*

D3 *Utilise Information Technology in the preparation, process and presentation of information*

D4 *Apply numerical skills in the collection and recording of data, interpretation and presentation of data, and the solving of problems*

D5 *Manage own roles, responsibilities and time in achieving objectives, learning performance, new and changing situations and contexts*

Source: University of Derby, School of Computing and Technology

Learners will bring with them varying levels of confidence, ability and motivation in relation to the range of process skills. This will reflect both their prior learning on-course, and broader learning experiences from within and outside formal educational settings. It is critical that students understand the importance of generic, transferable skills in the engineering curriculum in terms of their relevance to future employment prospects. Lecturers have a key role to play in promoting that understanding.

7.2 The role of the lecturer in developing process skills

From the outset lecturers need to be clear what process skills learners will require to meet the requirements of the programme and to enable them to undertake a specific project-based activity. Some skills may be included in the programme/module learning outcomes, others may not be formally assessed but will nevertheless be critical to the student's ability to complete the project successfully. Unless attention is paid to how these skills are to be developed, student achievement will be compromised.

Often, some learners will already possess some of the process skills needed for project-based learning. It is useful for lecturers to assess the existing skills profile of the group, perhaps by using an audit tool or asking the students to undertake a self-assessment exercise[(2)]. This knowledge will allow the lecturer to identify skills gaps in need of attention.

Some learners may perceive the acquisition of process skills to be largely irrelevant to the ‘real business’ of their programme of learning. Project based learning provides a rich opportunity for highlighting the value of process skills and demonstrating their centrality to the role of the professional engineer. Incorporating process skills into learning outcomes, teaching and assessment methods can enhance this message.

The lecturer can promote process skill development through a wide range of measures, including:

- Preparing a learning through projects guide offering pointers on such matters as project planning, working as a team, record keeping, report writing, etc
- Identifying useful resources and materials, eg books, articles, computer-based resources, physical/technical items etc
- Using the institution’s Virtual Learning Environment to support the project, including module information, key documentation, a discussion board, etc
- Delivering preparatory sessions outlining some of the key process issues learners will need to address in managing project work
- Offering specific, targeted input to individual learners in need of assistance/advice on particular process skills
- Incorporating within personal development planning activities a requirement to reflect on process skill development

Lecturers should be attuned to issues of diversity and equality in considering process skills. Individual learners will interpret messages in different ways, depending on their previous experiences which, in turn, are often influenced by socio-cultural factors. Some examples may illustrate the point:

- By virtue of gender differences in childhood, men and women may bring to project work very different experiences of what it means to be part of a team
- Members of different ethnic communities may bring different perceptions of what is appropriate/acceptable behaviour in groups
- People with certain disabilities may find it difficult to use particular communication media

There are no easy answers to these issues, and space precludes a more detailed discussion here. The central point is that lecturers have a responsibility to be sensitive to questions of diversity and to respond creatively to the range of student experience and need when considering the development and application of process skills for project-based learning[(3)]. This responsibility is increasingly reinforced by legislation.

On questions of disability, useful information and guidance can be found in the LTSN Engineering Guide *Working with Students with Disabilities*…
http://www.ltsneng.ac.uk/er/dis/dispguide.asp

This brief review of the lecturer’s role in developing process skills has touched on the implications of project based learning on the professional task. This theme is developed further in Section 9, which considers more broadly the professional role and supporting students in learning through projects.

The remainder of this section focuses on key groupings of process skills that have particular applicability to many different types of projects in engineering:

- Planning and organisational skills
- Teamworking skills
- Formal communication skills

For each area there is a description of what skills are required for what sorts of tasks, and some ideas on how the skills would be applied in project work. Illustrative examples drawn from current practice in a number of university engineering departments are provided.

7.3 Planning and organisational skills – laying the foundations for the project

Whilst students will need to utilise planning and organisational skills within any formal programme of study, it is important to recognise that learning through projects introduces a different level of demand on these skills. Project based learning provides an excellent environment for developing abilities in project planning and project management, both key skills for the professional engineer. Added to that, it is not uncommon within engineering programmes for skills in planning and organising to be formally assessed.

Learners will need to draw on planning and organisational skills to undertake a range of project planning activities. These are dealt with sequentially below.

7.3.1 Identifying what needs to be done

The starting point for any project is for students to be clear about what they are doing and why. They need to identify, define and justify the project. If the project brief has been defined by the lecturer, the student needs to check that their interpretation of the requirements is accurate. If the student is required to formulate their own project brief, it is critical that they define project aims and objectives that are clear and manageable within available resources.

7.3.2 Deciding who will do it

If the project is to be done individually this is self-evident. With a group project, however, it is essential from the outset to determine the roles and responsibilities of each member of the team. Without this, the group runs the risk of duplication of effort and/or things being missed. It is essential for the students themselves to undertake this planning process, in order to gain an appreciation of the achievability and potential pitfalls of the task.

7.3.3 Gauging how long it will take

This can be approached at various levels. It is helpful to think in terms of the specific tasks and activities to be undertaken, and to attach target completion dates to each. A flowchart or Gantt chart[4] mapping this out can be a useful aid. It may well be that certain tasks need to be carried out simultaneously whilst others will need to be sequential. The identification of time-critical tasks can be very helpful.

7.3.4 Identifying available resources

This involves students in locating the necessary resources, and planning to ensure the project can be managed within these constraints. Consideration needs to be given to time, material, financial, human and technological resources. Library staff can play an important role here, as can computer-based packages such as:

- RDN (Resource Discovery Network – www.rdn.ac.uk), a JISC-funded service containing a collection of relevant, high quality information
- VTS (Virtual Training Suite – www.vts.rdn.ac.uk), a service offered by RDN to teach internet information skills to HE/FE users
- EEVL (www.eevl.ac.uk), a site specialising in resources in engineering, mathematics and computing

7.3.5 Producing a project plan

The plan should address the following areas:

- Focus of project
- Rationale
- Aims/objectives
- Literature/theory base
- Methodology/design
- Resources
- Outcomes/end product
- Evaluation
- Dissemination
- Project schedule

For longer, more complex projects, the use of project planning software (eg Microsoft Project) might be a useful aid.

Two examples of guidance notes for students on producing a project plan appear below: one (referred to as a project proposal) is drawn from Electrical and Electronic Engineering, the other (called a feasibility report) from Mechanical and Manufacturing Engineering.

The Project Proposal

1. Project Title
Ideally a brief title describing the main project theme, eg Design of a Domestic Security System.

2. Name and Programme of Study
Clearly identify your name, the programme of study and the project tutor's name if known.

3. Aims of the Project
Between 3 and 6 aims (more does not necessarily mean better) of the form shown here:

- *To review the current market requirements for domestic security systems*
- *To design a domestic security system for a component cost under £25*
- *To build and test the domestic security system in a domestic environment*

These aims will provide the benchmark against which the success/failure of the project can be judged. It is important to be concise and clear about what you are hoping to achieve.

4. Project Definition
A section describing the facts, figures, technical background and any other information that is needed to define the project being undertaken. The aims of the project should be justified in terms of their relevance in a technical/commercial/social context, given the financial and time constraints placed on the project. Previous work in the area should be described, along with an explanation of how the proposed project builds on this work. Any special features of the project should be identified (eg industrial involvement, commercial potential, novel applications, intellectual property rights) and described in detail.

5. Plan of Work
This should include a timetable of events with brief explanatory notes. A critical path should be identified, if it exists. Each activity should include an estimate of the time needed to complete the element. It is vitally important to ensure you plan for lead times on items that require purchasing or manufacture. Your plan should clearly identify the progress you expect to have made at the time of the interim report. A planning chart (Gantt chart), of the type shown below, may be useful to help you identify when different tasks will need to take place.

6. Resources

Any costs above the specified expenditure limit should be identified here if possible, and will be subject to an application for the revision of project expenditure limit. This section should also describe any special laboratory facilities/access or equipment that is required.

7. Appendices
A risk assessment form must be completed and attached to your proposal. A copy of the risk assessment form can be obtained from the electronics technician or from the projects notice board outside room T007a.

	Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
	Planning						
	Background Research						
	Writing Proposal						
	Initial Designs						
	Revising Plan						
	Etc…						

Source: University of Derby, School of Computing and Technology

The Feasibility Report

1. Introduction
A statement of the project objectives and a concise description of the problems to be addressed. A summary of any background research you carried out.

2. The Product Design Specification
A description of your initial design proposal.

3. A SIMPLE group work plan
This should run to the end of the project, and must be updated to show what was intended and what actually happened.

4. Ideas
A description of the ideas generated to date.

5. Evaluation
A thorough and logical evaluation of the concepts considered. This will include comparison by preliminary calculations/costings/layout drawings etc of at least two of the most promising ideas.

6. Proposal
A description of the most promising conceptual solution(s) that you expect to develop.

7. Suggestions
Your suggestions for how you intend to develop the ideas, stating any further resources you would require to achieve this.

Source: Loughborough University, Faculty of Engineering

7.3.6 Monitoring progress

Progress tracking is important to keep the project on course and to provide a means of adjusting the plan or schedule when necessary. Various tools and techniques are available for this purpose. A decision needs to be made about which is most appropriate, taking into account the scope of the project and the constraints of time. Some methods – for example, PERT (project evaluation and review technique) or CPM (critical path method) - are time consuming and best suited to large scale projects. For most student projects a simple monitoring sheet, perhaps in the form of a Gantt chart as shown in the Project Proposal example above, is a useful device. Other options could include an individual diary or log book to record targets and achievements, or progress review records from meetings between team members and/or the project supervisor[5].

7.3.7 Planning for the end-game

Learners should be planning for project completion and delivery right from commencement. This will include consideration of how the project will be presented for assessment and, if appropriate, disseminated more widely. Options could include:

- Producing a written project report
- Giving a formal presentation (eg using PowerPoint)
- Participating in a poster session
- Demonstrating the workings of a design build

7.4 Teamworking skills – working effectively with others in projects

For group-based projects to be successful the group needs to be both efficient (able to function well as a team) and effective (able to deliver the required outcomes). It is all too easy for group projects to be neither. It is important to understand the difference between:

- a group, which is a collection of individuals who may or may not be working efficiently or effectively, and
- a team, which consists of a number of people working collaboratively to achieve common objectives.

To work well collectively a team needs to:

- establish ground rules
- clarify purpose and objectives
- agree on priorities
- allocate roles, tasks and responsibilities
- manage time
- check progress regularly
- communicate openly and effectively with each other
- hold each other to account and be accountable
- offer mutual support
- deliver the end product on time
- review and evaluate performance

An example of some ground rules for team meetings, drawn from a public inquiry project in a second year Civil Engineering and Logistics programme, is reproduced on the next page.

Ground Rules for Group Working

1. *Always attend team meetings*
   - *Team effort – unfair on colleagues if you don't*
   - *Will be penalised in self/peer assessment*

2. *Select a Chair/Coordinator*
   - *Not absolutely necessary – but gives experience*
   - *Rotate job*

3. *Agree an agenda for meetings*
   - *Doesn't need to be highly structured/formal but list points to cover*
   - *What have people done/achieved since last time*
   - *What needs discussing this time*
   - *Actions to be taken before next meeting*
   - *Assign tasks*

4. *Nobody to speak for longer than 3 minutes*
   - *Can help if some people are dominant – prevents them taking over*

5. *No interrupting*
   - *Gives everyone a chance*
   - *Ensures all ideas are listened to and explored*

6. *No putting others down – criticise the ideas not the person*
   - *Need to work as a team*
   - *People who are put down will become less effective/less inclined to pull their weight*

7. *Encourage everyone to speak participate*
   - *There's always more than one point of view*

8. *Set deadlines and stick to them*
   - *Team effort – unfair on others if you don't do what is expected*
   - *Need to coordinate actions – if one person is behind it may lead to bad decisions through lack of information*

Source: Aston University, School of Engineering and Applied Science

Groups that become teams are often seen to be going through the following stages:

1. Forming – coming together for the first time as a group
2. Storming – working out differences, disagreements, misperceptions
3. Norming – articulating a set of shared understandings and objectives
4. Performing – working together as a cohesive unit in pursuit of commonly agreed goals[6]

Teams work best when their individual members adopt complementary roles, each of which is necessary to the effective functioning of the whole. Individuals who work well in teams will possess or be acquiring a range of interpersonal skills. These will include:

- A willingness to share ideas, information and knowledge openly
- A willingness to listen to the contributions of others
- The ability to negotiate and compromise where there are differences of opinion
- The ability to recognise and value other people's strengths
- A willingness to support others where they are less strong
- The ability to give feedback that is constructive yet appropriately critical
- A commitment to the work and aims of the team rather than the goals and interests of the individual[7]

Case Study 10 (Colin Smith, University of Sheffield) describes a design group project, drawn from the third year of an MEng programme in a Civil and Structural Engineering Department, designed specifically to enable students to develop and practise teamworking skills. The project includes an initial teambuilding course, and an end of project team presentation. A brief extract from the study illustrates its purpose in this regard:

> *"The ability to teamwork effectively is widely seen as an important skill in industry. Even before graduation, such a skill should assist students to gain more out of project work. Students may be introduced to teamworking in a variety of ways, for example through short stand alone teamworking courses, perhaps with an outward bound element. This case study presents an alternative approach that integrates the teaching of teamworking skills directly with an existing credit bearing engineering design project. This gives the teamworking training an immediate relevance, which is often a key issue in getting students to engage with the material…..*
>
> *Rather than expect students to develop team skills indirectly as part of the process of working in a group, it was felt that they would get more from the exercise if they were given some initial teamworking training. Mistakes made in the training could be learnt from, enabling students to approach their project more confidently and see the direct benefit of the skills that they had learnt. To give the project a clear high profile end, each team is required to make a presentation to industry participants. The project then finishes with a debriefing session covering both the technical and teamworking aspects of the work."*

7.5 Formal communication skills – writing reports, oral presentations and practical demonstrations

7.5.1 Report writing

Written communication is an important process skill in learning through projects. Project reports, interim and final, are perhaps the most frequently used method of assessing the work of individual students and learners in teams. In design projects, design reports are common, requiring the student to combine written text with engineering drawings.

It is essential that students understand the coverage needed in such reports and are sensitive to issues of format and audience. A good quality report provides evidence of the ability to:

- Select appropriate material – word limits are often set to encourage conciseness, knowing what to leave out is as important as what to include, volume does not equate with quality, relevance is the critical factor
- Attend to issues of structure, layout and style – reports are usually best presented under section headings, colloquialisms and circumlocution are to be avoided, the target audience should influence the way the report is presented

7.5.2 Interim reports

An interim report would normally include any monitoring sheets completed by the project team. The report should cover such areas as:

- Contextual background
- Aims/objectives
- Methodology
- Results to date
- Emerging problems/issues and actions taken
- Any revisions to original plan
- Proposed future activities/timescales

7.5.3 Final reports

A suggested structure for a final project report follows:

- Title page – to include name(s) of student(s), institution/department, programme title, module title
- Contents page – noting the main sections/sub-sections of the report, with page numbers
- Synopsis – a brief summary of the project, covering aims, methodology, results and conclusions
- Introduction – the contextual background to the project, including aims, objectives and rationale
- Literature review – the theoretical/historical underpinnings that have informed

the work

- Methodology/design – a description of how the project has been conducted by the student(s), including drawings where appropriate
- Results – a summary of the project findings, including analysis of data and discussion of alternative interpretations
- Conclusions – an evaluative commentary on the findings, extracting the key points in terms of the project's aims and objectives
- Recommendations – proposals for further work, action plans or ideas for change arising from the project's conclusion
- Appendices – charts, tables, additional items referred to but not included in the main body of the report
- Glossary – an explanation of any technical or discipline specific terms used in the text
- References – a full list of all source materials used by the student(s), set out as per an agreed convention

It will be rare for students to be able to produce a final version of the report at the first attempt. More typically they will work up an initial draft for sharing with team members, the lecturer or relevant others, and will use their feedback to inform editing and revision. The final version will need to be proofed meticulously for spelling, pagination etc.

7.5.4 Presentations

With oral presentations, as with written reports, learners need to be clear about the purpose of the exercise and the needs of the audience as this will affect how the presentation is best structured and delivered. A presentation designed to provide a detailed explanation to an assessment panel of how the project was conducted would need to be very different in style as well as content to one aimed at a more general audience interested primarily in the project's findings.

A simple and widely used approach to presentation format runs like this:

- An introductory overview (tell them what you're going to tell them)
- The detailed presentation itself (tell them)
- A summary recapping on key points (tell them what you've told them)

It is useful to provide students required to give presentations with some general guidance on structuring and delivery. This should cover such pointers as:

- Start by deciding how you will finish – in planning the presentation focus first on what conclusions you will want to draw
- Select the key information – identify what the audience need to know to accept your conclusions, exclude material that does not contribute to this end
- Secure their attention – a short, compelling statement, often in the form of a question, is an effective means of opening a presentation
- Use connecting phrases – as you move from one stage of your talk to the next, signpost this for the audience

- Summarise the message – provide the audience with a concise, simple restatement of the key point(s) you wish to make
- Speak to the audience – face them, maintain eye contact, do not read from a script, use brief notes written on index cards if you need prompts
- Rehearse the talk – this will promote familiarity with the material and will help ensure you keep to the required time limits

Visual aids are an important feature of most presentations. Commonly used aids include:

- Flipcharts
- Whiteboards
- OHP slides
- PowerPoint
- Drawings

Professionally produced and properly used, visual aids can enhance audience engagement and retention. Poorly produced and badly used, however, they can be counter-productive. Similarly, student skills in using the medium are important. Presentations can be ruined by sloppy diction, information overload and poor timekeeping. Learners need to invest time in developing and practising skills in use of their chosen visual aid(s).

It is worth remembering that diversity factors apply here too. Students with dyslexia, for instance, can find formal presentations a major problem.

Case Study 1 (Peter Hedges, Aston University), drawn from the second year of a Civil Engineering programme, provides an interesting example of a particular type of project presentation, involving teams of students preparing and presenting a case for or against a proposed reservoir development scheme at a simulated public enquiry. A brief extract provides a summary of the process:

"The project involves students working as a team to acquire, interpret and analyse pertinent information, and to prepare and present their case at a simulated public inquiry. The student groups are allocated roles such as the water companies, the county council or local residents. Each group presents their case at the inquiry from the perspective of their allocated role.

The simulated inquiry follows as closely as possible the procedures of a real inquiry. It is presided over by an Inspector, who is a consultant engineer with practical experience of inquiries. The Inspector opens the inquiry, and the QCs for each group introduce their witnesses. The main procedure gets underway when the Council for the Appellants delivers an opening speech, and the principles of the scheme are outlined.

Subsequently, each of the expert witnesses is called in turn and reads their Proof of Evidence. They are then cross-examined by the opposition QCs, the Assessor and the

Inspector, with the appellant's QC having the opportunity to re-examine their witnesses in an attempt to rebut any evidence that has been discredited.

The Appellant's case is followed by each of the opposition groups in turn following the same procedure. The inquiry ends with each QC summing up their case in a closing speech. After the Inspector has closed the inquiry there is a brief review and feedback session."

7.5.5 Demonstrations

Demonstrations may be of particular relevance to engineering students who have undertaken design or build projects. Often supported by a written handout, demonstrations may take a number of forms:

- Exhibits
- Table displays
- Scale models
- Charts
- Photographs
- Videotapes
- Computer graphics

Demonstrations can be combined with poster presentations, frequently used at technical conferences. Posters will typically include the following items:

- Project title
- Author(s)/contact point(s)
- Abstract
- Project focus – usually in text or diagrammatic form
- Objectives
- Methodology
- Data analysis
- Results
- Conclusions

Again, learners will need to attend to a number of practical issues if the poster presentation is to be effective. These issues include space available for the display, weight of posters to be displayed and size/style of text lettering on posters to ensure they can be read from a distance[8].

7.6 Summary

The term process skills is used to describe the range of generic, transferable skills that all students need to acquire. In engineering, project based learning is a particularly effective means of developing some of the more complex, demanding process skills needed by the graduate engineer. Three key sets of skills relevant to engineering students are:

- Planning and organisation
- Working in teams
- Formal communication skills (eg reports, presentations and demonstrations)

There are a number of different ways you as a lecturer can promote the development of these skills using projects. What matters is that you include the development and assessment of generic process skills alongside more discipline/subject specific skills when planning to use learning through projects.

7.7 Endnotes

(1) Quality Assurance Agency for Higher Education, 2000, *Subject Benchmark Statements: Engineering*
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(5) LTSN Engineering, accessibility resources and guide
http://www.ltsneng.ac.uk/er/dis/index.asp

(6) The National CAA Centre
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(7) Harris, B., 2002, *Assessment of Individuals in Teams*, LTSN Engineering working group report,
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7.8 Additional references

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Section 8 Assessment

This section of the guide:

- Explains why assessment is needed
- Describes assessment design
- Explores the characteristics of good assessments
- Describes a range of assessment methods and specification
- Explores the issue of assessment marking

The majority of the Case Studies are relevant to this section.

Learning through projects provides the opportunity to develop more learner skills than traditional lecture based teaching. These skills include problem-solving, communication, team-working and independent learning. If these are part of the desired learning outcomes of the project then it is essential that they are appropriately assessed.

The use of real life problems within projects enables students to have an increased understanding of the inter-relationship between theory and its application. It promotes independent learning, encourages a greater sense of ownership of both the learning and assessment, and increases the transferability of skills gained at university to the work place.

It is clear from the current engineering benchmark statement [vi] that a highly desirable outcome of projects is that students develop a range of skills that can be applied in a professional capacity for example as a practising engineer. Assessment methods must be adapted to ensure that an accurate measure of these skills is obtained. As students become increasingly assessment-motivated, appropriate project assessment strategies also need to evolve to encourage students in the development of these skills.

8.1 Why assess?

Assessment is an integral part of teaching. Through assessment it is possible to:

- improve learning
- enhance course development
- measure student performance

The following table highlights outcomes from assessment under these three areas. Within this Guide the main focus is on assessment and the improvement of learning.

Assessment and learning	Assessment and course development	Assessment and student performance
Provides feedback to the learner so that they are able to more effectively plan their learning and benchmark their performance	Provides feedback to the module team as an integral part of the loop for review and development of the assessment strategy	Provides a measure of achievement encouraging students to reflect on their performance and how this matches the expectations of the assessment
Identifies where students need to develop skills and competencies	Allows evaluation of teaching efficacy	Ranks students allowing tutors to identify different ability groups and develop strategies to meet their individual needs
Increases student motivation	Promotes course development through curriculum review	Enables student progression by encouraging a sense of ownership in both their learning and achievement

8.1.1 Assessment and learning

Assessment is critical to the learning process as it develops those skills and competencies that are seen as essential to the student learning experience. Project-based learning provides a platform for testing out a range of skills, abilities and attributes, thereby fostering in students the ability to address a broader range of achievements.

Within a project an effective assessment strategy can be structured to achieve each of the following:

- Elicit higher order thinking in addition to basic skills
- Integrate with other instruction (e.g. lectures / tutorials)
- Encourage students to evaluate their own work

If a broad range of skills and attributes is to be developed and students are to adopt a systems thinking approach, it is essential that both the project and the assessments be appropriately designed to develop and test these skills.

8.2 Designing assessments

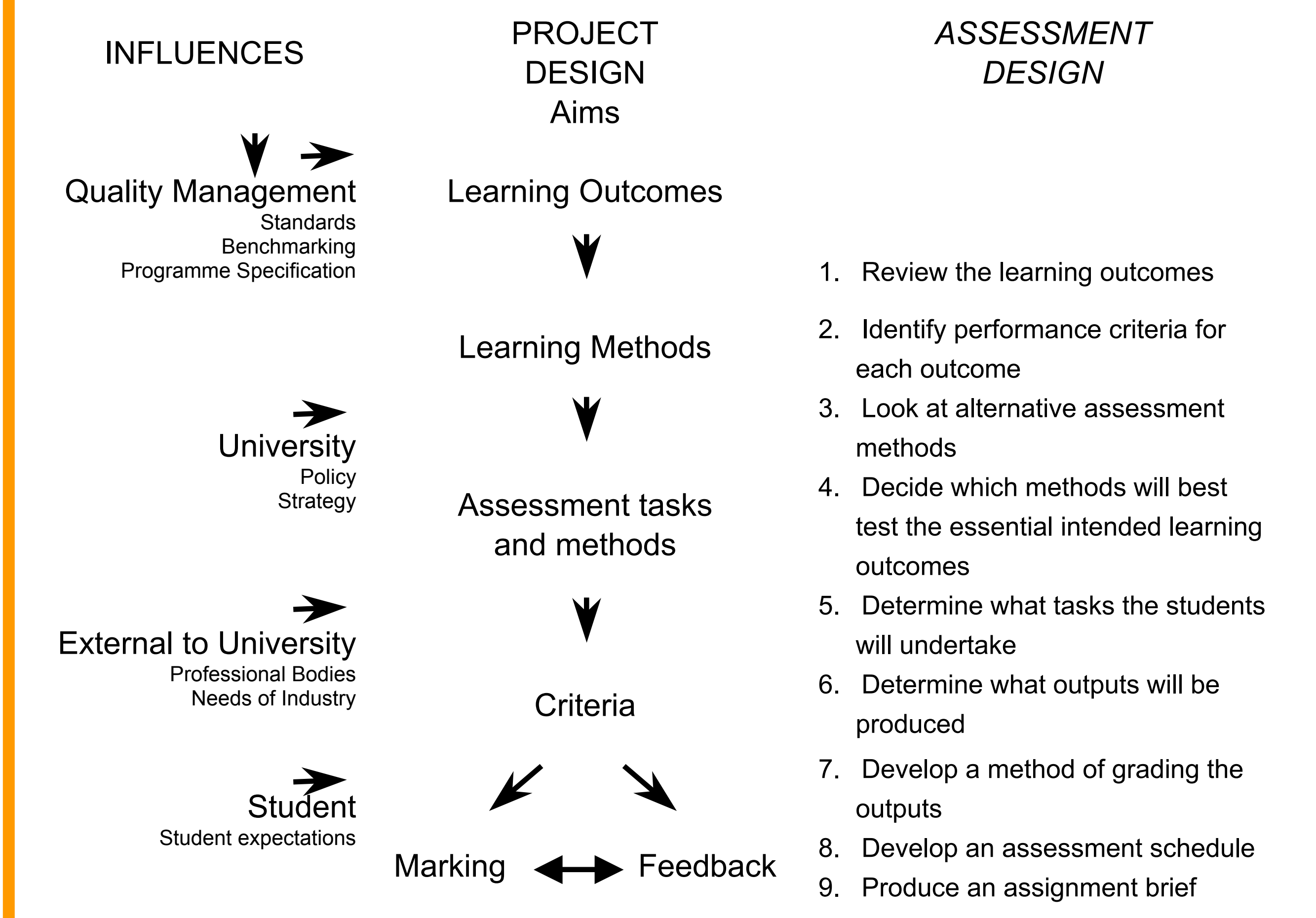
The integration of appropriate assessments with the aims, learning outcomes, and methods of learning is essential for effective assessment and forms the core of project design.

Case Study 3 by Melvyn Dodridge at the University of Derby describes how learning outcomes are defined and matched with assessment criteria and assessment methods within engineering/technology at the University and offers the following guidance:

> *"It is quite possible to specify a large number of learning outcomes for most modules of study, and the project is no exception. However, setting too many [assessed] outcomes can lead to over-assessment, which in turn can result in student underperformance. Where learning outcomes are to be formally assessed they need to be measurable by the tutor, achievable by the student and essential to the aims of the module."*

As part of the assessment design process other factors must also be considered, such as university policy, quality standards, student expectations, and the requirements of professional institutions. These factors will invariably be dependent upon the institution, subject discipline and student cohort.

The following figure illustrates the inter-relationship between the elements of project design and the outcomes. As the design of assessment is integral to the overall project design this has also been incorporated into the figure in the form of a step-by-step model. The steps within the model are covered in more detail in the following sections.



Adapted from Assessment: A Guide for Lecturers, LTSN Generic Centre, George Brown [vii]

8.3 Characteristics of good assessments

Well designed assessments can assist student learning, impacting adversely on both the learning process and the subject matter. Every effort must be made to ensure that assessment is applicable and robust; a good assessment strategy should show:

- Validity –The methods adopted must be appropriate to assess the learning outcomes
- Reliability – The assessment should be repeatable, accurate and objective
- Affordability – The assessment should be time and cost efficient. This is often linked to reliability, eg second marking can double the time taken, substantially increasing the staff costs

It can also be helpful to think of assessment as having four purposes:

Purpose	Implementation Notes
Formative – giving feedback that helps the student to shape his or her future learning identifying strengths and areas for development.	Used well, smaller tasks to be completed in the earlier stages of a module can enhance student performance thorough constructive feedback and encouragement. Phased assessment also provides module teams with an early 'warning system', identifying those students experiencing difficulties and acting as a barometer on the effectiveness of the teaching and learning strategy.
Summative – providing a judgment of performance, such as a grade or degree classification.	If summative assessment is used it should be underpinned by mechanisms designed to elicit individual student engagement and ability, e.g. student – tutor meetings, presentations, peer review. This helps to minimise the potential for student under achievement or possible failure.
Diagnostic – helping the lecturer identify which parts of the programme are causing difficulties	If any difficulties are identifies it is important to quickly take any measures deemed appropriate to address them
Informative – providing the student with a clear understanding of the purpose of the module and how it integrates with their other studies.	Contextualising the assessment with respect to the curriculum is important so that students have a sense of feeling central to the learning process.

The assessment process should therefore provide students with feedback on their learning and their performance and staff with feedback on the effectiveness of the teaching and assessment strategy.

Case Study 11 by Simon Tait, University of Sheffield describes how a group design project has been developed to introduce business and enterprise to civil engineering students at the University and provides an example of how a staged assessment is beneficial for students:

> *"At the end of each of these three stages the students attend an assessed meeting at which they present their ideas and their analysis of those ideas to the project tutors. The students are given feedback on their performance. This progressive type of assessment is considered to be very helpful in guiding students as to the performance expected of them in terms of the level and depth of ideas and analysis. At the end of the project the groups put together a final feasibility study report. This is a written document in which each group reports on the activities in each of the three stages."*

Formative assessment should be incorporated into all project work through continuous review and feedback. This is likely to result in improved quality of submissions for summative assessments. Formative assessment can easily be embedded, for example through student - tutor meetings to discuss log books which the learner has completed, presentations, or from scheduled peer review.

8.3.1 Plagiarism

Pressures on students, a lack of understanding by students of plagiarism and its importance, and poor assessment practices can contribute to plagiarism. International students, in particular, may not realise how seriously plagiarism is viewed in the UK.

There are a number of strategies that can be adopted to combat plagiarism:

- set assignments which limit opportunities for plagiarism, i.e. which reward higher order thinking skills and are not easily 'borrowed'
- raise awareness about:
  - what plagiarism is
  - why it is unacceptable
  - the penalties for plagiarism
  - the assessment criteria
- try not to set the same project title year after year
- involve students in the design of assessment tasks and the setting of assessment criteria for example through the use of negotiated learning contracts

The Joint Information System Committee (JISC) provide a useful online Plagiarism Advisory Service[viii]. This new service was inaugurated in September 2002 and is based in the Information Management Research Institute at Northumbria University. The service, aims to raise awareness of plagiarism in the academic community by providing:

- Generic advice for institutions, academic staff and students
- Educational tools for students in the area of plagiarism
- A portal to external online resources on the issue of plagiarism
- Guidance on copyright and data protection issues relating to plagiarism
- A link to the electronic detection service and training on its use

8.3.2 Assessing students with special educational needs

Many of the assessment methods within project work can create particular problems for students with special educational needs and disabilities. These difficulties can be in accessing resources for the assessment, rate of knowledge transfer or processing, or the ability to communicate the assessment. Many universities provide advice on assisting students with disabilities or learning difficulties, information is available on the Teachability web site [ix] and via a report commissioned by LTSN Engineering [x].

8.4 Assessment methods

The assessment method is the process that is applied to determine whether the student has achieved the relevant learning outcome(s).

For project work a range of assessment methods is available. Each method can be used to assess a range of different skills, and be evaluated, either formatively or summatively, by different assessors.

The following table outlines assessment methods that are frequently used within engineering projects, together with skills typically developed, some examples and comments linked to assessment methods, and appropriate personnel to act as assessors.

Method	Skills	Notes	Assessors
Written Report	Knowledge and application of theory Problem-solving Research / Independent learning Writing and desktop publishing	Case Study 6 (Peter Willmot, Loughborough University) describes how the first written project report is the detailed project brief: "We prefer that students are not provided with a detailed written brief as the first task is for the team to get to grips with the problem and generate their own detailed specification."	Tutors External assessors
Product, prototype or model	Problem-solving Design and manufacture	Depending upon the learning outcomes this can be assessed on a wide range of criteria including aesthetics, ergonomics, quality, design.	Tutor Peers Practising engineer
Performance Testing / Product Performance	Evaluation	Where the project has a physical end product, performance testing may be the most relevant assessment method. Project diaries and lab books can record progress and methodology and contribute a part of the final mark	Tutor
Learning log / diary	Independent learning	Style and structure should be clearly specified as there are a wide variety of formats eg templates completed for each task. By scheduling regular progress reports students will reflect on their progress to date and can receive invaluable feedback to help them progress.	Tutor Peers Mentors

Method	Skills	Notes	Assessors
Viva voce	Understanding Communication Reasoning	The viva voce examination should be structured and objective. Gives students the opportunity to verbally support their work and to defend it. This situation closely parallels work based scenarios.	Tutor Practising engineer
Presentation	Knowledge Understanding Ability to structure information and oral communication skills	Models a common work based scenario, questions from peers, tutors and employers can provide useful formative feedback.	Tutors Self Peers engineer
Poster	Presentation Communication Knowledge and application of theory	At some institutions students present a mid project poster with staff and students present and asking questions. Attendance by students from earlier levels can generate interest, add an element of competitiveness, indicate scope and what can be attained and ensure they start considering the project at an early stage.	Tutors Peers Practising engineer
Portfolio	Creativity Computer aided design skills.	A portfolio is more than a report and incorporates a number of project outputs. Often used for conceptual design projects. Increasingly these portfolios are containing diagrams from CAD and 3D modelling packages, which may be supported by initial designs and sketches	Tutors Mentor Peers Practising engineer
Written examination	Knowledge based skills Numerical skills	Pre-seen scenario open book examinations may be suitable for assessment, but traditional written exams are often not appropriate to assess many of the learning outcomes that result from projects.	Tutors

It is common that a number of different assessment methods and outputs are used within one project and it is important that these are appropriately weighted and scheduled to ensure ongoing student motivation and a manageable workload. Note: the choice of assessment method will determine the assessment workload.

It is important to review the assessment methods for their relevance to the desired learning outcomes and in relation to the criteria and marking. It is also worth considering:

- is the assessment method consistent with the level?
    - if not can more demanding / simpler tasks be set?
    - or if not should the method be changed?
- is the assessment load consistent with similarly weighted modules?
- does the assessment provide added value?

The next step is then to design an assessment schedule and produce an assignment specification for the project.

8.4.1 Assignment specification

A project is usually defined by a written technical specification. A specification should usually contain information on the following elements:

1. Assignment brief (covering the general outline of the project)
2. Learning outcomes
3. Assessment methods
4. Assessment outputs and weightings
5. Work and assessment schedule
6. Assessment criteria
7. Resources
8. Budgetary information
9. Supervision and support
10. References to supporting documentation

The level of detail in the specification is dependent upon: the time allocated for the project the intended learning outcomes, and the existing skill and knowledge base of the students.

Case Study 4 by Norton Farrow and Colin Fryer from the School of Design, Technology and Built Environment at University of Derby describes how progressive learning is fostered through scenario-based assessment. This case study provides an example of how they structure an assignment and project brief and the key factors that must be specified:

"Experience has shown that for project-based learning to be successful, it is essential for all assignments to conform to a standard template that includes:

1. *The submission date.*
2. *An overview of the assignment, locating it within the subject area and defining its relationship with other topics within the module and the programme as a whole, i.e. conceptual/contextual relationship*

3. Those learning outcomes to be achieved on completion of the assignment.
4. A brief specifying the nature and content of the assignment.
5. A clear statement of what the student is required to undertake in order to complete the assignment.
6. Recommended reference material that may be helpful as a starting point when undertaking the assignment.
7. Performance criteria specifying what is expected at the different levels of performance. For example, at final stage honours degree performance criteria were specified for first class, upper second, lower second, third, pass and fail.
8. The assessment weighting."

The terminology and language of the assignment specification are also crucial. Some topics may appear to generate little interest and enthusiasm from the outset as they don't provide relevant context. For example, a final year project title at Loughborough 'The analysis of buckling in thin walled cylinders' aroused no interest at all from prospective students whereas, the following year, the same project: offered as 'Crushing soft drinks cans' was a big hit.

Similarly, classic undergraduate structural or dynamic problems are frequently set as projects, often in earlier years, and raise little real enthusiasm. For example, "a D-metre diameter steel water container has a mass of X-kg it is held at H-metres above the ground and is acted upon by forces P, Q and R from this information, design suitable support members" will generate little interest and motivation and may be seen as a coursework chore. Conversely a competition, pitching one team against another, setting the problem into a realistic environment and possibly offering prizes can achieve the same educational outcomes but will be more enthusiastically tackled and enhance the learning experience. A degree of scope for flare and or invention can be introduced and varied according to the intended learning outcomes and assessment methods employed.

It is important to provide a context for the assignment as it will help the students to understand why they are carrying out the project and enhance motivation. This context should be in the form of technical, commercial and social considerations, and incorporated into the assessment methods. This will assist the learners in relating to the project which will improve their motivation.

Case Study 1 by Peter Hedges, Aston University, describes how project work is incorporated into a simulated public inquiry run during the second year of the Civil Engineering degree programmes at the University. The case study incorporates scheduled assessment outputs as illustrated by the project schedule below:

Week 1	*i)*	*Introductory briefing*
	ii)	*Issue of Project Format and Engineering Report*
	iii)	*Urban Renewal Case Study and ranking exercise*

Week 2	*i)*	*Discussion on operation of Broad Oak Scheme*
	ii)	*Film on history and consequences of a reservoir development*
	iii)	*First requests for information*
Week 3	*i)*	*The Planning System and the Format of a Public Inquiry*
	ii)	*Video of proposed development area*
	iii)	*Selection by each group of preferred development option* (Group Report 15%)
	iv)	*Issue of and requests for additional information*
Week 4	*i)*	*Allocation of groups' roles for Public Inquiry*
	ii)	*Team Skills*
	iii)	*Issue of and requests for additional information*
Week 5	*i)*	*Introduction to Proofs of Evidence*
	ii)	*The role of the Expert Witness*
	iii)	*Issue of and requests for additional information*
Week 6	*i)*	*Preparation of Proofs of Evidence*
	ii)	*Issue of and requests for additional information*
Week 7	*i)*	*Submission of Proofs of Evidence* (Individual Assignment 25%)
	ii)	*Preparation for 'reporting' on Inquiry*
	iii)	*Issue of and requests for additional information*
Week 8	*i)*	*Preparation for Inquiry: rebuttal of evidence*
	ii)	*Distribution of Proofs of Evidence*
	iii)	*Final issue of additional information*
Week 9	*PUBLIC INQUIRY* (Individual Performance 25%)	
Week 10	*i)*	*Submission of 'reports' on Public Inquiry* (Individual Report 15%)
	ii)	*Evaluation and feedback on project*
	iii)	*Self/Peer-Assessment* (Peer Assessment 20%)

The assessment procedures must indicate to the students the form and content of what they should be learning. Techniques should not only be accurately targeted but also be clear to students. It is important that staff and student expectations of what is required are well matched and are seen to be appropriate to the project. One method of transparently communicating the outcomes, the assessment method, and the submission date is to adopt an assessment matrix (see below)

Outcomes	Assessment method	Weighting	Submission date, by end of…
LO1	Project Plan	10%	Week 2
LO2	Presentation	30%	Week 5
LO3	Learning logs	20%	Week 8
LO4	Report	40%	Week 10

For a more detailed example see Case Study 3 by Melvyn Dodridge, University of Derby, which describes learning outcomes and their assessment in independent studies.

For multidisciplinary group projects the description should clearly identify individual elements and their relevance to specific groups of students from the various disciplines involved.

Supporting materials for producing the outputs may also be required, for example guides on delivering presentations, producing posters, writing reports and laboratory work.

8.5 Grading

Grading within project work is often difficult, as some of the skills that are being assessed, such as teamwork and communication, can often not be marked on the basis of written work alone. Alternative grading methods will have to be adopted for different skills. The use of a pro-forma for recording notes in presentations or viva voce examinations can provide a useful aid. When determining the grading method the tutor needs to ensure that the assessment is reliable, valid and affordable and to ensure that all of the learning outcomes have been achieved.

Two broadly different approaches can be adopted for grading projects: a criteria based approach or a marking scheme. The approach adopted will often depend upon the assessment output and both approaches may be combined for different aspects within one project.

8.5.1 Criteria based approach

In a criteria based approach one or more complete project outputs is graded globally by reference to a list of performance criteria or statements for a particular grade. Grades are usually categorised into broad divisions for example A, B, C, D, E, F (fail), rather than allocating percentage marks. Performance criteria should be related to the specific achievements expected of students as stated in the learning outcomes and therefore should be concise and focused. This approach is often adopted for designs, models and portfolios.

When writing performance criteria it is important not to make them too detailed as this can make it difficult to reward students that have adopted diverse but valid approaches to the project. There is also a danger that inadvertently the student is provided with a prescriptive guide for completing the assessment rather than developing their own approach through applying problem solving skills.

Case Study 5 by Warren Houghton, University of Exeter, describes how intended learning outcomes and assessment criteria have been developed within Engineering at the University of Exeter. They have adopted a criteria based approach which they have found to be effective. An extract from the Project Assessment criteria follows which indicates a small selection of the assessment and marking criteria:

<table>
<tr><th>Mark out of 10:</th><th>0-3</th><th>3-4</th><th></th><th>8-9</th><th>9-10</th></tr>
<tr><td>General</td><td>Completely unsatisfactory. Almost nothing to show for any work that has been put in.</td><td>Unsatisfactory. Aims not met. No evidence of any real progress. Nothing worthwhile produced, although evidence of some work, albeit unsuccessful.</td><td rowspan="3">....</td><td>Outstanding. A member of staff could be proud of this work. No student could reasonably be expected to achieve much more or present it better with the time and resources available.
In the top 5% of projects.</td><td>Clear candidate for best project of the year.</td></tr>
<tr><td rowspan="2">Preliminary report, preparation and literature review (progress report for group projects)</td><td colspan="2">Unsatisfactory report</td><td colspan="2">Good report</td></tr>
<tr><td>Little or no evidence of any research whatsoever.</td><td>One or two sources (probably books or magazine articles) read.</td><td colspan="2">Literature survey very systematic and comprehensive, student able to talk with confidence about other work in the field.</td></tr>
<tr><td colspan="3">...</td><td></td><td colspan="2">....</td></tr>
<tr><td>Individual contribution to Group functioning

(Group projects only)</td><td>No evidence of any communication with other members of the group, or behaviour towards rest of group entirely destructive</td><td>Little evidence of communication with other members of the group, or little positive contribution to group discussions</td><td>....</td><td colspan="2">A deep understanding of the group roles, strengths and weaknesses of all group members including self. Can use this analysis to modify own behaviour appropriately and support all other group members so as optimise both their performance and that of the group as a whole. Aware of the personal development of other group members and can give them constructive guidance.</td></tr>
</table>

8.5.2 Marking schemes

With marking schemes, the project is broken down into individual elements, marks are awarded for each element and the marks are aggregated according to pre-defined weightings within the scheme to produce an overall score. To help with this method of marking checklists are often used. However this method of marking can become particularly time consuming for lengthy pieces of project work, particularly if they are poorly structured. This method is usually adopted for exams and linearly constructed written work.

8.5.3 Methods of reducing marking time

Marking projects can be quite time intensive and there are several methods of reducing marking time within project work.

- By clearly specifying the assessment criteria and specifying size limits students will be encouraged to develop quality rather than quantity in their assessment outputs
- Providing both written and oral guidance on what is required will mean that fewer pieces of work are a long way off target; such work often takes a long time to correct
- It may also be appropriate to delegate marking within projects provided that appropriate assessment and grading methods are defined. This can be to peers, for presentations and posters, and to research staff for other aspects of project work, particularly those staff who have undertaken similar project work previously and have been appropriately trained.
- If students submit joint group reports repetitive marking is substantially reduced..
- Structured interim assessments reduce the weighting for the final assessed work, distribute the marking load more evenly throughout the project, and again reduce the risk of off-target work.

8.5.4 Computer applications within assessment

A wide range of computer applications can aid assessment, in terms of reducing marking time and administration. The following table provides a brief overview.

Application	Benefits
Formative and summative computer aided assessments	Fast marking time, can provide immediate feedback
Online coursework submission	Reduced administrative load
Recording and tracking of assessment marks	Quick and easy collation and monitoring
Plagiarism detection software	Useful for electronic documents or searching for a specific phrase or extract
Online assessment of peers marks	Anonymous, built in algorithm reduces collation time
Online learning logs	Easy to monitor, search, sort and read
Providing online assessment materials	Low cost, easy to organise
Assessment notice board	Immediate access

Computer based assessments can reduce marking and administrative time but often have a substantial set-up time. As projects also can be time intensive for academics to design and run these time considerations should be weighed up before embarking on computer based assessments in projects.

To reduce the set-up time you may be able to re-use existing questions and frameworks as part of your project assessment provided they are appropriate to meet the needs of the aims and learning outcomes of your project.

The online National CAA Centre[xi] provides information and guidance on the use of computer-assisted assessment (CAA) in higher education and offers information about a range of CAA resources, available in paper and electronic formats, including:

- Bluepapers: a series of in-depth papers covering a range of CAA related issues.
- Bibliography: contains links to materials and articles that have been written by members of the Centre.
- Online Resources: links to CAA related websites
- FAQs: answers to some of the most frequently asked questions about CAA
- Guide to Objective Tests: An excellent resource on objective tests

There is further information in Section 9 which relates to how computer applications can be used to support projects. For an example of how information and communication technology can be used extensively within a project see case study 2 by Patrick Littlehales of Aston University which describes 'facilitating collaborative design through ICT'.

8.5.5 Peer and self assessment

For individual and group projects the use of self and peer assessment can often help students gain an understanding of skills, knowledge and the learning process. Peer assessment also allows rapid feedback even with a large number of students.

Self Assessment - Students make a judgement about the standard of their own work. It can be applied to a broad range of formative and summative assessment types which incorporate part or all of a project including reports, oral and poster presentations, and design portfolios etc.

Peer Assessment – Students make a judgement about other students' work, ie they are involved in the assessment of the learning of others. Peer assessment can also be formative or summative and applied to many differing types of project assessment. Unlike self assessment, peer assessment can be anonymous. Assessment may be carried out by one student assessing the work of another student or by a group of students assessing the work of others.

It should be noted that group based assessment of project work may incorporate both self and peer assessments. For example, within a project self assessment may be undertaken by individuals or the group as a whole; peer assessment could take the form of students from the same or different groups assessing each others project work.

There are a number of benefits to self and peer assessment:

Student benefits	Staff benefits
• Improving student learning - increased student ownership of learning - promotes “deep” learning based on understanding and reflection - develops students’ independent learning skills • Supporting skill development in a number of areas eg - team working - communication - interpersonal - organisational • Enhancing motivation and enthusiasm - encourages active participation in the learning process - makes assessment a shared, collaborative activity • Increasing level of feedback - improved understanding of assessment requirements - can strengthen future performance	• Increasing opportunities to monitor student progress and identify potential problems • Strengthening assessment criteria and marking schemes The utilisation of self and peer assessment methods invites a re-visiting of how achievements are to be evidenced and judged. • Promoting student centred learning Self and peer assessment necessitates that assessment is part of the learning process and that students are active participants in their learning.

There are also some risks associated with self and peer assisted learning. Self and peer assessment challenges well-established beliefs about who should rightfully assess students work and the respective roles/responsibilities of lecturers and students. The methods can be contentious and invite debate about the maintenance of standards.

Prior to implementation, it is advisable to involve colleagues and external examiners in discussions about the introduction of self/peer assessment and to explore issues related to design, implementation and review.

Time is needed in setting up self/ peer assessment processes within a project, allocate time for:

- assessment briefings and supporting papers
- developing skills in students to undertake what may be new and threatening roles
- tracking and monitoring progress
- constructing assessment criteria and ensuring a good appreciation of their

meaning
- debriefing following completion of assessment process

Student Response
Students may feel anxious when embarking on self and/or peer assessment due to fears about the impartiality of students when undertaking the assessment of other students or worries about the impact on relationships with other students where assessment outcomes may not have been favourable. Such concerns should not be minimised and opportunities must be made for these anxieties to be aired and considered.

Awarding marks
In group or team projects it is important to determine the requirement and procedures for awarding individual marks. A written report produced by a group can make effective use of resources since all members of the group can share a range of procedures and processes without needless repetition in the report production. In some group projects students may be individually responsible and marked for specific sections of the finished work. In other cases individual marks within groups can be adjusted according to peer weighted marks. Ensuring that the students understand the criteria used for any form of assessment helps avoid heated debates in the latter stages and can lead to better submissions.

The LTSN Engineering Working Group Report: Assessment of Individuals in Teams[xii] contains a number of case studies which have adopted peer assessment as part of their group based project assessment. A brief summary of the methods employed is described within the case studies in this report. For further details on methods of deriving individual grades from group assessments see Lejk et al, 1996[xiii].

8.6 Summary

The key principles of assessment are:

- assessment and learning are integrated
- assessment methods must be aligned to the learning outcomes
- appropriate criteria must be matched to the methods
- frequent appropriate feedback is required
- marking must be reliable and valid

The following steps are a guide to production of effective assessment:

- Review the learning outcomes
- Identify performance criteria for each outcome
- Look at alternative assessment methods
- Decide which methods will best test the essential intended learning outcomes
- Determine what tasks the students will undertake

- Determine what outputs will be produced
- Develop a method of grading the outputs
- Develop an assessment schedule
- Produce an assignment brief

8.7 Endnotes

(1) Quality Assurance Agency for Higher Education, 2000, *Subject Benchmark Statements: Engineering*
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8.8 Additional references

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Section 9 Supporting Individuals and Groups

This section of the guide:

- explains why learner support is important for projects
- identifies mechanisms for providing support to learners
- explores peer support and supporting teams
- examines health and safety issues
- looks at how to identify and rescue failing projects
- provides illustrative examples of support in Engineering projects

Learning through projects requires support both for the theory and content and for the process skills that are developed through a project. The support that the students require will depend upon the nature of the project and the assessments and on the familiarity the students have with project work.

It is particularly important that students, who are new to an aspect of project work, such as teamworking, are provided with support and guidance throughout this process.

9.1 What support is required for learners undertaking projects?

Within projects the support should be aligned to the learning outcomes and the assessments, especially if it is intended to develop a skill or attribute which students have had little previous need to demonstrate.

As a greater number of skills and attributes are usually developed during projects than through more traditional forms of teaching, a wider range of support is required. This support can cover areas such as:

- Encouraging effective team working
- Developing problem-solving skills
- Ensuring good communication in presentations and vivas
- Developing independent learning skills
- Developing IT skills

Projects can be a vital step to building students confidence and provide valuable support to students. Case Study 12 by Andrew McLaren, University of Strathclyde, highlights the importance of using projects to provide student encouragement:

"First year engineering students need support in the transition from school to university study. The new class "Design and Engineering Applications 1", which accounts for 25% of the credit load for first year Mechanical Engineers, seeks to provide this support while giving an introduction to engineering design. The class aims to illustrate the relevance of the students' engineering science classes to the design process, to build the students' confidence in their own abilities and motivate them to research and discover things for themselves."

The same case study also illustrates how peer and tutor support provide a good environment for developing other skills:

"They are encouraged to study and find things out for themselves, and to estimate, simplify and approximate. The class is largely taught and assessed in groups of four students, which develops team working and presentation skills."

9.2 Support roles

As alternative approaches to learning are adopted and students develop new skills within projects other support options can become available:

- for group projects, support on theory, communication and team working skills can be provided by peers.
- within individual projects feedback and support can again be provided by peers through review of presentations and posters.
- if students become effective independent learners it may be possible to provide them with paper-based self-support materials
- online support tools are now available to enable students to track and audit their own key skills, which helps students take control of their learning

This does not overcome the need for support from project tutors, but it can reduce the tutor's workload and help students further develop their skills through projects.

9.2.1 Project tutor

The project tutor is responsible for the co-ordination and monitoring of support. This co-ordination includes:

- putting appropriate support procedures in place
- making students aware of support mechanisms
- organising regular supervision meetings between supervisor(s) and students
- ensuring that there is adequate record keeping of meetings
- identifying support requirements by tracking progress against the project plan
- co-ordinating and monitoring support from other staff, including other project supervisors (particularly for multi-disciplinary projects), industrial partners, and other resource providers eg technical, IT, and library support staff
- providing timely and appropriate feedback

For individual projects the supervisor should encourage the student to accept responsibility for managing the project and progressing the tasks to a conclusion within the time scales agreed. It is most important that the supervisor reviews progress with the student on a regular basis to ensure that they are progressing on schedule and taking responsibility for their project. The interval between reviews will depend on the project length and student level.

For group projects the supervisor needs to ensure that there are regular team meetings and to monitor support and feedback within team meetings.

A range of support mechanisms are available to the project tutor. These, and their advantages, are outlined in the following table.

Support mechanism	Advantages
Paper-based support materials	encourages independent learning, a re-usable resource
Lectures/seminars	allow detailed support on theory/skills and immediate response to queries.
Notice board for online support materials	low cost, easy to update and access
Discussion board	avoids re-answering the same queries
E-mail	immediacy, ease of use, privacy if required
Monitoring learner logs	identifies where students have been focusing their efforts, and which skills they have been developing
Assessment feedback	essential to keep students on track, and to identify where support is required
Group meeting facilitation	allows students to develop team working skills, to guide them to appropriate support and identify problems which require intervention
Meeting supervision	allows detailed tailored support, substantial opportunity for feedback
Group debriefing/reflection sessions	allows students (with guidance) to reflect on their current performance and identify strategies for improvement.

9.2.2 Self support

As students become independent learners and more aware of their preferred learning style, they will become increasingly comfortable with supporting particular skills through self support. The self support materials may be either:

- self sought
- supplied by the tutor
- provided as a suite of online support materials.

Case Study 2, by Patrick Littlehales, Aston University successfully facilitated collaborative design through ICT for a multi-institution project run around-the -clock in 3 different time zones:

> *"A new online environment to facilitate experiential learning projects was developed from a simple web based communications mechanism, used in undergraduate programmes. This interactive environment which logged the development process overcame the need for unregulated email and had the feature of keeping all team members fully informed of progress. This record of the development process was a valuable project output, consisting of a narrative, media rich documentary."*

Teamworking and support across the institutions was also successfully facilitated, during this case study, using NetMeeting:

> *"The project used NetMeeting, available with MS Windows operating systems, to enable group to group discussion at handover sessions. This component was easy to use and configure and provided audio, web-cam video and text communication between networked computers"*

Online support tools are now available to enable students to track and audit their own key skills, such as RAPID[xiv] to record academic professional and individual development.

These self audit tools help students take control of their learning, identify which skills they need to develop and determine where further support is required

9.2.3 Peer Support

Peer support is also a valuable means of providing support amongst students, particularly within a team project. This peer support is often enhanced by defining guidelines or by adopting a particular peer support format or structure.

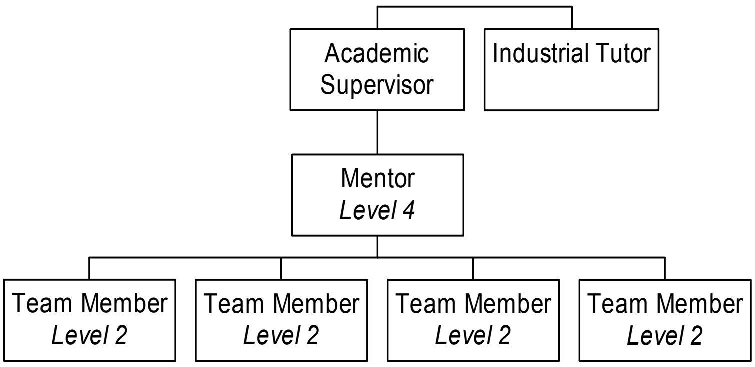
Case Study 10 by Colin Smith, University of Sheffield, offers explicit team training to develop team working and support mechanisms within a civil engineering student cohort:

> *"Rather than expect students to develop team skills indirectly as part of the process of working in a group, it was felt that they would get more from the exercise if they were*

given some initial teamworking training. Mistakes made in the training could be learnt from, enabling students to approach their project more confidently and see the direct benefit of the skills that they had learnt."

Student mentors from a senior year may also be used to provide additional peer support and guidance.
Case Study 7, by Peter Willmot, Loughborough University, shows how a mechanical engineering MEng Module was developed which helped widen the project based learning experience for final year students by allocating them as mentors to provide project supervision and support:

"Finalist M.Eng students are appointed as mentors to a team of four younger students engaged in an industry based research and design project. Through this, they gain first-hand experience of project management and leadership. The experience is built into a module offering practical support and opportunities for self-reflection...”



Group Structure

...The mentoring experience forms the major part of a final year module ‘Project Leadership’. This is a 10 credit module that, crucially, takes place at the same time as the mentors are themselves participating in a level 4 (30 credit) industry based team project, hence there are opportunities for the role of team-player to inform the task of leading a team through a smaller but similar style project. Students are encouraged, for example, to pass on their final year level experience at project planning and control to the second year team they are mentoring."

In undertaking this peer based mentoring the mentors develop responsibility and a professional attitude which reaps benefits in other project work:

"What is most noticeable is the mature attitude the finalists invariably bring to this work. The motivation not to let their charges down is very high, but the acquired responsibility of mentoring a team also influences the attitude to the parallel final year project work where we now see an unprecedented degree of professionalism."

Structures may also be set up to facilitate peer teaching. For example, in place of a tutor centred lecture on a range of technical topics, teams may be allocated one topic each and be required to research it themselves. They then make short presentations to the whole class, perhaps providing a resource pack aswell. This interim exercise not only transfers technical information but develops skills. The tutor must however, be familiar with the material so that he or she can fill in gaps or make corrections as appropriate to the presentations.

9.3 Project Teams

Students usually enjoy team-working when the team is working well. Motivation is high when competent and hard working students support and encourage each other. Unfortunately, the opposite is also true and a student who is part of an ineffective or disruptive team is likely to remember only the conflicts and achieve little.

Case Study 12 by Andrew McLaren, University of Strathclyde, highlights how to address difficulties that can arise in teams within mechanical engineering project work if there is not an equal distribution of effort:

> *"The high level of group working necessitates some checks and balances to ensure that all group members have contributed equally to the group effort. This is achieved by confidential peer marking exercises, which are completed by students during the course. Peer marking sheets require each student to award a share of some arbitrary quantity of marks to each group member, including themselves, with some words of justification. This method quickly reveals "passengers", and also shows up possible personality conflicts within groups."*

This means that great care must be taken in putting teams together, in monitoring their work, and in developing appropriate skills.

Case Study 8 by Barry Lennox, University of Manchester, describes how they deal with the issue of groups that have 'passengers' in the School of Engineering:

> *The single, largest problem that has been encountered with the PBL programme is that associated with 'passengers'. Each group contains 1 or 2 students that provide little or no contribution. In the first year that the programme ran, this problem was, perhaps naively, unexpected and students who had failed to contribute to the PBL activities continued to receive high group marks. This caused major resentment with hard working students, both towards PBL and their peers. To address the problem a peer review scheme has now been introduced. At the end of each PBL activity the students provide a grade, out of 5, for the contribution that each member of the group has made. These figures are then processed and the group work mark for each student is moderated accordingly. Students can appeal if they believe that they have been unfairly treated by their peers but must provide factual evidence to confirm that they have contributed. This evidence typically takes the form of minutes and attendance from the meetings that are routinely held during the PBL activities. Although there have been some practical problems with the peer review system, these are beginning to be ironed out and the students are becoming appeased with the procedure.*

Case Study 7, by Peter Willmot, Loughborough University, indicates how Leadership and team working skills can be developed through experience:

> *"Team leadership comes more easily to some than to others and some candidates are surprisingly ill at ease in this situation in the first instance. They are usually self-critical when asked and noticeably improve as they gain experience"*

9.3.1 Size

Choosing the team size

Size matters.

The Learning Objectives and Module Specification will normally dictate whether the project is to be an individual or team effort. If run on a team basis, the team size will depend on cohort numbers, the tasks involved and the resource provision. However, teams of 3 or 4 generally work well, while those beyond 5 or 6 generally become unmanageable.

The number of possible interactions between pairs in a group (of size n) is given by:

$$n(n - 1)/2$$

In a team of 4 there are 6 possible interactions, in a team of 8 there are 28.

Space matters too.

Timetabling for teams is a bigger problem than commonly thought, particularly with large cohorts, but good, appropriate rooms make for good projects. An effective meeting space is crucial if students are to work in teams without supervision. A studio environment with dividers and conference tables is desirable.

Factors influencing team size

Factors likely to influence team size include:

Factor	Comment
Overall numbers	If there are very large numbers overall it can be tempting to increase the team size. Experience does suggest that 6 is the practical limit for effective teams.
Complexity of the task	The team has to manage itself, its members, and the task. If the task is very complex then this may not leave time or energy for managing the team.
Skills mix	It may be desirable to bring together a particular combination of skills – especially in inter-disciplinary projects – this can influence team size.
Roles in teams	There may be particular roles that need to be performed. This can be particularly important in multi-disciplinary projects

Team skills of members	One of the requirements for a successful team is that its members can work well together. An inexperienced team, working on a complex task, probably needs to be smaller rather than larger.
Ease of meeting	For the team to function it has to be able to meet. It is usually harder to arrange a meeting of a large team than a small one.
Venue	Does the team have somewhere to meet? The availability of a team base room is often seen as critical to success.

9.3.2 Virtual teams

The use of email has changed the nature of many teams. Virtual teams (sometimes called computer mediated communication – or cmc – teams) can operate effectively, although they usually work best if there is also some face-to-face (f2f) meeting.

The dynamics of virtual teams are different. People who are timid in face-to-face teams may become more forceful in a virtual team because the method of communication is different.

Email or some other form of online discussion can be used to supplement the team's meetings, and this may allow the use of larger teams than would otherwise be the case.

9.3.3 Team selection

Team selection is critically important and there are several options available:

- Self Selected - students pick their own teams
- Tutor Selected - the tutor selects the teams
- Tutor Seeded - the tutor selects some members and the students select the rest

Not surprisingly there are advantages and disadvantages associated with each of these. There are also issues about roles within teams. The Tutor Seeded approach, for instance, may mean that the tutor selects the team leader, but this is also possible with the other approaches too.

These will be discussed in more detail a little later; there are, though, some basic principles that will apply whatever selection method is used:

- everyone should be a member of a team
- teams should be of approximately equal sizes
- team membership should normally be stable
- it should be possible to assess students fairly
- it should be possible to take account of minorities
- the tutor should have a record of team members

Special support may be needed for teams with minority members, and it may not be the minority member who needs the support. It is always worth asking whether there are individuals who may feel uncomfortable in teams, or whether there are teams that may feel uncomfortable with some of their members. A confidential discussion with any such individuals will be a good start to addressing any issues.

Decision about how to select teams will be driven by aims and outcomes. If the primary aim is to develop technical skills this may lead to different decisions from someone whose primary aim is to develop skills of team-working.

Self Selected

Pros	Can encourage student participation. • Can naturally take account of social factors that might otherwise be missed, eg teams of students may share living accommodation or workplaces, making it convenient for them to work together. • For students following a range of options, self selection may overcome timetable conflicts which can otherwise make collaboration a major difficulty.
Cons	• Self selected teams can create wide ability variations as the better students join forces. This may be less of a problem then might be expected, since good teamwork can compensate for lack of individual ability. • The main danger is the isolation of individuals who are recent arrivals, perceived to be difficult, or less able.
Comments	• Teams that are allowed to self select will do so through three principal drivers: established friendships, ability levels and geographical proximity. • Members of minority teams may cluster together. You have to decide whether this is acceptable. • If you allow self selection then you must have mechanisms to deal with the students who are left out.

Tutor Selected

Pros	• Equality of selection process – as long as is genuinely is equal. • Can encourage students of different abilities or backgrounds to work together. • Multidisciplinary teams may be built by monitoring the participants' choice of optional modules for example, or by selecting mixed abilities through previous examination results. • Imitates industry hence students must become accomplished at getting along with others.
Cons	• With tutor selection there will always be complaints from students not allowed to work together, resulting in rumbling disquiet and reduced enthusiasm.

Comments	• Assessment mechanisms must be fair. • It must be possible to justify the approach to the students, the QAA, and – possibly – parents.

Seeding Selected

Pros	• Can encourage students of different abilities or backgrounds to work together. • Guarantees a minimum level of ability in all teams and avoids the totally weak teams which may arise from pure self selection. • Enforces an element of team mixing, to foster valuable transferable skills, while retaining an element of self selection to promote harmony. • Ensures that the tutor can arrange the correct number of teams, of the correct size, in a short time.
Cons	• The selection of leaders by past academic record is relatively straightforward but the judgement of leadership qualities may be more difficult. • The possibility of conflict may arise, where individuals are dissatisfied with their team and react against the leader. • Where teams are made up from different years of the course, or in multidisciplinary projects, it may be difficult to achieve an even distribution of skills or experience.
Comments	• May be the best or worst of both worlds.

In conclusion, all selection methods will bring advantages and disadvantages. Difficulties may relate to particular situations or individuals and may not generally. Examine each case individually and avoid change for change's sake.

Where teams are made up from different years of the course, or in multi-disciplinary projects, it may be difficult to achieve an even distribution of skills or experience. When severe imbalance occurs, the formation of "consultancies" should be considered. The members of the predominant element can gain essential input from individuals or sub-sections, serving more than one team.

The LTSN Engineering working group report 'assessment of Individuals in Teams'[xv] provides several examples of different approaches to group formation.

9.3.4 Team support

Regular meetings are required between students in the same team. To help a team to become self-supporting, tutors need to provide the following:

- guidance on how to team-work
- clear reporting mechanisms to help keep the team on track
- a formalised schedule of regular team meetings

Case Study 1 by Peter Hedges, Aston University, which describes the running of a simulated public enquiry for civil engineering students, highlights the importance of spending time meeting with students particularly if they are finding the work difficult:

"...ensuring that the less strong students, or those lacking in self-confidence are not pushed to the periphery or threatened by some of the activities, can be a challenge. Spending some time with each group every week, discretely supporting and drawing out the strengths of these students, has been found to be the best course of action."

The team meetings need to address student issues in relation to all of the project learning outcomes, for example not to focus solely on theory if process skills are important.

9.4 Health and safety issues

Standard health and safety procedures must be adopted when running a project. These procedures must be complied with in all project environments including, workshops, laboratories, project rooms and in industry or on-site for projects in conjunction with industry. It is worthwhile obtaining advice from the designated departmental health and safety officer.

Health and safety is an essential element of the support documentation and part of the briefing programme within project work.

The following is from “A Guide for Students” issued by The University of Nottingham, for Mechanical Engineering Courses. It is distributed to all students before the commencement of their individual projects:

Safety and use of laboratories and workshops
The University Safety Handbook sets out general safe working practice which students must follow. Every student should be in possession of a Safety Handbook. Particular attention should be paid to the Control of Substances Hazardous to Health (COSHH) Regulations 1988. You must not carry out any work which could expose yourself or others to hazardous substances, unless the risks and necessary precautions have been assessed. If a substance can damage health, it falls within the scope of the Regulations. For example, corrosive acids, toxic gases, wood dusts and solvent based typists' correction fluid all fall within the scope of COSHH. Substances already in use in the Department will have had an assessment carried out and you must read the safety information on them before they are used or fresh supplies are ordered. If you wish to use a substance which is new to the Department, a COSHH assessment must be carried out. This must be done in consultation with your supervisor who may ask you to undertake the following steps:
1 Gather all the relevant safety information.
2 ....etc

By looking at Health and Safety issues students also have the opportunity to assess risks and obtain experience of completing a risk assessment form. A risk assessment often forms part of the summative assessment schedule for projects. Risk assessment forms must be evaluated by the project tutor. If there is unnecessary risk it may be necessary to adapt the project aims, outcomes and assessment methods.

9.5 Rescuing failing projects

Sometimes even when a feasible project has been carefully designed, the full implementation may not progress as scheduled. This may be for reasons out of the project tutor's control and can result in substitution of parts (or all) of the project.

If a project is failing it is important that this is identified early to try and prevent problems from escalating. It is possible to identify a failing project by:

- acting as a facilitator for groups
- regularly reviewing learning logs
- facilitating and responding to e-mail correspondence
- careful setting and monitoring of project milestones
- using interim reports to provide an early warning of problems

Often a failing project can be rescued. In order to do this the tutor needs to diagnose why the project has failed. The following pointers offer a useful guide:

- identify the root causes of the failure
- identify positive outcomes and determine likelihood of complete failure
- take remedial action
- put appropriate support mechanisms in place
- increase the frequency of project monitoring and review

Group projects often start to fail due to a breakdown of communication within the group, which in turn often results from an uneven distribution of work within the group. There are a number of ways to seek to remedy this. If it is early in the project you may be able to restructure groups or talk to the group and do some team building. Later in the project it may be possible to subdivide tasks and allocate individual marks for those tasks, or to adopt a peer marking system which incorporates an appropriate weighting.

Despite attempts to assess the feasibility of a project, the full implementation may not go as planned in which case you may need to adopt mid-course correction techniques:

- issue a revised brief
- modify the assessment criteria
- substitute the project for a new one
- terminate the project

9.6 Summary

- learning through projects requires support both for the theory and content and for the process skills that are developed through a project.
- a variety of skills are often developed within a project that may be supported through a diverse range of mechanisms
- support within projects is available from peers, project tutor(s) and from the student
- the appropriate selection and structuring of groups is essential
- health and safety must be embedded and supported within the project
- it is important to identify failing projects early, and to put mechanisms in place to rescue and support them

9.7 Endnotes

(1) Recording Academic Professional and Individual Development (RAPID) http://rapid2k.lboro.ac.uk/

(2) Harris, B., 2002, "Assessment of Individuals in Teams", LTSN Engineering working group report http://www.ltsneng.ac.uk/downloads/resources/Bobharris_webfinal2.pdf

9.8 Additional references

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- London, Routledge
- Day, K., Grant, R. and Hounsell, D., 1998, *Reviewing your Teaching*, Edinburgh, CTLA
- Luck, M., 1999, *Your Student Research Project*, Aldershot, Gower
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Section 10 Resources

This section of the guide:

- identifies resource issues within projects
- explores the role of staff in resources
- identifies space and time constraints
- describes resource funding issues and opportunities
- considers equipment and consumable resources
- identifies library and computing resource issues

Project work often involves the student independently learning the relevant theory, designing and building models, carrying out product performance tests, producing posters, and delivering presentations. Due to the nature of the work involved in learning through projects a wide range of resources are often required by the student.

Project resources can be much more than the materials used for producing models. Within a project the provision and support of the following resources should be addressed:

- equipment, eg manufacturing machinery and consumables
- workspace resources, eg project rooms, computing laboratories, and workshops
- computing, eg online instructional materials and computer modelling packages
- library, eg texts, journals and videos
- staff resources, eg academics, administrators and laboratory technicians

These resources are limited by time and cost constraints, and will require management by both staff and students in order to use them to their full potential. Appropriate support materials and instruction will need to be incorporated into the project if new or different resources are to be effectively utilised.

Prior to running a project it is important to consider what minimum pre-requisite skills are required in order to use the resources, bearing in mind the time scale of the project and ability and level of the students. This will enable you to determine what additional support materials will be required.

10.1 Staff roles

The teaching schedule in project work has some significant differences from lecture-based programmes where a rigid timetable of events (lectures, tutorials, and laboratories) is set out in advance.

If the students undertake a significant proportion of independent learning within their project, it is likely that the project tutor will no longer be the primary source of information and will instead take the role of advisor or facilitator. In some instances the tutor will also be learning within the group, this is often the case for multidisciplinary projects.

It is important that the in-class support focuses on questioning the students' logic and reasoning. As a facilitator the tutor should:

- provide feedback on how the students are progressing
- help students identify where reasoning may have gone awry
- provide hints to keep students on track
- identify and help resolve communication issues, particularly for groups projects
- direct students to appropriate resources
- model effective approaches

This should be done whilst maximising the opportunity for students to develop problem-solving and independent learning skills.

A useful method of guiding students whilst developing problem-solving skills is through Socratic dialogue: this involves using focused, open-ended questions to create structured discussion. The use of Socratic dialogue encourages participants to reflect and think independently and critically.

Student	"Is this supporting beam of sufficient size?"
Tutor	"What is the purpose of the supporting beam?"
Student	"To support x, y and z."
Tutor	"How can you calculate the size needed to support x, y and z?"
Student	"I could calculate it by method A, B or C."
Tutor	"How can you determine whether A, B or C is the best method?" …etc

In addition to the project supervisor's time commitment and role, staff issues for colleagues should be considered. Where appropriate, colleagues should be consulted in producing the module specification, the project documentation, time tabling the project and assessment(s), and throughout the running of the project.

Colleagues whom the project tutor should consult include:

- workshop / laboratory technicians
- other academics contributing to the project
- teaching assistants / research assistants / student mentors
- library services

- computing support services
- departmental administrators
- industrial partners

It is important that the project learning outcomes and schedule are examined so that the best method of meeting the outcomes with the staff resources available can be determined.

It is also important to recognise that a shift to a more facilitative way of working will often require new skills, such as the Socratic Dialogue approach. Practice may be needed and there is a danger that – under pressure – staff will revert to more familiar didactic methods.

In order to determine staff roles and responsibilities the following need to be addressed:

- which staff are involved in supporting the project?
- what time can the staff members commit?
- how can they be best used to support the project?
- how will their input be scheduled (if scheduled)?
- how will students have access to staff?
- are staff aware of their roles and responsibilities to the project?

If there is involvement of specialists from other disciplines or industry it is crucial to arrange availability and access.

The way in which staff resources are delivered in projects may be new to students, so it is important that they are briefed on the staff resources that they have access to and on how to use them effectively. They, too, may tend to drift back to more familiar approaches.

10.2 Space

Space requirements for projects are often varied, involving seminar rooms, studios, computer suites, workshops and laboratories. Time-tabling can be a major issue particularly with large cohorts. It is important to work in conjunction with colleagues in addressing the space resources required and how they will be allocated. For example, project work carried out within a laboratory may have to fit in with projects from other modules and research work.

An effective meeting space is crucial if students are to work in teams without permanent supervision. In order to meet this need a number of engineering departments have developed project rooms which are studio environments, containing screen dividers, conference tables, swivel chairs and core project resources such as PC's and poster boards. The availability of suitable room space and the seating arrangements are likely to influence the size of student teams for group projects.

Case Study 6 by Peter Willmot at Loughborough University, which describes running team projects in co-operation with industry, identifies the importance of having a suitable work area and facilities for mechanical engineering project students:

> *"An important consideration in setting up such a scheme is the need to provide meeting space for a large number of teams at the same time. We provide a large studio with separate project areas and have a number of small study rooms for team meetings. Motivation is soon lost if suitable accommodation is not available. Coping with this demand has proved difficult however the income from the scheme has enabled us to gradually bring in additional presentation equipment etc.* "

One of the key factors that has been identified for the successful running of group projects is that each group should have its own independent work space.

For projects run in conjunction with industry the project tutor needs to ensure that, if students are carrying out project work within a company, they have a suitable work area and that health and safety requirements are met.

10.3 Time

Major operational problems result from the flexible time tabling of project work. Where students have different backgrounds or take different modules, the formation of groups and the time tabling need careful consideration.

10.3.1 Staff hours

Setting up a project

Experience from engineering academics indicates that there is a substantial set-up time the first time a new project is run, which diminishes substantially when the project is run again.

Case Study 12 by Andrew McLaren, University of Strathclyde, Department of Mechanical Engineering, provides an example of staff contact time for an intensive first year project class:

> *"The resource implications of such a class are significant. The intensive discussions with small groups of students, and the variety of activities that are involved, require substantial staff time if they are to have the maximum benefit for the students. As an example, in the mechanical dissection class four members of academic staff are on hand for six hours per week over 20 teaching weeks, during which time each group of four students will have individual discussions with at least two staff for in excess of two hours. However, given the goals of the class, and the high level of technical engagement which has been achieved by first year engineering students, this level of resource is deemed justified."*

This Case Study also identifies, for an innovative design class for first year mechanical engineers, that significant teaching input will be required before the project starts and the importance of careful project scheduling:

> *"The logistics and organisation of a class of this nature should not be under estimated. Highly complex timetabling issues have to be addressed, which involve staff from two departments and activities taking place in six locations. The schedule of events has evolved over the four years that the class has been run, so that sufficient capacity is built into the timetable to allow groups or individuals to catch up in the event of difficulties or illness. Simplicity in timetabling is vital so that each student and group know exactly where they should be and what they are doing at all times. Clear deadlines for completion of each element are detailed in advance. All timetables and scheduling information are given on the departmental web pages for ease of reference"*

On multi-disciplinary projects timetable conflicts across departments are likely to exist and therefore it is essential to limit the number of joint staff meetings. A formal meeting of all participating staff should be held as early as possible, where action, responsibilities and dates can be agreed.

Running a project
Both students and staff can become increasingly motivated through involvement in a successful project and spend more time on project activities than anticipated. It is therefore important to track and manage time spent on project work and for students to develop their own time management and project planning skills.

Various tools and techniques are readily available for project planning and the supervisor should decide which are most appropriate, taking into account the scope of the project and the time available. PERT (Project evaluation and review technique) or CPM (Critical path method) methods are more applicable to large scale projects with many interacting tasks and may not be suitable techniques for student projects. At a simple level, the students should be encouraged to use Gantt (or bar) charts to help define the project tasks and timescales for completion. These can then be reviewed on a regular basis at progress meetings and modified if necessary. Alternatively, if the project is more complex such as a final year group project, it may be worthwhile introducing the students to specialist project planning software such as Microsoft Project®.

To reduce the workload in supporting and facilitating a project, staff often run projects in conjunction with other tutors, which demands careful coordination of roles and responsibilities. The development of a staff project plan, which includes the set-up, running and assessment of the project, can be help to define responsibilities and commitments.

Departmental research staff are often utilised to support projects; this can be particularly valuable if the staff have completed the same, or a similar project, as part of their undergraduate studies. In addition student mentors from a higher year are increasingly being used to mentor students through a project that they undertook one or two years previously. See Case Study 7, by Peter Willmot, Loughborough University, which describes 'Widening the Project Based Learning Experience with Student Mentors' for fourth and fifth year mechanical engineering students.

10.3.2 Student hours

The time to be devoted to a project should be established in terms of both the contact and independent learning hours needed. These should be detailed within the module description in which case the project should be designed to comply. When a project forms only a part of a module, its role and time allowance must be balanced appropriately against the remaining module content.

Students tend to spend more time on projects than on other activities, especially as they become more involved and more motivated. It may sometimes be necessary to remind them that they have other work to do too.

Case Study 10 by Colin Smith, University of Sheffield, provides an example of how civil and structural engineering students undertaking projects to enhance teamwork can spend too much time on project work and how this can be regulated through adapting the project scheduling:

> *"The existing group project had, in previous years, run continuously through the first part of the Semester in parallel with conventional lecture courses. While this approach permitted students to get well immersed in the technicalities of the project, it did in many cases lead to students devoting too much of their time to it.*
> *The timetable was subsequently revised to block the project into a concentrated intensive 2 week period on its own. As well as limiting the time spent on the project by students, this requires students to work efficiently as teams, and to manage their time wisely. There is no 'spare' time for inefficiencies in the project work, as the students are constantly under time pressure."*

Feedback from staff and students in terms of time requirements and scheduling is clearly helpful, especially if the project, or a similar one, has been run before. If starting from scratch, then allowances need to be made for student level, ability and previous experience of project work. For example, first year students usually require a greater tutor input than those in their final year.

Milestones are useful to provide control of time expenditure and modifications may need to be made to the brief if there is indication of a severe over or under-estimation of time allocation.

Case Study 6 by Peter Willmot at Loughborough University, describes a project schedule for mechanical engineering students working on projects in conjunction with industry, which contains clear milestones and deadlines:

"The module leader generates the project schedule. The outline schedule remains unchanged from year-to-year with all activities related to the module happening on a fixed half -day every week. The projects run from mid October to early May with a break during the examination period in January….

Example schedule (Final Year)

Week 1	*Introduction to the scheme, team and company allocation*
Week 2	*Factory Visits*
Week 3-5	*Tutorials with academic supervisor*
Week 6	*Progress Meeting with company tutor*
Week 7-11	*Tutorials with academic supervisor*
Week 12	*Intermediate report handed in*
Week 13-15	*Examination Period*
Week 16	*Progress Meeting with company tutor*
Weeks 17-24	*Tutorials with academic supervisor*
Week 25	*Hand in Final Report*
Week 26	*Preparations for week 27*
Week 27	*Conference (am) and Exhibition (pm) with industrialists"*

Ensuring that the students have a sequence of summative assessments distributed through the project helps to avoid overloading with a large assessed project at the end of the module, when exams are taking place in other modules. More detail is included in Section 8 on assessment.

The use of learner logs can also be a valuable method of tracking student time, provided the logs are regularly reviewed by the tutors.

The following is a useful example of a logbook specification from "A Guide for Students" issued by The University of Nottingham, for Mechanical Engineering Courses, distributed to students before the commencement of their individual projects:

Logbook
We require you to keep a project Logbook, mainly as a tool for managing your work. It will also be an invaluable aid when you come to write up the progress and final reports and, additionally, it is a means by which you can provide evidence to others about your approach to the project.

The Log Book should be kept in a hard-backed A4 laboratory notebook. As a minimum requirement, the Log Book should record:
i) a statement of the overall general aims of the project
ii) a work plan for the first semester
(both of the above should be prepared by the you during the first week of the project and agreed by the supervisor)

In addition, a weekly log should be kept, giving:
i) a summary of activity since the last supervision meeting
ii) an agreed statement of action before the next supervision meeting
iii) the date of the next meeting

The Logbook will also be the best place for you to keep a detailed working record (sketches and graphs, experimental results, analysis etc) as your project proceeds. This record will be invaluable when you come to write up the project."

Case Study 8 by Barry Lennox, University of Manchester also describes how a reflective log is used within group based problem activities for students in the School of Engineering and describes how these form part of the assessed work:

Continual self-evaluation is encouraged throughout the programmes, and the students keep a reflective log known as a learning journal as part of their Personal and Academic Development Plan (PADP). For the duration of the PBL exercise, the student keeps a record of his/her own notes, teaching materials received from other group members, and a reflective commentary on his/her own progress. This commentary includes personal skills acquired through team working and may also include the roles played by individuals in the group, how well the group stuck to the task, time management, and how the group resolved differences.
...The 'Personal Development' mark is an accumulation of the personal and academic development plan report marks that are assessed by the tutors.

10.4 Finance

When running any project the project tutor needs to assess the funding available, the estimated outlay in terms of consumables, travel and equipment, and to plan the budget accordingly.

Sources of funding
The following sources have been used at institutions to cover project costs:

- departmental general teaching funds
- departmental and/or university funds for specific initiatives
- research project funds
- industrial (and in kind) funds

Industrial and/or external funding or in kind support, eg supply of equipment or consumables, is particularly beneficial in reducing overall costs.

It is normally expected that the industrial partners are involved in some sort of sponsorship of the project. This may take the form of an actual cash contribution (in the region of £500-£1000), in-kind support, through loan or donation of equipment, use of company personnel time, or through provision of prizes.

Case Study 6 by Peter Willmot, Loughborough University describes how students work on projects in conjunction with industry and industry contribute financially:

> *"The companies pay a small fee to the university that allows us to fund the necessary industrial visits, hospitality, cover basic project costs and maintain a high standard of report presentation."*

It is important at the outset of the project, that resources and funds are available and that there is an agreed written statement of who has responsibility for each element of the budget statement.

10.4.2 Budget

At the outset of the project the project tutor needs to make an estimate of equipment and consumables costs, so that the students can complete the project to the required standard.

The tutor should determine what costs can be reasonably borne by the students and what should be provided via the department.

For example, students often pay printing and production costs for posters but don't usually buy their own materials for producing models or carrying out product performance testing. It is important that students are not disadvantaged as a result of project costs borne by them.

In estimating the likely costs per project team you need to consider:

- travel costs, eg visits to industrial partners
- equipment costs, eg hire charges for a digital video camera
- consumables, eg model materials, photocopying, telephone calls

Allocate a project budget bearing these in mind according to the total funds available. It is important that the budgets are properly managed to avoid overspending, particularly for multidisciplinary projects where costs can accrue in different departments.

Purchasing requirements should be established in advance of the time tabled project, following consultation with workshop and laboratory staff.

Control of expenditure
It is often a significant outcome of a project that students develop their financial management skills. Students should also be instructed to maintain full records of all items of expenditure and regular budget/expenditure reviews should take place involving both supervisors and students.

Record keeping is good practice for students and enhances project management skills. A simple budget spreadsheet for calculating the costs of consumables, equipment and activities enables easy calculation and monitoring of budget costs.

Expenditure monitoring is particularly important for multi-disciplinary projects as costs can accumulate in different departments and be approved by different supervisors, making control of expenditure quite complex. To ensure adequate monitoring, supervisors need to ensure students maintain good paperwork, and meet regularly to review expenditure.

A Sample Budget Costs Form for Multidisciplinary Projects was provided in Section 3 – Project Design.
Such a form can provide a simple method of calculating the budget costs for individual items of equipment or activities within the project. By compiling such forms in a spreadsheet for all components/activities within the project, total budget costs can be calculated and subdivided between the departments involved.

Budget management may form a useful part of the student reporting and assessment process.

10.5 Equipment

10.5.1 Consumables

The range of consumables which a student uses within a project will depend upon their discipline, the project weighting, the assessment methods applied, the availability of resources and the project budget. Typical project consumables include:

- materials for producing posters
- photocopying, fax and telephone
- product or model materials
- workshop consumables, such as cutting tools
- electronic components

The project tutor may choose to allocate an overall budget for the purchase of these consumables or to allocate a maximum for each heading.

Once a consumables budget has been set it is important that the students are told of how they can spend against it and provided with relevant catalogues or supplier contact details to purchase the goods.

Stock lists
Rather than providing students with individual project budgets the project tutor may wish to use existing materials or bulk purchase a fixed range of in-stock materials which the students are free to use. These may typically include available raw materials, stock shapes, electrical components, materials for producing posters etc.

If the project tutor adopts this approach then they will need to supply students with a list of available consumables, applying limits on quantity where necessary. This list may be in the form of a specific stores inventory.

Again it is important that the available consumables, how to obtain them and how to use them are detailed for the students

10.5.2 Process resources

The available process resources also need to be outlined for students, for manufacturing, computing, independent learning, design and presentation. Examples of these resources are included below:

Knowledge based resources:

- library facilities
- specific texts
- relevant research papers
- patents
- standards
- inter-library loans

Manufacturing process resources:

- a list of machining and manufacturing resources
- labour time available in the departmental workshops
- a list of workshop facilities for student use
- construction and assembly methods available
- associated health and safety documentation and equipment

Computer based resources

- compatible PC/Mac/Unix machine
- software

- printer
- networking / modem
- manuals

Performance testing resources

- measurement devices
- data acquisition hardware
- associated health and safety documentation and equipment
- Presentation resources:
- binding machines
- printing facilities
- stationery and report covers
- photographic services

Additional equipment for use in the project:

- adjacent parts
- computers
- power supplies
- general laboratory equipment

With all available resources, it is important to specify the procedure for obtaining the resource, the location of the resource and the staff member responsible for supplying. For example the procedure may involve completion of specific forms which are countersigned by the project tutor.

An example of instructions issued to students for supporting resources for a 2nd year Mechanical Engineering group project (described in Case Study 6, Peter Willmot Loughborough University) follow.

SUPPORTING RESOURCES
During the project you will need to keep contact with both your sponsoring company and the suppliers of various items of equipment.

Photocopying
A photocopier is available on the top floor of the departmental building, this copier is capable of multiple copies via the sheet feeder, double-sided copies and magnification. Each group will be issued with sufficient units to allow copying of the reports and for a reasonable amount of contact with their company and suppliers. The cards are available from the teaching contract secretary. You may obtain additional cards at your own expense from the Main General Office at any time.

Virtual Learning Environment (VLE)
Several items of interest in this project are posted on the VLE information page for this module. Items include, these course notes, the various forms needed and a clickable guide to information searching in the library.

Telephone Calls
Please ask your tutor if you need to make extended telephone calls in connection with your project. They will normally allow you to use their office phone.

Email
Make use of email wherever possible - it is free to you and allows the recipient to respond at a convenient time.

Video Camera
A video camera to record any items that are of use to you in your project is available on short-term loan and again you must present a form signed by your tutor. You will be held responsible for the care and security of the camera whilst it is in your possession. Contact the Departmental Photographer (Room Number…).

Still Cameras
In addition to the video camera, the Department has a 35mm SLR camera for loan to students. The arrangements for borrowing this are similar to those for the video camera. You may, pre-arrange for the Departmental Photographer to take photographs for you subject to his availability. A digital camera will be made available later this year.

Scanning
Available in study room (Room Number…)

Model Making
Workshop (Engineering Applications) access is available in the ground floor of the Department off the main entrance. You may need to book this facility in advance. All safety procedures and the instructions of the workshop staff must be strictly adhered to. In addition, there is now a model making facility accessed from the main workshop. You must arrange for storage of your equipment when you are not working there, DO NOT LEAVE IT ON THE BENCHES (or it may well be removed permanently).

Care of Equipment
You will be held responsible for the care of equipment you borrow, not only taking care yourself but also preventing others from damaging the facilities.

10.6 Library resources and documentation

Developing independent learning skills is often a key outcome of project work. For students to undertake this effectively they will need appropriate direction and access to learning resources.

Often a student will first search for information on the WWW. The quality and level of resources on the web are not always of an appropriate academic standard. It is important within project work that students also use texts, and where appropriate journals, to access and distil high quality information.

The majority of core texts and journals should be available within the university library. So it is important that students are directed to use the library as an information source and given instruction on how to search for relevant information. A number of libraries run either guided or self-guided tours which indicate how to find resources, these tours are usually worthwhile for project students to undertake.

To ensure students have access to the resources and don't become frustrated, it is essential that there are sufficient copies of books, journals and other library resources, and is there appropriate instruction on how to use these library resources once they have been found.

If there are not sufficient resources then consider each of the following:

- arrange purchase of multiple copies
- make a copy of the texts available in the project or design room
- talk to the library subject specialist, to see if they can suggest an approach which will help
- put core texts onto a short loan, or reference only basis

For other documents such as archived reports pertaining to a particular project it may be that the tutor will keep copies which are signed out to students.

Peter Hedges, Aston University, provides documents on request as part of a civil engineering project which simulates a Public Inquiry, Case Study 1, and also indicates other important aspects of resourcing a project:

> *"The information underpinning the project has been drawn from a wide variety of sources. However, at the core is the documentation produced prior to, during and after the original Broad Oak Public Inquiry. The majority of the various reports, drawings etc. have been distilled from this. Beyond the underlying data, the only resources required are: adequate room space, support from an external professional to act as the Inspector; a photocopier; and boundless energy and enthusiasm!"*

If part time or sandwich placement students are carrying out their project within the workplace, then the project tutor will also need to ensure that there is adequate access and provision for off-campus learners. ICT can help.

10.7 ICT

Information and communication technology (ICT) is increasingly being used throughout projects, for learning, support, and presentation. Examples of ICT applications within projects include:

- directing students to use online materials for independent learning
- instructing students to produce a portfolio using a 3D drawing package
- supporting a project via a web based notice board and discussion board
- requiring students to write or apply a computational model as a part of the design process
- supporting students off-campus

To enable the learners to undertake these tasks there must be adequate resources. If it is anticipated that ICT will form an essential part of the project consider the following:

- do the students have sufficient IT and programming skills to undertake the task in the time available?
- do the students have access to appropriate hardware?
- do the students have access to the necessary software?

If the students run in to difficulties it is essential that technical support is available for:

- software installation
- programming and de-bugging
- hardware problems such as the PC, printer and network

The project tutor may need to work with computer support services to ensure the provision of the resources and of the support. Computer support staff may well need briefing on the demands that students will place on them and their services.

Appropriate instruction or direction may need to be incorporated into the project if these resources are to be used effectively. This is particularly the case for computer intensive tasks such as programming, computational modelling and computer aided design.

The WWW

The internet can be a valuable information source but it can also be a substantial drain on student time. It is sometimes difficult for students to guarantee that web-based material is of the right level or quality. There are a number of online tutorials for engineering students that guide students through effective and objective sourcing of material on the WWW.

As part of the project resources provided to the student the project tutor may wish to include a web page of relevant electronic information sources

This will help to guide their study and to ensure that the web resources are appropriate and relevant.

Computer Aided Learning
The project tutor may wish to use Computer Aided Learning (CAL) software, to facilitate learning, communication and assessment. Improved visualisation has been shown to help students understanding of complex concepts or processes. A wide range of freely available, online interactive tools such as Java applets exist which may be a useful resource within the project.

Web links are provided in the endnotes to two examples of online Java materials:

- digital signal processing Java applets developed by Dr. Dave Laurenson and Dr. Mike Jackson, University of Edinburgh[xvi],
- virtual physics laboratory (includes: mechanics, dynamics, electronics, optics etc) developed by Prof. Fu-Kwun Hwang, National Taiwan Normal University.[xvii]

ICT facilitation
ICT resources can also be used to support and facilitate learning through projects, for example briefing documents, project notices and discussions can be delivered over the web, an intranet or via e-mail. More details can be found in Section 5 on Learners and Case Study 2 by Patrick Littlehales, Aston University, which describes 'Facilitating Collaborative Design through ICT'.

10.8 Summary

A wide range of resources are utilised by students during project work. Careful consideration needs to go into planning and budgeting of these resources, which include:

- consumables
- equipment
- library resources
- information and communication technology resources
- work rooms
- staff time

Additional issues have also been identified for:

- large groups
- off-campus learners
- multidisciplinary projects

It is important that project staff liase with their colleagues in the use of resources, particularly in terms of planning and time commitment.

The production of good documentation, such as a staff project plan, which includes the set-up time, student spreadsheets for budgetary control and learner logs to track progress will help with the management of resources.

10.9 Endnotes

(1) Virtual Physics Laboratory, Prof. Fu-Kwun Hwang, National Taiwan Normal University http://www.ee.ed.ac.uk/~mjj/dspDemos/EE4/home.html

(2) Digital Signal Processing Java Applets, Dr. Dave Laurenson and Dr. Mike Jackson, University of Edinburgh http://www.phy.ntnu.edu.tw/java/indexPopup.html

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Appendix – Papers from PBLE Competition Winners

The following are the papers written by the PBLE competition winners, describing their projects:

1. Meeting Undergraduate Students' Needs Through Third Year projects
   Claire Davis, Elizabeth Wilcock
   Department of Metallurgy and Materials, School of Engineering,
   University of Birmingham, Edgbaston, Birmingham, B15 2TT

2. A Project for Group Working with Foundation Year Students in Engineering
   Roger Penlington
   Northumbria University, School of Engineering & Technology,
   Newcastle upon Tyne, NE1 8ST

3. Assessing thermodynamics by design projects
   Norrie S. Edward
   School of Engineering, The Robert Gordon University, Schoolhill, Aberdeen,
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Meeting Undergraduate Students' Needs Through Third Year projects

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Abstract — *Individual final year undergraduate research projects are a fundamental part of the engineering and science courses in the Department of Metallurgy and Materials. Within the Sports and Materials Science course, final year undergraduate projects typically involve experimental research into the materials used in an item of sports equipment. However, as the course has developed, and more students have been recruited with a range of backgrounds and career aspirations, it has been noted that not all students want to use their science and engineering skills to move into technical careers but instead would like to become teachers. In order to meet these students' needs, in 2002 a new style of project was offered to the final year undergraduate students on the BSc course (in addition to the technical researched-focussed projects). The project required students to develop case study teaching (including hands-on experimental activities) for pre-university level students in the area of sports materials. This paper describes how the project was developed and implemented. Feedback from the undergraduate students on the effectiveness of the project is also discussed along with feedback from workshops carried out with groups of 14-15 year old students using the case study topics developed by the final year undergraduate students. This paper concludes with a summary of good practice identified and the key considerations to be made if replicating this project in other institutions.*

Index Terms — *Final Year Projects, Teaching and Learning, Motivation, Evaluation*

BACKGROUND

The Sports and Materials Science BSc course at the University of Birmingham was the first of its kind in the UK (introduced in 1997) and combines an appreciation of the advanced materials used in sporting equipment with the practical and theoretical knowledge of sports and exercise sciences. The materials aspects of the course have been based on well-established courses, such as the BEng and MEng Materials Science and Engineering degrees, offered by the Department of Metallurgy and Materials, and therefore the structure of the newer course follows similar guidelines and methodology. An individual final year undergraduate research project is a formal requirement of the UK Engineering Council and the Institute of Materials, Mining and Minerals for accredited materials engineering degree programmes. Whilst the BSc Sports and Materials Science course is not accredited, the perceived benefits of using final year projects meant that this aspect was also incorporated in the degree programme.

It is now well documented that students can learn most effectively when actively involved in the learning process [1, 2] and student-centred project work is a valuable means of achieving this. Active learning confers ownership of the learning process from the teacher to the student and through this process, students can engage in higher order-thinking tasks such as analysis, synthesis and evaluation [1]. Furthermore, active learning opens up opportunities for the development of student skills such as independent learning, group working and communication. Using projects can provide students with practice in the use of methodologies and forms of analysis and can also be used to develop professional skills in tackling real world problems [3].

The final year project in the Sports and Materials Science BSc course typically involves research (including experimental investigations) into the materials and processing techniques used in an item of sports equipment. The Department of Metallurgy and

Materials has developed considerable research expertise in the areas of golf clubs and balls, safety equipment (e.g. body protection and helmets), Formula 1 components, tennis rackets, bicycle frames and prosthetic limbs for athletes enabling the undergraduates to carry out well-supported and in-depth research projects. As the BSc course has developed, and more students have been recruited, it has been noted that some of the students have different career aspirations than those traditionally seen on the BEng degrees. Most of the BEng undergraduate students are interested in using their engineering skills e.g. either as practising engineers or consultants, or using their generic skills (numeracy, project management, communication etc) e.g. in accountancy etc. However, we have found that some students on the BSc Sports and Materials Science course are interested in becoming teachers. These students are less interested and motivated by research projects looking at the detailed aspects of materials properties. In order to meet these students' needs, in 2002 a new style of project was offered to students on the BSc course (in addition to the technical research-focussed projects). The aim of this project was to develop case study teaching in the area of sports and materials science where the students were expected to research into the theory of case study teaching (group leaning, learning styles etc.) and the materials used in a piece of sports equipment (to include background information and hands-on experiments suitable for the target audience). This is discussed in more detail below.

METHODOLOGY

The final year undergraduate project accounts for a third of the final year marks (40 out of 120 module credits) and runs over 20 weeks in the first and second terms. The students select their project titles from a list provided by the lecturers in the department and are required to discuss any projects they are interested in with the project supervisors before submitting a rank order list of their three choices. Project allocation is made to ensure that as many students as possible get their chosen project. Projects are usually supervised by one or two lecturers with a graduate research student as an assistant (whose research area matches the project titles). The case study development projects were proposed by a lecturer who was awarded a National Teaching Fellowship in 2000 and has been researching good practice in case study teaching in higher education thereby providing a suitable level of expertise to supervise the students. In addition, this lecturer is research active in the links between microstructures and properties, predominantly in metallic systems (including automotive, aerospace and golf equipment), and supervises a number of PhD research students. Additional input to the project supervision was provided by other lecturers in the department on specific issues where required.

Six students chose this project, titled 'Case Studies in Sports and Materials Science – Theory and Practice'. The initial stages of the project involved students examining curriculum content for the age group targeted for the case studies (14-15 year olds) to determine areas relevant to Materials Science (e.g. from Science, Design and Technology, Physics, Chemistry syllabi). Students also reviewed educational literature concerning case study teaching (e.g. case-study definitions, benefits of case-study teaching, learning styles of students etc.). In addition, students carried out research into their target audience (teachers and school pupils) in order to determine an appropriate format for their case studies. This involved designing, implementing and analysing questionnaires. The main part of the project was for the students to develop a case study on an area of science in sporting equipment of their choice, informed by their earlier research. The students carried out experimental investigations on items of sports equipment, for example determining the bending stiffness of vaulting poles and sectioning the poles to determine the composite lay-up etc. They used their experimental results to design appropriate hands-on activities for their case study suitable for the chosen audience.

Group Working

The initial generic tasks, such as the educational research, curriculum review and target audience research, were carried out by the whole group with individual members choosing which tasks to carry out and then report back to the group. The benefits of group working are well documented. Group learning can be used to promote active learning [1], aid the development of communication, leadership, organisation and problem-solving skills [4] and has clear vocational relevance. However, although most students recognise and acknowledge the benefits of group working, many are concerned with conflicts and uneven workload within groups [5]. Therefore, to aid the group process, weekly group meetings were held with the project supervisors to ensure that all tasks were carried out equally and that students managed their time effectively. Students were also encouraged to come and discuss their work with the supervisors individually by making appointments with the appropriate lecturer.

Individual Work

Projects are a good vehicle for encouraging students to carry out independent research, i.e. outside of the lecture/tutorial environment, and this can be useful for promoting active learning and self-regulated learning. Once the students had completed the educational literature review, they started to develop their individual case studies. This involved researching background technical information for the chosen piece of sports equipment and developing an appropriate hands-on practical component. Students were expected to perform experiments to determine underlying science and recommend case study content for their chosen audience. Graduate research students provided assistance to the project students and they were also able to use the research facilities within the research group. In addition, students have full use of the general department laboratories and there are several technicians who provide additional support. Group meetings with supervisors continued to be held each week to ensure progress and identify any problems.

External Involvement

Involving external sources can add new dimensions to a learning activity. For this project, students had contact with a company called ‘Sports by Design’ who specialise in running sports/science workshops in schools. The students attended one of the company’s interactive lectures and the director of the company also met with the students to help brainstorm ideas. Through the regional SetPoint (government funded organization which operates as a focus for teachers to obtain information about resources, schemes and initiatives concerned with science, engineering, technology and mathematics) students were able to 'test-run' their case studies with school pupils visiting the University. A group of 15 pupils from local schools, as well as three students from Frankfurt, Germany, attended a workshop at the department and carried out some of the case studies produced by the undergraduate students.

Assessment

Final year projects provide a good opportunity to incorporate a variety of assessment strategies and within this project a number of components were assessed. Students submit a draft literature source review (2000 words) at the end of the first term and have a viva for 15 minutes to discuss their understanding of work and the plan of work for the remainder of the project (mark contributes 25% of the total project mark). Students submit a project report (mark contributes 45% of the total project mark) and give a 20 minute presentation (mark contributes 10% of the total project mark) with 10 minutes for questioning, presented to two members of staff and a group of their peers. The report is approximately 5000 words long and is double blind marked by staff not responsible for supervision of the project. If marks differ by more than 10% than the project is moderated (marked by a third member of staff and the closest two marks averaged). Finally, students are given a supervisors mark (mark contributes 20% of the total project mark). The project supervisors do not mark the project report, presentation or viva but have a separate mark which covers aspects such as attendance, experimental competence, independence of work and contribution of ideas. Whilst these are final year students and it is assumed that they are well practised in communicating their work (i.e. reports, presentations), support is still provided by running practice presentations and issuing tips and advice for effective communication on a support website.

EVALUATION

On completion of the project, student questionnaires were administered to gain an insight into the students' perception of the learning experience and to uncover any areas for possible improvement. The main aim of going through this process is to enhance the quality of student learning and to promote reflection, both by the students and the lecturer(s) involved.

As this was the first year that this particular project has run, feedback is limited (although generic feedback on final year projects is generally very positive). However, feedback received from the six students involved in the project has been very encouraging. It seems that students chose the project because they were interested in a career in education and wanted to explore this in a materials project. Comments included:

- 'I was thinking of teaching as a career and thought this would be helpful'
- 'I was more interested in looking into the educational side and applying it to materials'

All of the students stated that they found the weekly meetings with the supervisor and the 'test-run' of their case studies particularly helpful.

- ‘The meetings really kept me on top of things. It also meant that it was possible to ask questions and make sure you were on the right track’
- ‘The test run with the school pupils was great because we were able to see what we had developed as a project which was excellent feedback!’

These are all areas that will be included in the future running of the project. One point that the students did raise was that they felt, due to the structure of the project, that they did not have enough time for their experimental work and write-up of the report. One student commented:

- ‘It would have been better to start the practical work before the end of term’

This will be considered when next running this project and students will be advised to complete their experimental work earlier in the project leaving more time for writing the report.
Feedback from the lecturers supervising the project suggests that the students were extremely well motivated in carrying out the research and were generally proactive in determining the direction of the project.

ADDED VALUE

Funding from the Engineering and Physical Sciences Research Council (EPSRC) enabled the Department of Metallurgy and Materials to run three one-day workshops for GCSE students in July 2003. This provided an excellent opportunity to use some of the activities that the final year project students had developed. The workshops were designed to give Year 10 students a chance to investigate how science contributes to sporting performance and the development of sports equipment; the main aim being to motivate and encourage those students who are interested in taking their science studies further and would like to find out more about science and engineering at university. The project students were aware of the possibility that their activities could be used for this event and this added extra incentives to the project. The students were also encouraged to take part in the workshops as they would gain further hands-on experience relevant to their potential careers. On each workshop day, 35 pupils and 7 teachers from 7 schools attended and took part and feedback was very positive. Four of the student’s activities were used and two final year project students and four graduate research students helped run and organise the workshops. Comments from pupils who took part in the workshops included:

- ‘I’ve learnt how much science is related to sport’
- ‘It was cool to speak to the instructors about university life’

In addition, a web-site was developed to accompany the web-sites which contains all the details of the workshop activities along with some supporting information, images and photographs from the day [6].

CONSIDERATIONS AND BENEFITS

By actively involving students in a subject that interests them and widening knowledge of possible career paths, it was hoped that this project would increase motivation and desire to learn. The feedback seems to concur with these aims. For those students who had a particular interest in teaching, they were given the opportunity to gain a better understanding of the school curriculum and explore teaching and learning styles whilst keeping a materials science viewpoint. In addition, the opportunity to work directly with schools was a real highpoint of the project as students gained an insight into various aspects of teaching and greatly benefited by the experience of working with school pupils. Working with the company 'Sports by Design' added further benefits in terms of potential career knowledge and professional contact.

However, when carrying out a project of this nature there are key points to consider to ensure that the main project aims are achieved. In this situation, the project was made possible because some members of staff are actively involved in educational research and development. Therefore, they were qualified to set project tasks and direct and advise students in their research. If this project was to be replicated in other departments, it may be necessary to contact educational support networks such as the Learning and Teaching Support Network (LTSN) and the Institute for Learning and Teaching in Higher Education (ILTHE) for information and advice. A further consideration is assessment. Whilst the project supervisors were familiar with educational research they were not responsible for the assessment of the project. In this case, markers were briefed on the main criteria that should be assessed and students were advised to write the report in the same format as a scientific report.

CONCLUSIONS

The experience of introducing a final year undergraduate project that allows students to develop interests in teaching as well as developing their technical knowledge has been both encouraging and rewarding. Feedback from the students indicated that the main aims of the project, i.e. increasing motivation and widening knowledge of possible career paths, were achieved. The supervisor support and scheduled weekly meetings proved to be a valuable component of the project and gave students the confidence to approach materials science from an educational viewpoint. Furthermore, the involvement of experts outside the normal range of contacts and the opportunity to use their case studies in school workshops added an extra dimension to the project and gave students a real insight into the various aspects of teaching.

ACKNOWLEDGEMENT

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A Project for Group Working with Foundation Year Students in Engineering

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Abstract *— Project based learning is used with a diverse group of students on an engineering Foundation year. A design and make project is used to illustrate to the students design evolution and engage them in the process of problem solving. The project incorporates aspects of mechanical engineering, electrical engineering and computing skills. The assessment scheme focuses upon the process of their group work and incorporates reflection and review meetings which support the embedding of personal development planning.*

Index Terms *— Group project work, problem solving, design and make, group assessment.*

INTRODUCTION

This paper describes the use of project based learning in the School of Engineering & Technology, Northumbria University, within a module entitled 'An introduction to engineering design and problem solving'. This is a core module for students on all the School's Foundation programmes which lead to undergraduate programmes in Mechanical Engineering, Electrical & Electronic Engineering, Computer Network Technology and Product Design Technology. A characteristic of these programmes is the broad range of backgrounds, prior learning experiences and the state of motivation of each student beginning their university experience by this route. The module is very much about engagement with the learning process, encouraging the student to become responsible for his or her own learning, working towards the University's aim of promoting challenging and innovative teaching which empowers the active learner.

The project described here forms the entire second semester of this year long module, following a series of shorter, directed, exercises such as an introduction to communication by graphical methods, plagiarism and referencing and design analysis. The objective of the task may be summarised as 'developing the ability to tackle design and engineering problems by thinking and describing'.

As a project which aims to stimulate a diverse group of students assessment of the learning process, student's engagement and final project outcome is required. To meet these objectives the project is based upon the use of PC controlled servo motors to carry out an electromechanical task.

THE PROJECT TASK

The project will contribute towards the following module learning outcomes;

The student will be able to:-

- Analyse a problem, break it down into constituent parts and recognise the knowledge required for a novel solution.
- Employ an interdisciplinary approach to describing the solution to electromechanical design problems.
- Demonstrate the ability to plan and control the progress of group work.
- Tackle engineering problems by 'thinking and describing'.

The students are guided through the project in a manner which meets the purpose of the module, develops learning skills, motivates and allows assessment in self selected groups of three or four. The class size of around 25 is supervised by two staff members within a space which allows free access to open bench space, a workshop, experimental and test facilities and computing facilities. At present the only facility not locally available is a photocopier, this forces the students to be more innovative within their communication and hopefully develop their sketching and summarising skills which were introduced earlier within the module. The students make full use of these facilities for the 'design and make' portion of the project.

The project outcome is only given to the students in its broadest form, for example they are told that they are to produce an electromechanical device – they are not given 'detail' which may allow any short cuts within the design or problem solving process.

The first tasks of the project take the form of directed research of background themes, for example the students would be expected to research and sumarise general charactistics of transmitting motion through gears, cams and levers. Each group will have a progress review meeting with the staff members at appropriate stages, each week during the early stages, less frequently later on. During the 12 week project these meetings allow the students to be fed the detail of the task, make a record of their progress whilst allowing motivational input by staff.

The purpose of the drip feeding the task to the students has the aim of introducing specific knowledge, what is seen as being needed for the task, as a directed foundation, to guide the groups towards a solution within a framework of decision making. It is felt that without this introduction to the task and support the students would fail to make their own decisions and would refeer to existing solutions available from the World Wide Web, thereby short circuiting the learning process.

To illustrate this process a typical outline teaching scheme would be as laid out in Table 1.

The review meetings serve as progress checks, being very face to face, two staff members and three or four students. It has been found that as the projects develop the students will approach these meetings with differing expectations. With a well motivated group that has felt the benefit of their reflection it is very much a session driven by the students and a window on their process. For a poorly motivated group it follows a period of frantic activity where they attempt to come to the meeting with some progress. Often for these students things tend to 'fall apart' during the review and this is where their reflection takes place. Groups do not in general put themsleves in this position more than twice. If the students are asked to 'cost' their work – often based upon the hourly rate of their part-time jobs, where the module expects each student to contribute 100 hours – they will develop a value of their education.

TABLE 1
STUDENT AND STAFF ACTIVITY THROUGH THE PROJECT

Week	Student activity	Staff activity	Specific task
1	From groups, carry out specific task and complete log	Introduce the project, describe assessment process and resources available	Investigate motion transmitted through gears, cams and levers
2	Report back on gears, cams and levers, reflect on progress in log. Move onto servo motors	Review meetings with each group – explore their understanding of the previous specific task, specifically their understanding of torque and power.	Investigate servo motors, characteristics, uses and limitations
3	Report back on servo motors, group reflection, continued development of log.	Review meetings with each group – explore their understanding of the previous specific task, introduce the groups to the detailed task – 'a walking device'	Investigate 'walking motion devices'
4	Design process begins, brainstorming etc., initial draft specifications.	Monitor group discussions.	
5	Report on initial designs, reflect on 'practical issues' of the design	Review meetings on initial designs – probe the practical issues, loadings etc. of the designs and also build issues	
6	Build stage		Begin manufacture of prototype motion components etc.
7	Build stage with some testing and reflection	Review meetings of initial build and test	Specifics of final performance test given out
8	Build of final design		
9	Build of final design		
10	Testing and programming, reflection on device performance	Review meetings 'will you complete the performance test?'	
11	Testing, rebuild?		
12	Performance demonstration of device	Final assessment and feedback session	Submit log 'as is'

PROJECT ASSESSMENT

The project serves several purposes, as described by the aims and learning outcomes, in addition to developing an understanding of the students responsibility to the learning process. Assessment becomes complex were there is process and outcome. With traditional approaches to assessment the process would be incorporated as formative assessment and the outcome providing the summative component measuring achievement for progression. In this case the process is accumulated into the summative assessment, although it is seen as important that the weighting of the various components is not stressed to the students to avoid ‘enough to pass’ weak effort. For this reason a process to outcome ratio of 60:40 is used, I am most interested in the process and the student is motivated by the outcome, if the process is strong then it may be expected that the outcome will also be strong and it would not reward a group not engaged in the learning progress but able to generate a strong outcome.

The approach employed with this project is to develop a measure of student performance during the process which is a record of the formative review process. During the project the student is engaged in the review and reflection process whilst being aware of the future summative use of the forms. This focuses the students attention on the immediate task, i.e. the development of their learning skills, whilst the student sees it as efficient because they are aware that these sheets, with the addition of a final reflective summary, serve the purpose of a part of their final report – thus removing a later task. The submitted final report is the collated research notes, sketches, doodles, rough calculations etc. combined with the reflection element of the review meetings. This form of report removes the rather false written report which may attempt to describe a process but which is entirely produced with hindsight. This form of report also supports the allocation of marks to the process when the module is reviewed by both the internal moderator and the External Examiner.

As the project is supervised by two staff the opportunity to develop a confidence within the continuous generation of a final assessment. Significant feedback is given to the students, ranging from verbal guidance and encouragement, written comments and targets on the review sheets and then a final summary with the summative measure of achievement.

The final outcome is internally moderated, although the moderator will also informally observe students during the process, and also subject to evaluation by the Programme External Examiner due to Professional Body Accreditiation.

Figures 1 and 2 below show two walking devices which may be used to illustrate some features of the assessment scheme.

Both walkers completed the final task of a three metre course with obsticles to both pass over and around but when the learning experience of the groups is considered then the process of developing the walker in Figure 2 was a better demonstration of design development and problem solving.

The walker in Figure 1 did not evolve through a learning process, it functionally mirrors commercially available devices and only incorporated minor advances upon the initial design outline. As the project assessment scheme recognised but only placed a low weighting upon the practicing of practical build skills then the competent tool users of this group did not have an advantage.

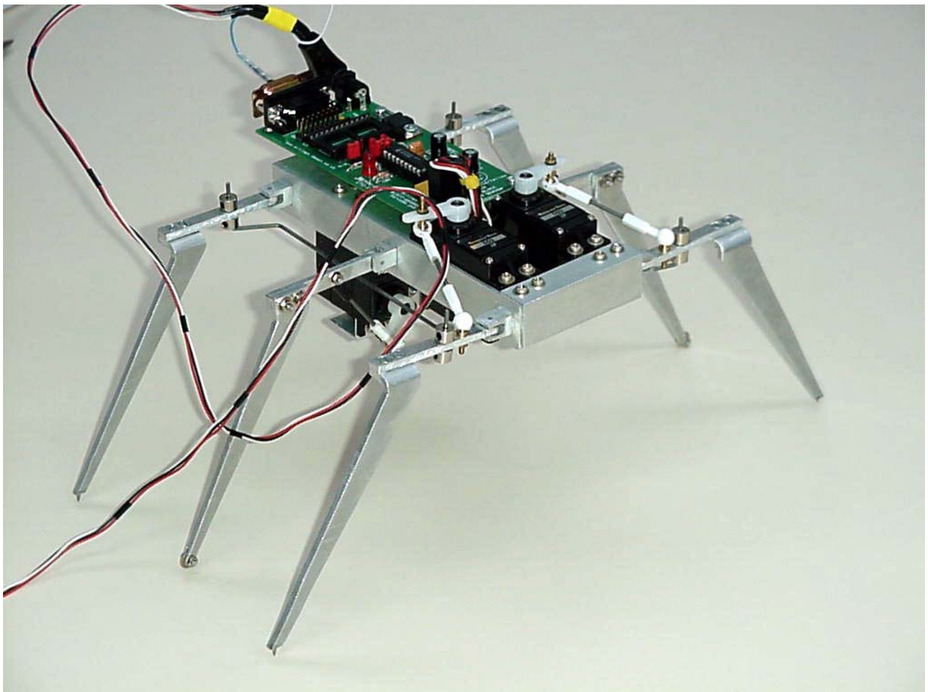

FIGURE 1
WALKER OF GOOD BUILD QUALITY BUT REPRESENTING A REDUCED LEARNING EXPERIENCE.

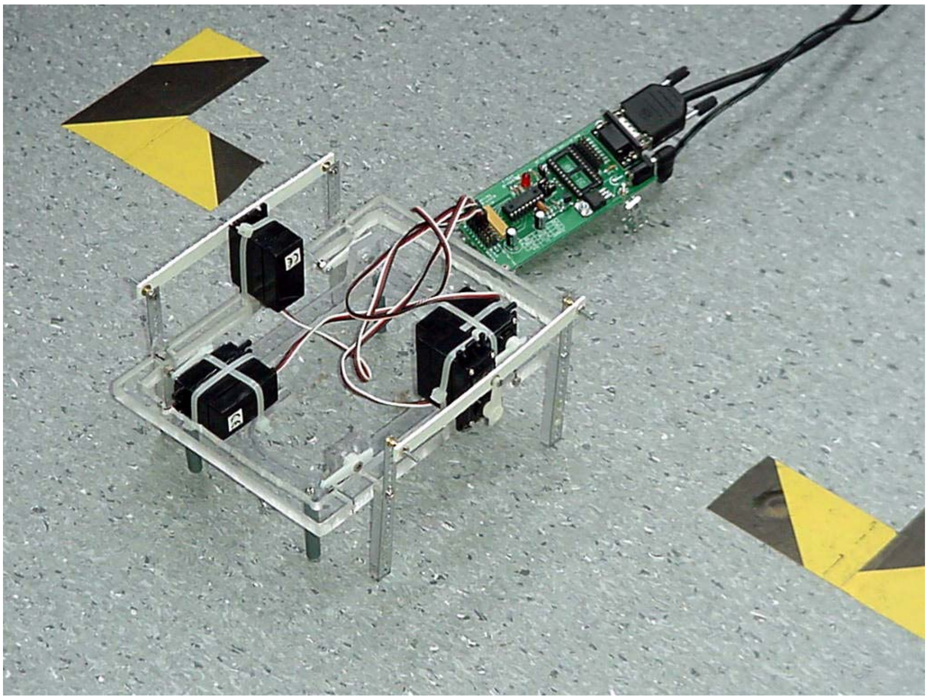

FIGURE 2
A WALKER WHICH DEMONSTRATED A GOOD LEARNING PROCESS WITH THE STUDENTS RECOGNISING THEIR ABILITY LEVEL AND OPTIMISING THE OUTCOME THROUGH THE DESIGN AND EVALUATION PROCESS

The group responsible for the walker in Figure 2 did not approach the task with one design in mind, they had early outlines of two device types but established that their practical skills with tools and materials would limit their ability to produce a sound light weight rigid structure. Therefore thy needed a self supporting device which would reserve a large portion of the motor output for overcoming friction etc. in their less 'crafted' device.

SUPPORTING STUDENTS

Student support is a significant feature of the Foundation Year, with a diverse intake and serving to prepare students for engineering and technology undergraduate programmes, motivation and preparedness for HE are key issues. The project has been designed to incorporate the support of 'Personal Development Planning' (PDP or Progress Files). The project was supervised by the Programme Leader and another member of staff who also delivers another module – this serves to give some familiarity and also linkage between 'knowledge' and 'skill' components of the programme.
During the process of the regular project progress review meetings and the students filling in the review sheets they are expected to; "Reflect upon your process so far, Did you plan well?, How well did your group work together and how will you approach the next weeks work?, Have you developed the knowledge that you may need?". The review sheets are appended by some supervisor comments and retained by the student. The design space and workshop facilities are available to students outside time-tabled hours and technician support is also available.

CONCLUSION

This project has been developed over two years and has proved to be both challenging and enjoyable for students and staff. While the profile of students on the Foundation year is changing then the difficulties of encouraging active learning change. For this reason two areas are receiving attention.
Currently there is some concern relating to students who do not fully engage with the staff and do not complete the course. With foundation students from diverse backgrounds this is to be expected and and the subject of much debate, how much can be done for these students, is it good for them to try something and decide they don't like it? Where students do not discuss any issues they have with staff then it is possible that something could have been done. This is the subject of continueing development of this module.
A further development being undertaken, through a University funded scheme, is the creation of networked electronic design space for groupwork. It is intended that an intranet will have a design space for each group where all work in progress will be stored, sketches scanned in, spreadsheets saved etc. The supervising staff and each member of the group will have access and discussion may take place electronically. A key aspect that it is hoped this system will overcome is the disruption caused when group members having distributed sets of notes, sketches etc. and not necessarily being at the right place at the right time for efficient group working. The part-time jobs of these students do impact upon groupwork in a negative manner.
It must be recognised that projects such as this do demand more resources than many traditional teaching activities, this is becoming a significant within the current HE financial structure.

Assessing thermodynamics by design projects

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Abstract - *The aim of the projects was to apply thermodynamic principles and materials properties to the design of heating/insulating or air-conditioning systems for a stone-built or modern domestic dwelling. Student groups applied theory, sourced data, investigated standards and selected materials and systems in a defended solution to the problem. Students gained an awareness of the need to justify decisions by providing technically defensible evidence. They also learned that the solution required compromise and that judgement as well as analysis was needed. A feature of the projects was that groups were paired with each acting as consultant for one project and customer for the other.*

Index Terms - Design-led learning (DLL), Stage 1, thermodynamics, student perceptions

INTRODUCTION

Design may be considered to be one form of problem-solving or, as the author believes, an activity which shares many of the attributes of problem-solving but also has attributes which make it distinctive. The distinction lies in the creativity which is implicit in the term. There is evidence that problem-solving skills can be taught and that they are, within a limited sphere, transferable. The evidence on the possibility of teaching creativity and of its being transferable is tenuous but such as there is suggests that, while one can provide techniques which help one to deploy one's abilities, the ability itself is largely innate. This should not deter the use of design-led learning activities in engineering courses. Creativity is an essential but small part of the overall process. The danger of a concentration on this aspect is that design is reduced to an enjoyable but undisciplined process – and thus one which produces fanciful but unrealistic solutions. Rigour must be instilled to ensure the feasibility of the output. Students must learn that feasibility is a multi faceted term. They must learn to apply theoretical analysis to ensure technical feasibility, economic analysis to ensure financial viability, understanding of the need for defining excellence in terms of getting the right product to the market at the right time and understand manufacturing imperatives to ensure that the product can be made efficiently and reliably.

The activity described in this paper was conducted with first year students. It was a design activity but was not used in a design Module. Assessment, therefore, was not predicated on the creativity of the solution but on the effectiveness of both the processes of analysis and of the accuracy of the application of appropriate theory. It was team-based and a deliberate element of competition was introduced to try to improve motivation to excel. The activities were evaluated by soliciting student opinions. This was done to avoid staff impressions being the sole judge of the success or otherwise of the approach.

INTENDED LEARNING OUTCOMES OF THE PROJECT

The projects undertaken by the students were a component of a strategy adopted in an attempt to address difficulties which students had had with this Module in the past. Not only were pass-rates very low but performance in subsequent Modules gave a clear indication that students had failed to master the concepts involved. A deliberate attempt was, therefore, made to change the emphasis from analytical theory to conceptual understanding and from lecture and tutorial to active investigation. The Module, entitled Properties of Materials, had two main divisions, materials science and thermodynamics. It was, historically, the latter element which students found difficult. The projects which were assessed were conducted over the second half of the semester and approximately half of class time was devoted to them.

The intended learning outcomes were :

1. Ability to apply heat transfer principles to a specific application
2. Ability to select materials to optimise insulation but taking account of other constraining factors
3. Understanding of design methodology for a thermodynamic system for a given application
4. Ability to apply effective problem-solving strategies to an engineering design requirement
5. The development of group working skills
6. Presentation of technical information effectively in written and oral form
7. Demonstration of the ability critically to appraise technical information

The students were divided into four groups and each was allocated a brief to design a thermodynamic system for a house in a particular location, Table 1.

Table 1
Project definition summaries – groups 1 and 2 and groups 3 and 4 were paired

Group	Type of House	Type of System
1	Modern construction in climate typical of North East Scotland	A heating system to maintain an internal temperature of 20C
2	Traditional stone construction in climate typical of North East Scotland	A heating system to maintain an internal temperature of 20C
3	Modern construction in climate where average temperature is 28C and humidity is low	An air-conditioning system to maintain an internal temperature of 20C
4	Traditional stone construction in climate where average temperature is 28C and humidity is low	An air-conditioning system to maintain an internal temperature of 20C

The students were not taught the specific theory nor told what theory might be applicable. They were, however, given a good grounding in general theory and in the concepts. Specifically a part of the first period of the activity was devoted to a workshop where methods of sourcing and evaluating both theory and quantitative data were developed. It was emphasised that it was more important that the students' methods of seeking, evaluating, selecting and applying theory and data were more important than that the lecturers might have made the same decisions.

STUDENT SELECTION

The group formation was suggested by the academic staff but where students expressed a wish to work together this was accepted provided (i) overall group sizes were not affected (ii) none of the other students affected objected to the change. The four projects, two pairs of two, were very similar and were allocated arbitrarily to the groups. The allocation thus determined which groups would be paired and become customer/consultant for each other's projects. No dissent was voiced by any student either about group formation or about the conduct of particular members.

PROJECT IMPLEMENTATION

The groups had to design their own house in terms both of the type, e.g. detached 3 bedroom villa, and the construction materials. They agreed the dimensions and then had to evaluate the thermodynamic performance given their choice of materials. These building materials had to conform with the house type. They also postulated a family of occupant which allowed them to assess the energy input from both the occupants and the use of appliances. Clearly this could only be done on a relatively arbitrary basis. They sourced meteorological data to determine the probable ambient conditions throughout the year. Based on this they assessed heat losses and heating requirements taking account of the ambient conditions in all seasons, occupants and appliances. They selected insulating methods based on the technical and economic advantages of options. The groups generally used web-sites and d-i-y stores to obtain information on types of appliances which might be installed. Energy supply options were analysed using theory which some groups derived from first principles while others used "ready reckoner" types of formulae found on the web-sites of system suppliers. In the latter case particularly the students were required to identify the assumptions implicit in the theory and justify their application. Most evaluated about three options and on the basis of this analysis a system was selected. Emphasis was placed on the students' sourcing (textbooks, internet, industry etc.) and applying both relevant theory and technical and economic data. Assumptions had to be stated and selections justified and technical rigour was demanded.

PROJECT ASSESSMENT

Although scheduled class time each week was devoted to tutorial on the projects, a decision was made not t include a component of the assessment based on these on-going surgeries. This was because it was felt that it would inhibit imaginative design if the students felt pressure. In retrospect, and in the light of the experiences of others, [1], this was perhaps the wrong decision. It seems probable that motivation would be increased on the less productive group members if they knew that these surgeries contributed an individual component to the grade. The assessment was equally divided between a mark for a group oral presentation and one for a group formal report. The oral presentation attracted a group mark assessed by two members of staff for clarity, effective use of visual aids but mainly for the robustness of the technical case. At the same presentation each group's effectiveness in questioning their pair group was assessed for ability to challenge weaknesses in the other's case.

Individual reports were required which were marked separately by both members of staff and moderated (upwards) after the second marking. Clearly each student in a group was reporting on the same activity and conclusions and so standard data produced by the group such as calculations, tables and diagrams were allowed to be copied. The presentation and in particular, the discussion was required to be each student's own interpretation. Peer moderation was avoided with these first year students but students could lodge complaints against non-performers. (None did)

The Grade distribution is shown in Table 2. The grades awarded are considered to be a fair reflection of what was perceived by the staff involved to have been a competent approach by the majority of the students. Their analysis was technically defensible and the designs, based on evaluation of several options were effective solutions to the situations. Also shown in this table are the results of a diagnostic test which was intended to gauge the students' understanding of thermodynamic concepts. The latter was voluntary and only ten students completed it. It was based on questions of multiple choice and similar formats and was scored out of eighty four. The scores have been rebased for comparison purposes into a six point scale. These results were disappointing as they failed to confirm the apparent gains in understanding of concepts which the lecturers felt had been demonstrated in class.

TABLE 2
GRADE DISTRIBUTIONS OF ALL STUDENTS IN DESIGN PROJECTS

MODE OF ASSESSMENT	0	1	2	3	4	5	6
Design activity (n= 14)				3	7	4	
Diagnostic (n = 10)			4	6			

SUPPORTING STUDENTS

This was a design project and so the facilities needed were mainly information resources. Possible sources of both technical data and theory were discussed. A session was organised with the library on making effective use of on-line databases. This was a hands-on session and students had been asked to prepare for the session by identifying information they desired which would be relevant to their project.

The basic theory and properties of materials were taught, with tutorial follow up, in class but specifics had to be sourced and evaluated. Students were encouraged to use as many sources of data as possible. This included the Internet, library, (including standards) and d-i-y stores. (There use of different sources was evaluated by questionnaire and although the Internet was the most use it was clear that a wide variety of sources had been accessed). This was intended not only to introduce them to the way in which a professional engineer would approach a design problem but to encourage a critical approach to the evaluation of different sources of information.

Tutor support was provided with 2 staff for the four groups for 2 hours per week. Students frequently took advantage of our "open door" philosophy to discuss their progress and concerns. Staff acted as facilitators i.e. they encouraged effective use and questioned both the process and solution to the design. They did not offer solutions or judgements. We found that the most important function with these first year students was to maintain their confidence in their own abilities to solve the problem and to resolve ambiguities. Students were asked to rate the level of tutor support and all reported that it was neither excessive nor too little.

External Involvement

There were no formal links with any outside organisations. Students were encouraged to use sources like d-i-y stores, heating and ventilating engineers etc to obtain relevant data. It is not known how many did so but it is known that some did. Students were questioned about their use of various information sources. The Internet was by far the most used medium where both company web-sites and sites offering explanations and theory of thermodynamics were about equally utilised. Although contact with organisations such as heating and ventilating engineers was considerably lower this may have been because groups heeded the advice of staff both the send only a representative and to think out carefully in advance what information they were seeking. Handouts were more widely used for theory than textbooks.

Project Design and Development

This was the first year in which this approach had been used. Previously the Module had been assessed mainly by examination. The low performance in these examinations had been a cause of concern. The entire approach was altered. The emphasis was changed from analysis to an emphasis on concepts. Assessment was altered to be 100% coursework. A deliberate attempt was made to provide familiar contexts to illustrate the concepts which were been discussed. It was a natural adjunct of this to use project-based activities as the means of assessment.

Project effectiveness

Thermodynamics tends to be an abstract subject. Students have difficulties with visualising phenomena and relating concepts to their contextual experience. This project gave them a familiar context and asked them to apply the theory they had learned. It also taught them that engineering design requires the sourcing of data and the evaluation of mathematical models. We emphasised that all engineering design involves a degree of approximation. Students gained an awareness of the need to select a model which gave an appropriate level of approximation and the need to state the assumptions on which their solutions were predicated. These are fundamentals which are rarely addressed in a conventional approach to thermodynamics teaching.

This was a design only project and so there were no financial or materials resource implications. It has to be accepted, however, that the approach is staff intensive. We believe this to be a price worth paying. We were seeking, and believe we achieved, not only the cognitive outcomes nor yet just the development of problem-solving skills but affective changes. Much is said about encouraging independent learning but little is often done to promote this. By encouraging planning, analysis, selection and critical appraisal in a supported environment we believe we have achieved progress towards independence in these learners. This, we believe, will allow their future project activities to be conducted with less intensive support.

The author's research shows that students and even graduates have difficulty in applying theory. Graduates appear to attribute this to their own deficiencies rather than to its being a result of the way in which theory is taught at University, [2]. A major objective of these projects was to provide a familiar context to which the students could not only apply, but understand the rationale for the application of theory. One group approached the author in some confusion. Some members favoured the use of methods developed from the theory presented in a text book. Others, having found more tailored formulae in a heating systems supplier's web-site thought that it should be more relevant. It took some considerable discussion before they accepted that both essentially performed the same functions and were based on the same principles but that the commercial site made more specific assumptions about the application. As will be noted in Table 3 below students generally felt that they had gained a better understanding of the application of theory by these projects than through conventional teaching methods.

STUDENT FEEDBACK

Student perceptions were obtained through questionnaire, Table 3, and interview. The majority of the students enjoyed the experience and believed they had learned more theory gained a better understanding of the application of theory and gained better problem solving skills than they would have done from a conventional approach. A cautionary note, however, to those enthusiasts for PBL who believe that all students "love these activities" is sounded by the finding that around a quarter of the students would have preferred a conventional approach. This has been a consistent finding of several such evaluations. Again as has been found before these students chose to remain anonymous and so their objections can only be the subject of speculation. There were significant correlations between virtually all of the students' perceptions of the experience. Does this mean that those who enjoyed the experience spent more time on it and so learned more? Or did learning more lead to their spending more time and therefore to their enjoying having acquired an understanding? Interviews suggest that those students generally had a favourable impression and probably all that can be read into their responses is that as a result they used the high ends of all scales. Those who had less favourable views chose to remain anonymous and, of course, declined to be interviewed. Whether they actually learned less and if so it was because the cause or the result of lack of enjoyment can only be the subject of speculation.

TABLE 3
PERCEIVED LEARNING BENEFITS IN COMPARISON WITH A CONVENTIONALLY TAUGHT APPROACH

Factor	-2	-1	0	+1	+2	Average
Technical knowledge gain		1	3	16	1	0.8
Problem solving skills gain		2	5	13	1	0.6
Appreciation of application of theory gain			7	11	3	0.8
Combined measure			9	9	2	0.8
Students' ratings of time spent on the activity	1	2	7	5	5	0.6
Enjoyment of the activity	1	2	7	5	5	0.6

The pass-rate for the Module and for this coursework was 100% with the average grade achieved in the project being 4 (3 = bare pass, 6 = maximum), see Table 2. Less encouraging, however, were the results of a multiple choice diagnostic test of thermodynamics principles which around 60% of the students voluntarily completed. The average score was slightly below the 40% which would normally be consider to be a pass.

We asked the students to complete a learning styles inventory [3]. They proved to be mainly activist, sensory, visual and near the middle of the sequential/global scale. These averages, of course, conceal wide individual differences. It had been hoped that perceptions of the experience would be related to learning style as had been found by others, [4]. Perhaps because most of those who had not enjoyed the approach had opted to be anonymous, no correlations were detected. The students themselves were aware that the project-based approach did not suit all. Several of those who had favourable impressions made comments to this effect at interview.

We were aware from previous use of projects with first year students that they would need close supervision and support. This was confirmed by our findings. Although we did not uncover evidence to support it, our belief is that students with a low tolerance for ambiguity and those tending to be reflectors and intuitors are more likely to find these activities stressful. We do not anticipate making any major changes to the approach next session but we will introduce the activity earlier in the semester, provide more detailed documentation and provide milestone checks for the weekly surgeries. There are also plans to set up a Virtual Campus group to promote discussion and peer evaluation of ideas.

INNOVATION

The main features which we consider to be noteworthy are:

- The subject was thermodynamics and materials i.e. not a conventional design project
- It was first year (first semester) class. Some consider that such classes lack the skills and knowledge to conduct projects. We demonstrated that, given selection of context and level and sufficient support, such projects can be successful

- Each group was both consultant and customer. This encouraged both rigorous justification of their own design and critical appraisal of their partner group's efforts.
- Search methods skills tuition was included in the schedule.

CONCLUSIONS

This use of DLL activities was considered to be a qualified success. The students obtained an introduction to group activities in the quest for solutions to open-ended briefs. All groups both tackled the tasks systematically and with technical rigour and produced effective and defensible solutions. The suggestions that first year students lack both the abilities and the knowledge to conduct such activities was proved to be unfounded. Similarly it was shown that design need not be confined to the traditional product design and make activities of mechanics modules. If design activities can be used as the basis of assessment in thermodynamics there is no reason that the cannot be extended to virtually any subject. The reports that the breadth of coverage of subject matter is limited was, however, not refuted. The overall strategy employed in the Module addressed the immediate problem of low pass rates. Tentative evidence does not suggest that this was entirely divorced from the assessment methods employed rather than to dramatic improvements in the students' conceptual understanding of the subject.

[1] Edward N (2001), Occupational socialization - A new model of the formation of the professional engineer. Paper 8 B5 presented at the *International Conference on Engineering Education* August 6 - 10 2001, Oslo Norway

[2] Edward N., (2002), Design in Undergraduate Engineering Courses – invited paper STEP the collaborative Conference of SPAT/PROGRESS in York November 2002 and subsequently published and disseminated in a special edition by PROGRESS

[3] Felder, R (1988), "Learning and Teaching Styles in Engineering Education", *Engineering Education,* April 1988 pp674-680.

[4] Felder, R., (1993), "Reaching the Second Tier: Learning and Teaching Styles in College Science Education." *J. College Science Teaching, 23*(5), 286-290 (An article containing an updated presentation of the Felder-Silverman model.

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