

## CHAPTER FIVE

### CAPABILITY THROUGH ENGINEERING HIGHER EDUCATION

Susan Weil, Peter Lines and John Williams

#### Introduction

##### *Finniston and beyond*

Higher Education has a vital role to play in developing capable engineers who can influence the advancement of the profession, the future of the economy and the quality of life generally in society. But just what does this challenge entail, as we move towards the next century? And how are academic staff involved in engineering higher education responding?

Some ten years ago, the publication of the Finniston report (HMSO, 1980) led to the establishment of The Engineering Council. This set the standards and routes to registration for the profession.

However, post-Finniston there are still many issues to be faced:

- a) What kinds of learning opportunities should HE be providing.
- b) Just what will a 'capable engineer' mean in future and how might such a person best be developed, given limited resources ?
- c) How can the quality of engineering education be enhanced and indeed, what does quality mean in a move from an elite to a mass higher learning system?
- d) Has the familiar approach of laboratories, lectures and tutorials in some cases become a treadmill and if so, what alternatives are there and how can they best be introduced?
- e) Are current ways of assessing students' abilities and potential as future engineers the best, and if not, what alternatives are there and how can they be introduced?

##### *The need for capable engineers*

High level technical knowledge and skills are critical to the economic prosperity of the nation (HMSO, 1987) But is this enough?

A strong basis of specialist knowledge and the ability to apply it is essential to underpin effective engineering responses to new challenges and new markets. Today's engineers also need to be market conscious, commercially adept, environmentally sensitive and responsive to human needs (Engineering Council, 1985). Employers want graduates who are flexible and broadly educated, can solve unfamiliar problems, and can work in teams (Engineering Council & SCUE, 1988).

Engineers need to know how to make continual and effective use of workplace and educational resources to manage change and to update their specialist knowledge. This requires continuing education throughout their professional careers, the need for which has been recognised by the Engineering Council (Engineering Council, 1990). Greater emphasis on continuing professional development - stimulated by the rate at which technological knowledge becomes obsolete - must produce a re-appraisal of the role of the first degree in relation to continuing education. The obvious pattern is for continuing education to provide the specialist 'topping' to the first degree. First degrees will need to be mostly concerned with helping students to grasp fundamental principles, and to acquire transferable skills.

HE is rising to these challenges in the initial education of engineers. The development of specialist knowledge is being underpinned by opportunities for students to participate in the development of criteria against which they can gauge their progress. More and more, students work through learning opportunities that simultaneously challenge them to take risks, make decisions, monitor their effectiveness as learners, be creative, and evaluate critically various solutions to unfamiliar problems. Such learning need not be at the expense of the acquisition of hard

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book ([www.iclml.com](http://www.iclml.com))

knowledge; instead, an approach that entails responsibility and accountability can drive a far deeper conceptual and intellectual grasp of vital engineering principles and material (1).

### ***The need for more engineers***

Employers assert that there are insufficient engineers to meet national needs. The number of engineering graduates employed in industry has in fact increased by 50% in less than ten years (Bonwitt, 1990).

This change has come about at a time when the government is urging a significant increase in the higher education age participation rate (HMSO, 1991). The demand for places on engineering courses among the declining 18 year old cohort remains far too low (Smithers, 1990) although there are some signs that this trend is reversing (2). The recruitment of students with more varied academic, work and life experience becomes essential if the supply is to meet the demand.

In this context, current levels of drop out and examination failure in engineering is of concern. It is in fact the highest for all subjects both in the universities and in the polytechnics and colleges' and is now the subject of considerable research (Parry, 1990).

Structural solutions are commonly proposed. The staircase image predominates. Stepping on', 'stepping off', 'pausing on the landing', are the kinds of metaphors that underpin arguments for modularity, the assessment of prior experiential learning, new interfaces between BTEC and A levels at school, and more engineering partnerships between FE and HE (Ball, 1989, 1991). It is also argued that public perceptions of engineering courses and careers need to change.

Creative and challenging courses that build effectively on the different starting points and aspirations of students and equip them to respond effectively to not just the known but the unknown in the profession, are likely to prove more effective in attracting and retaining students (3).

### ***The context for such changes***

Such developments in engineering education cannot be divorced from significant challenges affecting higher education as a whole. They have to be considered within the context of the massive expansion of student numbers in higher education combined with growing demands for accountability, quality assurance and assessment, and responsiveness to more and different students. And this must be achieved with reduced central funding.

Innovations in teaching and learning have resource implications and we cannot shy away from these. However, staff need to find time and space to develop new strategies for engineering education, whereby existing resources can yield long term pay off in educational terms.

### ***Capability principles and practices as a way forward***

The examples that follow in this chapter represent a wide range of interpretations of capability principles and practices. They illustrate the different ways in which academics are seeking to improve the quality and responsiveness of their programmes. They offer a variety of responses to the challenges of change, undertaken within the constraints and opportunities of their particular institutional or departmental situation. Some developments have been undertaken with the aid of external funding, some have not.

Challenges are inevitably posed for students, teachers, course designers, professional and validating bodies, managers and funding councils. Obstacles are charted, and the different strategies used to overcome these are identified. The emphases on one dimension as opposed to another obviously vary across the various examples. But singly and overall, they raise issues relevant to introducing capability principles and practices into engineering courses.

## **Theme One: Reviewing and Building on Experience**

### ***Introduction: First Year Initiatives:***

Engineering faces particular challenges in setting a culture for first year studies. Students now vary substantially in their expectations of teaching, learning and assessment as well as in their background knowledge.

Most students are used to comparatively small classes and expect a formal setting. The first year must motivate students and this often implies a substantial content of engineering applications. Yet at the same time, the first year has to contain the necessary engineering fundamentals.

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book ([www.iclml.com](http://www.iclml.com))

Also, the first year carries the responsibility of developing students as independent learners, and as teamworkers - concepts that can sit uneasily with students' previous experience and pre-conceptions of higher education. Yet if such expectations and culture are not established in the first year, it becomes progressively more difficult to establish it in subsequent years.

This section explores ways in which first year students can be introduced to some of the challenges that will later confront them in the profession they have chosen.

Issues addressed through the examples suggest, for example:

- how changes in the ways students learn can improve their grasp of engineering principles
- ways in which capability based programmes can help to counteract high attrition rates
- the importance of support from validating and accrediting bodies and senior management
- how students can be motivated and introduced to fundamental engineering principles through a problem based approach
- how introducing opportunities for student responsibility and accountability can change staff and student expectations

At *Polytechnic South West*, first year HND Civil Engineering students {195} are briefed to act in groups as junior members of a consultancy reporting to a Partner'. The intention is to use their innate curiosity as the starting point for grappling with initial principles of construction engineering and management.

The consultancy activity has the following purposes:

- to increase awareness of construction procedures relevant to below ground work
- to foster self awareness, imagination, creativity and interpersonal skills
- to enhance an individual's effective and efficient application of construction procedures.

Individually, and as a team, students submit staged reports on the feasibility of constructing a motorway - to the alignments and through the ground conditions indicated on an Outline Drawing. In doing so, they identify, research and report on construction problems, assess relevant construction procedures and propose/develop optimum solutions.

This experience also provides a focus for reflecting on the benefits and problems of teamwork.

At the end of the unit, students undertake an 'open book' style assessment.

Programmes such as these are often seen as competing with academic priorities' as defined strictly in content terms. This example shows that content and process need not be placed in opposition. When they are integrated the quality of teaching and learning can improve significantly.

*The approach adopted has freed time for the lecturer to concentrate on coverage of 'key' topics/issues. However, it has placed emphasis on the need to provide access to adequate, relevant reference material . {195}*

As students gain more experience of taking responsibility, they also become more forthright in saying how they might better be prepared for a different approach. The following student feedback captures some of the above themes.

*I think the first project should have been individual and easier with an obvious structure, amount of work needed, etc ..... For further projects, the students should be in groups of 3 maximum. This would allow for better/easier work distribution within the Project, and make it easy for group meetings to do any work/reading which should always be done with group members around to allow for discussion, etc. Apart*

***from these structural problems, the actual work involved in the projects was very relevant ..... I found the exam (open book) interesting to do and even enjoyable! {195}***

At the *University of Newcastle upon Tyne* students at the beginning of their Engineering Foundation Year {138} participate in a module on Oral communications and teamwork! This programme anticipates the development of students as future engineers:-

- they experience working in groups of various sizes
- responsibility is placed with the individual, but not at the expense of an emphasis on the learning community
- students are helped to relate their current experience as students to situations they will confront as engineers
- Emphasis is placed on the skill of giving feedback. A check list is provided to facilitate peer group assessment of individual presentations.

This programme places particular emphasis on oral presentations. One student writes with considerable self-awareness about this experience.

***Giving a presentation can be an intimidating experience. You are laying yourself open to embarrassment in front of your peers, mockery, criticism and humiliation. ... In my experience, these feelings are the end of a long process of change in my perception of the ordeal to be faced. Initially, in relation to my title, I feel blank, and have the response, 'I can't think of anything.' This panic gradually subsides as I resign myself to the fact that it has to be done. Then, miraculously, I have a wonderful idea for a radical new approach which will dazzle everybody with my brilliance. This euphoria lasts for varying amounts of time - usually until I have finished writing, and then this too subsides and gives way to serious doubt.***

***This is the most dangerous phase since I start to change and rewrite my plan, often nearly beyond recognition. ....***

***Gradually calm descends and the presentation is finally organised. Relaxed, cool, calm and collected I am eventually ready to give the presentation. Things do not stay this way, the inevitable last minute panic seizes me seconds before it is my turn, but it is too late. I am committed to this version!***

***The first few sentences come out in a garbled haste, but then I am able to settle down and perhaps even enjoy giving the presentation. It is all over before I even knew it had begun - and the dominant feeling is a relief. My strong points as a presenter are a reasonable command of the English language and an ability to 'ad lib'. An injection of humour or self mockery can keep the audience alert and perhaps even interested. Once I am committed to the final draft and am standing in front of the audience I have quite a good degree of self confidence and can project my voice well....***

***Presentations do become easier the more you practice, but in my experience, you never lose the last minute panic. Once complacency sets in, a mediocre performance will ensure. As with most things, hard work pays off. The more time that has been spent preparing the presentation, the more familiar you are with it, the more confidence you have. ... This means you have more eye contact with the audience, and this is important since giving a presentation is merely a formal manner of interpersonal communication. {138}***

This student shows how her involvement has helped her to attend more explicitly to her competence and continuing development as a communicator - a quality that employers are now seeking in engineering graduates.

At the *University of Hull*, *Software Engineering* students {68} work in groups of four on a software system production exercise. Members of staff act as live clients and customers for the systems to be developed. Each member of staff is allocated a project, and remains the customer throughout its development. The student groups, however, change clients at the end of each of the four stages of requirements analysis; systems specification and design, implementation and testing.

***From the students point of view, they are responsible for achieving essentially two goals. The first, the ostensible goal of the exercise is to take a vague system description and develop it into a well defined,***

*effective and feasible system specification, calling upon theoretical and practical knowledge gained in a variety of courses taught in the first year. The specification is then developed into a design, implemented and tested. The second goal requires students to explore and learn effective ways of organising themselves and the activities of the group. It is this second goal which provides the student with what we feel are the crucial challenges and opportunities. {68}*

Employers were also involved in this programme, ensuring that the approach had relevance to industrial practice.

*We had very useful discussions on the relevance of the exercise generally to industrial practice with representatives of the Ford Motor Company, who incidentally are presenting a prize to the best group effort. .... the exercise was designed so that the students would have to tackle these problems in the ways in which they would be tackled in industry. {68}*

Experience at Hull suggests that the challenge to teachers and course designers is

*to ensure that the exercise results in the students acquiring skills and knowledge. It is a fact of life that students are more interested in building systems than in educating themselves... The most crucial factor to consider is the views and attitude of the staff who will be involved as clients as well as teachers.*

*There were a number of benefits to students, including the realisation that working in a group requires communication skills and organisational effort. Technically, they learnt that the production of even an apparently 'simple' piece of software requires substantial effort at the requirements and design stage. Most groups, predictably given their level of experience, left a substantial proportion of design to the coding stage....One of the aims of the exercise was that it should help to equip the students with the communication, co-operation and presentational skills likely to be of benefit to future employers. {68}*

At *Coventry Polytechnic*, automotive engineering design and mechanical engineering students {28} share a common, traditional first year course. In the second year the automotive engineering design students move to a problem-oriented approach. Students are responsible for solving the problems posed for them, drawing on their own knowledge, experience and interests. This approach focuses their attention on the skills they will need to improve their problem solving abilities.

The second and subsequent years are studio-based.

*where group work flourishes and a very useful by-product, peer teaching, has developed strongly. The automotive flavour of the problems set to students (for example, the design of a motor car cooling package including radiator, fan and water pump) has been found to be very motivating. {28}*

The validation panel for the course included eminent representatives from the automotive industry and staff from other faculties with operational experience of the proposed learning and assessment methods. Validation was conditional upon a staff development programme. A strategy was developed, beginning with the course document as the basis for a training needs analysis. Members of the course team were encouraged to identify issues and concerns relating to unfamiliar aspects of the new curriculum.

Thus the staff development strategy itself adopted a problem-centred approach. In this way, a deeper sense of involvement and ownership was fostered:-

*The outcomes of the first day-long activity were used to plan a week long intensive workshop based programme. The general areas which were addressed included experiential approaches to learning, specifying learning outcomes, working in groups and assessment. A particular aim of the workshops was to enable participants to develop realistic project based activities that would be appropriate ...*

*An evaluation .....indicated that for the most part the aims of the programme were achieved and that the staff involved received it positively and enthusiastically.{28}*

At the *Polytechnic of East London* {43} students have opportunities to enter engineering degrees through a foundation programme that is based entirely upon the notions of student responsibility and accountability.

This programme comprises four components:

- i. Professional orientation and vocational guidance
- ii. Core maths and science
- iii. New technology appreciation
- iv. Specialist study

The programme content is student derived and managed. Students profile themselves, plan personal development paths and goals, and demonstrate their achievement through negotiated continuous and final assessment in a portfolio. Vocational guidance and counselling support is given. Subject support is given through workshops, tutorials, drop in learning resource centres and some lectures.

Students may also choose to follow a recommended core content course covering prerequisite knowledge and skills required for all 26 undergraduate courses to which the programme is linked.

The Professional Orientation component aims to develop relevant skills and understandings relevant to getting the most from a capability approach. They are helped to integrate these into their process of knowledge acquisition.

*The first six weeks are spent in training and development in capability skills so that students have the tools to develop a 'capability' perspective in their studies and assessments, and to take responsibility to achieve this. Skills developed include study, time management, organising, decision making, communicating, interpersonal, leadership and team membership. Study methods include individual and group work, non-directed private study, practice at using resource based learning, case studies, simulations and closed circuit television. Students design and negotiate a study contract. The final portfolio of work is assessed on the knowledge acquisition through laboratory, theory and practical studies. {43}*

A capability approach requires teachers to have expertise not only in their subject area but also in the guidance and support of student learning.

*Teachers have had to adopt new teaching strategies, making the monitoring of student progress and tutoring in capability as integral to their subject expertise. They have developed communicating, negotiating and advocacy skills to support students' negotiations to join specialist departments. {43}*

Time and space to make sense of the learning derived from new ways of working are essential:

*Tutors spend considerable development time discussing the challenges 'educating for capability' has made to traditional learning conventions in science and engineering. They each developed sample study contracts in which excellence of knowledge acquisition and capability were integrally developed. This practice led to the rejection of study contracts in which subjects were conventionally sequenced, tutor paced, content determined and assessed in a standard format. {43}*

Time release for course teams involved in ambitious capability initiatives such as this programme is an essential consideration.

*The team members had time release to attend development meetings. These were run as Workshops. A specialist tutor led the group for a specific component to develop overall aims and objectives. Sample study contracts were then developed for the component, demonstrating how capability skills and knowledge were complementary. {43}*

An approach such as that adopted on this programme inevitably develops students who have gaps in certain knowledge bases, but considerable strengths in others:

*Feedback from students who chose to transfer to universities from the first two cohorts indicates that whilst they might still require a broader knowledge base to compare with standard entrants, the quality of their knowledge and its application and their capability skills give them an advantage over their peers. {43}*

## **Theme Two: Planning, Negotiation and Approval**

### ***Introduction***

The development and negotiation of learning agreements with students is a fairly new development on engineering programmes. The examples that follow illustrate the different ways in which negotiating and contracting processes

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book ([www.iclml.com](http://www.iclml.com))

are being gradually introduced into engineering education: from Open Learning modules across a School of Engineering, to the use of learning contracts and negotiated work programmes with a community partner - in this case a museum.

Issues addressed through the examples include:

- the purpose of learning contracts and how they can be developed
- involving employers and community representatives as partners in learning agreements
- determining the parameters within which negotiation is and is not acceptable, thereby setting out the boundaries within which students can be responsible and accountable.
- negotiation as a means of increasing student motivation and the quality of learning outcomes.
- negotiating with large groups of students

At **Wolverhampton Polytechnic {243}**, students have the option of contracting directly with an employer to receive credit for off site work based projects. A special module called Learning contracts' was offered on a pilot basis to part-time and full-time undergraduate and post graduate students in Computer Science, Business Information Systems and Information Technology.

Developed with Training Agency funding, this programme enables students to complete part of their course through the negotiation of a contract between the Polytechnic and a third party, normally the employer of the student. For example, two contracts were negotiated with Tarmac Quarry Products, both in the Information Systems area. They resulted in the production of software of a high calibre and the company is keen to use this method again.

Polytechnic tutors are timetabled for 4 hours of negotiation followed by 12 hours of tutorial support.

The definition of a learning contract was applied as follows:

***A Learning Contract is an agreement for a programme of future study negotiated between the student, the employer and the Polytechnic. {243}***

Students have the option of studying any appropriate module through a learning contract approach:

***A contract need not match an existing module exactly, although if it is being used as a pre-requisite for future modules this must be taken into consideration. There is no set credit value for a contract nor set length of time. The level, credit value, timescale, content and assessment method will all be agreed when the contract is drawn up between the normal teacher of the module, the student and the employer. {243}***

Students are accountable for producing something of value to the employer, and for learning new material over the course of the contract. Employers are accountable for ensuring that the student's learning needs and interests are given time and attention.

Experience has demonstrated just how challenging this can prove to students:

***Most students felt that a contract had been a more difficult mode of study than the traditional method and that it required considerable motivation and perseverance. {243}***

Preparation for a capability approach is essential:

***Evaluation of the pilot scheme has led to the conclusion that students need to be prepared for this degree of self-directedness, especially if they are to be rigorous in their approach. A key issue in the success of contracts could well be the selection of motivated students with a good track record. Students need to be made aware that this is likely to be a more difficult mode of study. Setting an initial hurdle, such as the production of a brief, might help to ensure more dedicated effort. Groups of students can be self supporting, which could cut tutorial support. Readily available distant learning material could also assist. The role of the employer in terms of help and advice also needs to be clearly identified in the contract. {243}***

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book ([www.iclml.com](http://www.iclml.com))

Also at **Wolverhampton Polytechnic**, students on the BSc (Hons) in Computer Science {241} and other courses have the option of taking a module on Business Information Processing during the final year.

Teaching and learning methods, working arrangements and assessment procedures were determined by ongoing negotiation between staff and students. By the end of this module, students were required to demonstrate a critical understanding and the ability to apply project management techniques to the development of large scale software products. Each week a regular meeting (one hour) was held to discuss the previous class and to plan the next. A written plan and report was produced each week.

Prior to this programme students experienced a year of industrial placement. This motivated them to wish to exercise more control over their learning and to use the skills they had acquired at work. This module provided the opportunity to draw together technical knowledge from previous modules in relation to project management, operating in teams and managing people.

***Negotiation is a key factor in these processes and thus was appropriate as the central tenet in this module. {241}***

Staff had gained confidence in student centred methods of teaching and learning through Enterprise in Higher Education workshops.

This example addresses common concerns of engineering academics to ensure coverage of particular content areas. In the case of this example, the broad content of the module was not open to negotiation. This included project planning and control, project estimation and costing, quality assurance and reliability, system life cycle and maintenance and systems analysis and design.

The basic assessment strategy was also pre-determined:

Assignment 1: an individual critical review of an appropriate topic

Assignment 2: a group assignment based on the application of knowledge and skills to a problem set out in the form of a case study.

Both elements were required to have written and oral components.

What was open to negotiation included:

- teaching and learning methods
- order of material
- assessment content (within the above constraints)
- assessment weighting
- assessment marking: self/peer/staff
- selection of teams
- mechanisms for negotiating

Even with these clear parameters, the challenges to students were considerable:

***The actual negotiation was the most difficult part of the process during the first year. Students tended to opt for safe traditional methods such as standard lectures and had to be encouraged to select more enterprising modes of work. A number of group activities were devised, the most successful being the formal review of the project schedule which each team had devised. {241}***

After the first year of this programme, the course team decided to change the emphasis of negotiation between staff and students to negotiation primarily between students. This strategy is also well suited to large groups of students.

Students are now allocated to groups of 12-15, each of which functions as an information systems consultancy company. Advertisements are issued for the managing directors posts, and applications are received freely from the entire student group. Each applicant gives a presentation to other applicants on their suitability for the job. The applicants themselves select the managers required.

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book ([www.iclml.com](http://www.iclml.com))

Each company is then commissioned to undertake two major information systems projects. The focus and completion of these takes place entirely within the 'company' - in other words, through student-student negotiation. One hour per week is set aside for a formal full company meeting where lecturers attend as observers. Informal sub groups are held as required. Both oral and written reports are produced by each company. Tutors also now plan to liaise with the Information Systems Managers to determine students' grades, based on the appraisal system agreed among company members.

At the *University of Exeter* {51} up to 100 students in the School of Engineering take advantage of an Open Learning module in the second year of their engineering degree. This is compulsory and counts towards degree classification. It may, by negotiation, be a non-engineering study or project.

Students negotiate personal study or project programmes including collaborative initiatives with local industry and commerce. The module leader helps to match what the student wants to do with the support available within and outside the university.

Targets and strategies for meeting them are negotiated between tutor and student, with the involvement of external agencies where appropriate. This agreement provides the basis for assessment of achievement.

The module allows for the development of self-awareness in relation to skills such as communication, organisation, scheduling and appraisal.

The flavour of the module is perhaps best illustrated by a quote from the preliminary note to students:

***The idea behind this module is...to provide an opportunity to practise the skills of setting your own targets, meeting your own deadlines, assessing your own performance, and generally getting organised for serious self-directed learning. We shall ask you to submit your preliminary ideas for Open Learning, including:***

***Targets: what do you want to do, hope to achieve***

***Processes: how do you intend to go for your targets***

***Outcomes: how will you present and evaluate what you have done?"***{51}

Internally, the decision was taken to locate the module in the second year of a four year course so that first year skills could be further explored and built upon. Colleagues in the department are now exploring the scope for extensions of the capability approach in subsequent years.

Academics in the School of Engineering were approached in order to identify their willingness to support students who wished to participate in this scheme. Detailed preparation was provided through individual discussion with the two staff responsible for operating the module.

***The difficulty in introducing such an innovation is in persuading staff to recognise that they have more to contribute to the educational process than just their proven expertise in a specialist field. Tutors can be reluctant to allow students to take real responsibility for devising personal study/project programmes when they do not appear to have 'respectable' technical content. {51}***

Experience builds confidence, as the quality of learning is seen to be enhanced:

***The local Chamber of Commerce helped to develop contacts in support of the open learning module. The Industrial Advisory Group that monitors the curriculum of the School of Engineering is also supporting the scheme. The science advisers of the local education authority assist in making contacts with schools, to allow for 'peer tutoring' opportunities. Professional and external bodies have been generally supportive and instrumental in developing the open learning module. {51}***

Contracts in engineering and technology tend to be informal rather than formal. However, at the *Polytechnic of North London*, students on a BTEC HND in Science (Polymer Technology) {141} engage in negotiation and planning for a work programme with the Science Museum. The programme is intended to deepen students' grasp of fundamental principles in polymer technology. The specific objectives are for students to:

- a) study the factors affecting the ageing of celluloid articles
- b) determine the nature of the degradation processes

c) suggest a method to arrest this degradation or storage conditions that will prolong the life of the material.

This development was introduced in response to requirements by BTEC in their Policies and priorities into the 1990s' document and subsequent guidelines. In particular, the unit was designed to develop a range of personal, interpersonal and problem solving skills while at the same time simulating the environment typical of the polymer industry.

The Science Museum offered an ideal opportunity for fostering intellectual, professional and teamwork capabilities:

*The Science Museum has a dilemma in trying to preserve articles only designed for relatively short lifetimes, particularly those which are naturally based (eg. cellulose polymers) as opposed to some oil based polymers. [It] has limited research resources and the students have limited opportunities to tackle such realistic problems. Thus a preliminary investigation into this problem seemed ideal for students commencing their careers in the polymer field. {141}*

Students are challenged to engage in recurring cycles of investigation, group problem solving, negotiation, planning and assessment:

*Students initially visit the Science Museum and a factory currently producing mouldings from nitrocellulose (celluloid). In groups, the students then review the problem and research the necessary background information. After discussion of the project, students devise an investigative action plan. This is negotiated with the lecturer, as well as with peers, with a view to work-load distribution and deadlines. Regular meetings (usually weekly) take place with the staff responsible for the assignment. Each small group discusses their goals and progress towards them.*

*Assessment takes place at each of these meetings with groups negotiating grades for each member - encompassing peer, self and lecturer assessment together. Members within the group are accountable for reporting regularly to each other, both orally and in writing. They also report to the class as a whole and the lectures, so ensure everyone maintains an overview and to enable a discussion on priorities to take place. Formal presentations to the class are also made at specific times during the project.*

*Each student is obliged to prepare an individual report on their area of the literature review (including communications with relevant companies and other non-library sources of information) together with suggestions for the direction the project would now follow. These are collated to produce a final dossier that backs up a final presentation to peers, lecturers and representatives from the Science Museum. {141}*

This example illustrates ways in which students can be involved in major ongoing research projects, through which their intellectual grasp of academic content is given meaning through their experience.

### **Theme Three: Active and Interactive Learning**

#### ***Introduction***

Active and interactive learning has become a key feature of engineering and technology degrees. Case studies, projects and problem centred approaches to teaching provide students with opportunities to integrate and relate their understanding of pertinent theory and principles, while developing skills relevant to planning and managing their own learning, individually and within groups. Increasingly, such activity now involves collaboration with industry and/or other disciplines

The examples which follow illustrate the following:

- how to accommodate a problem based learning approach within a conventionally taught degree
- ways in which a greater emphasis on active and interactive learning can further students' intellectual understanding
- how a capability approach can foster an appreciation of the needs and cultures of their disciplines, through the ways in which students are made accountable

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book (www.iclml.com)

- ways of tackling timetabling, workload and resource challenges
- the importance of support from library and laboratory staff
- the challenges posed to academics and their students when swimming against the mainstream of teaching/learning approaches

At *Imperial College* {74} an alternative approach has been introduced into the third year Vibration Analysis course. This example illustrates the efforts of a lecturer whose introduction of a capability approach requires him and the students to navigate their way against the mainstream currents of the programme as a whole.

The entire course is organised around a set of problems, the solutions to which are a major part of the assessment. The problems are typical of those met in industry. Students work in groups and are required to solve a selection of problems acting as consultants to a client group. The client group prepares a critique of the consultants' solution, and discusses it at an oral presentation session. Roles are reversed for the other problems. The course is divided into 3 phases of 6-7 weeks, each phase ending with oral presentations.

This innovation arose out of a single lecturer's concern that an excessive emphasis was being placed on technical theory at the expense of students developing an intellectual and practical grasp of real engineering problems.

The challenge was to fit the approach into the standard timetable, to ensure that the workload was similar to that of conventional courses.

Evaluation confirmed that this was achieved (Cawley, 1989), but, as is so often the case when students take more responsibility, they become more highly motivated and involved:

*student time input was somewhat greater than their estimates, since students could frequently be heard discussing the problems in the coffee room, an almost unknown occurrence on conventional courses.*

When introducing an approach that significantly jars with the dominant culture of teaching and learning, proper preparation of students is vital. In this case, an introductory session helps students to decide whether or not to take this option. Formal input consists of 4 mini lectures/demonstrations designed to illustrate the way in which systems vibrate, as well as a bibliography and some printed notes.

*The students clearly enjoyed the course and felt that they had learned as much technical material as they would on a conventional course .....The most commonly mentioned features were its focus on real problems, the absence of examination, and the fact that students were treated in 'a mature way' (Cawley, 1989)*

Tutors observed that student enjoyment and skills development were enhanced and,

*discussions were more productive and at a higher level than amongst students on conventional courses. Students also were highly motivated and tended to deal with many of the basic issues themselves. The oral presentation sessions also became important learning forums, with incorrect statements being seized on by students, not merely tutors, with clarification through ensuing debate. The retention of points raised in this way also proved to be very high. (Cawley, 1989)*

In the Department of Civil Engineering at the *University of Bradford* {12} a number of difficulties were identified with the conventional teaching of the second year course in Concrete Technology and Water Engineering. Students were not making the necessary connections between these courses and others on the timetable, and were not, for example, appreciating the link between the microstructure of concrete and its in-service performance, or the selection of treatment processes and the desired water quality.

It was decided to adopt an industrial pattern of small group problem based learning.

*Thus, the students are literally confronted with the connections in a more obvious manner, whilst learning both task and process skills. ....the solution to the problem cannot be achieved without making the required connections. The problems increase in complexity, scale, time allocated and academic expectation as the course progresses. Problems set have included a pipeline in the North Sea, a dam site in Scotland and a sewer interceptor scheme loosely based on that built in Edinburgh. {12}*

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book ([www.iclml.com](http://www.iclml.com))

Assessment of student progress is through a combination of written reports, oral presentations, diaries, summaries, essays and short question/answer exercises.

The committed involvement and initiative of a few staff who bring a clear sense of purpose to the re-design of a programme is often the starting point for more widespread change. In this case, the innovation was also assisted by the provision of Enterprise in Higher Education funding.

The lecturers involved in this course development described their stance:-

***The process (learning how to learn, applying the engineering method) is as important as the task (learning the academic content, the scientific principles). It is therefore necessary to equip students with the process skills required for industry based learning. Traditional engineering teaching has been essentially passive: learning followed by problem. Industrial learning is active with problems being presented without all the necessary knowledge to hand. It is also conducted in small groups working towards an accepted common goal. As such, students need to create and take opportunities, accept responsibility and risks, solve problems, turn ideas into action and work effectively with other people. Desirable as they are, developing these skills does not easily fit the traditional teaching style. {12}***

Students are prepared for this problem based approach through Communication skills courses. Aspects of group work such as strategies for problem solving, leadership, oral and technical report presentations, role playing exercises, non-verbal communication and information retrieval are encountered.

The support of library and laboratory staff has been identified as critical, lest the learning style being encouraged be subverted by a weak link in the chain.'

On the whole, the response of students has been positive and encouraging:-

***Particularly impressive has been their response to a challenge. The more difficult the issues, the more the students rose to meet them. {12}***

The key lessons learned from this development are, as described by tutors:-

***(a) It is essential that the student's creativity is not stifled by the imposition of the teacher's solution at any stage.***

***(b) More preparation is required to account for the variety of feasible responses that students can make.***

***(c) Problems need to be structured to make intermediate goals explicit, so as to sustain motivation.***

***(d) Communication skills need to be introduced prior to this programme, rather than in parallel. {12}***

At **Hatfield Polytechnic {61}**, all engineering undergraduate students participate in a one week interdisciplinary design project during their second year. This is intended to demonstrate how the general principles of design can be applied across several disciplines. A substantially common first year design course provides the foundation for this activity.

Students are brought together in teams which are deliberately interdisciplinary. They have to come to terms with working in a group with others who have different backgrounds, interests and specialist expertise.

***The design projects are chosen to be realistic, real life problems which demand contributions from more than one discipline. They require students to think laterally, to exercise initiative and imagination and to come up with a solution within very tight timescales. Examples have included a vehicle weighbridge, traffic cone laying, litter clearance from canals and a supermarket checkout. {61}***

Teams are allocated to staff supervisors whose duties are to encourage, advise and assess. Following two preliminary meetings, all teams have the complete week to plan and carry out the design to satisfy the project brief. The design is a 'paperwork' exercise only, involving sketching, technical drawing, CAD, modelling and calculations.

Students are required to present the results of their work to a panel of judges:

***This is required to include a report and a display stand. Issues of cost and implementation are required to be addressed, together with issues such as marketing, ergonomics and public acceptability where relevant. {61}***

Also at Hatfield, first year Electrical and Electronic Engineering students {63} undertake project work jointly with Diploma students from the Hertfordshire College of Art and Design who are studying Three Dimension Design and Model Making. The projects are sufficiently open ended to allow creation of imaginative solutions. They involve the design and construction of a working prototype for a range of potential market areas.

The interdisciplinary project week represents only a small proportion of the overall student workload in the 2nd year. The influence of this has, however, been seen as pervasive for both students and staff:-

***Students found the projects highly motivating both as an exercise in their own right and as a different form of teaching/learning experience. Many students became deeply committed to the success of their projects and put in many hours of additional work. {63}***

Substantial benefits have also resulted for staff:

***Many have come together in an interdisciplinary context for the first time. It was evident that staff from the different disciplines found the experience of supervising interdisciplinary groups stimulating and valuable. ...an off-campus briefing workshop was offered for those involved in the supervision and assessment of the projects. This generated wider ownership of the idea, and a commitment to making it a success. An annual feedback workshop has enabled staff to reflect on their learning, based on this experience, and to plan improvements for the following year. {63}***

At **Dundee University**, students following the B Eng (Hons) Civil Engineering {34} undertake a project to design and build a real bridge for a client.

Students define the brief, identify the optimum design and prepare all technical, financial and planning details necessary to build the 10m bridge. The bridge is constructed during a week long residential field trip and must withstand the crossing of agricultural vehicles over a stream on farmland in the highlands.

The design element of the exercise was a compulsory project based component. The construction element was optional but the majority of students participated.

The exercise was split into 3 separate phases:-

- i) problem definition and concept design
- ii) detail design - primary
- iii) detail design - refinement.

Students work in groups of three for each phase, and are required to make an illustrated presentation designed to sell their solution. This is subject to general discussion and appraisal, including consideration of the technical and management decisions controlling the next phase. Students are required to criticise and assess their own work and that of their colleagues. Each group is also required to submit written reports.

This innovation originated with a concern over the extent to which conventional teaching concentrated on analysis with a strong emphasis on numerical calculations in accordance with previously defined procedures:

***There is comparatively little emphasis on the wider aspects of problem-solving, especially aspects which require critical judgement and decision making by the students - eg definition of the problem and appraisal of alternatives. If the construction stage is omitted, then there is no opportunity to develop and practise the teamwork skills necessary to achieve completion of any significant project. There is also no opportunity to review the complete project and learn from the implementation phase. {34}***

Real problems based on real needs of real clients make it difficult for students to avoid taking the work seriously:-

***The exercise provided valuable opportunities for students to draw on knowledge and skills learned in other aspects of their course eg materials, structural analysis, and detailing, drawing, report writing, presentations etc and apply them in a practical context, thus demonstrating the relevance of their studies***

***and reinforcing the learning process. Besides providing obvious opportunities to develop skills in design and management, it provided practical opportunities to demonstrate and practise concepts which can be difficult to grasp in a classroom situation: eg teamwork, planing for contingencies, safety, accuracy and tolerances. {34}***

By the end of the construction phase, a marked increase in general capability and confidence of students was noticeable. Students found the work:

***stimulating, hardwork and enjoyable. On completion of their degree, many stated that this exercise was the highpoint of their entire University course. Students found the exercise a very good talking point in employment interviews and employers commented favourably on the exercise and on the way students talked about it. {34}***

This development required consideration of staff and student time, the availability of suitable clients and projects, safety/liability issues and finance. (Funding came not only from the university but also from the client and industrial donations arranged with the client's assistance.) Staff also identified a need for wider change:-

***Acceptance by University staff appraisal/promotion committees and higher education funding councils of the value of teaching, and positive recognition of quality in teaching (ie considering excellence in teaching as a valid promotion criterion), is essential to maintain staff enthusiasm and motivation. {34}***

#### **Theme Four: Assessment**

##### ***Introduction***

In engineering, conventional examinations have, in the main, traditionally been used to assess the extent to which the students have acquired a command of key principles. There is now however a growing development of more varied strategies such as case studies, open-book assessment, project work and self and peer assessment.

There is also growing attention to the assessment of how students tackle problems, and of their ability to engage in processes that are key to their effectiveness as engineering professionals. For example, teamwork, communication and the ability to take responsibility for their abilities in design and problem solving activities. Issues of particular interest and debate include the assessment of individuals in group projects, the moves towards criterion based assessment and general concern over assessment loading on students and staff.

Overall, given the new challenges facing higher education generally and engineering education in particular, there is much evidence of experimentation with approaches that relate more directly to claimed learning outcomes of engineering programmes and enhance the quality of student learning and involvement.

The examples address the following kinds of issues:

- what is being assessed, and for what purpose?
- different approaches to self and peer assessment
- strategies to promote employer involvement in assessment
- the use of portfolios as an assessment technique
- staff-student negotiated criteria as a framework for assessment
- the assessment of group projects
- the use of collaborative assessment, based on multiple perspectives and sources of evidence

At **Imperial College** first year Chemical Engineering students are involved in a course on problem solving (Higgins, et al, 1989). The aim of the programme is to provide an introduction to processes and procedures of problem solving that students can build upon in subsequent design and related projects over the duration of their undergraduate course, and subsequently over their professional careers.

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book ([www.iclml.com](http://www.iclml.com))

The course is divided into four stages. In the first stage, they learn about theoretical models for analysing and describing problems. In the second stage, groups of students tackle problems set in a real engineering context. They are obliged to record their progress, on the task and in their work together as a group:

***The first two stages are run in parallel: if the first is done before the second, the students do not see its point; the problem used in the second stage is chosen so that it cannot be solved without the material learned in the first. (Higgins, et al, 1989)***

The third stage confronts students with an artificial problem. The groups observe the process of problem solving adopted by one member of the group. Finally, groups compete to produce a diverse quantity of solutions.

Assessment is based on a detailed project evaluation guide that students submit during the second week.

***Roughly, a third of the marks are given for the technical solution itself, a third for the presentation of that solution and the remaining third for the process by which the problem was solved and the solution obtained. ...prompting by staff is necessary during time out sessions before a group of students grasps the importance of the marks given for process aspects. Indeed, despite the best efforts of the staff, a few groups never do grasp this. (Higgins, et al, 1989)***

Lest students confuse the tutors' roles as educators with that of assessors, no work in the first week is assessed:

***This has the additional benefit that the students can experiment and make mistakes without penalty. The work in the second week, in contrast, is assessed and counts towards each student's degree grade. (Higgins, et al, 1989)***

Solutions are presented in a plenary session on the last day of the second week. Wall posters and table displays are reviewed by all before staff undertake the marking, using a project evaluation guide checklist. Each working group then attends a feedback session of about 20 minutes:

***The students are taken through their solution and the marking is explained. The same mark is awarded to each member of a group. Staff are aware that at times the allocation of a group mark may be unfair to individuals. Nevertheless, it has always been felt that any attempt to assess individual contributions would be detrimental to the group working as a team. The feedback session is also used to encourage students to reflect on the skills they have developed during the course and how they might use them in future....***

***Technically, the work which the first year students do is as advanced as work which used to be undertaken by third-year students. The presentations which the students make are much more interesting, both for the students to prepare and for the staff to assess, than are conventional reports. The students are much noisier and more sociable in their groups than they ever were when working alone. (Higgins, et al, 1989)***

Students are perceived by staff who take them in later years to be,

***more capable of devising a wide variety of possible solutions to a problem than previous generations of students who had not taken the course and would have been content with just one. (Higgins, et al, 1989)***

Lower, et al (1982) make the point that the dilemma of how to assess individual contributions to a group effort is not dissimilar to the one faced by industry,

***where a member of a project team has expectations of recognition of individual effort by increase in salary or promotion, or merely praise.***

The point is made that this can be pointed out to students to good effect, although in the author's experience, the traditional emphasis of higher education on grades and competition is difficult to override. But the point is also made that the observation and subsequent assessment of product and process is of central importance when group projects are used

At *Sheffield City Polytechnic* [175], in an integrated engineering programme supported by the DTI, students build up a personal and professional development portfolio. Some sections are for personal reference only ; others are designed to provide a focal point for reflection, critical reviews, action planning and general discussions with tutors, careers specialists, and others, including course colleagues and friends.

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book ([www.iclml.com](http://www.iclml.com))

However, the major function of the portfolio is to gather evidence of progress and achievement against a professional engineering profile, which includes technical, professional and personal aspects.

Assessment in the final year of a presentation by the student of selected material from this portfolio will contribute 25% of the final degree mark (the scheme started in October 1990, and the first students will graduate in 1994).

The portfolio not only provides a vehicle for integrating technical, professional and personal development, but also for carrying forward and recognising achievement in earlier years of the course. Students may also include evidence of achievement from training placements and industry-based project work.

In recent years, concern has grown to broaden the range of abilities, knowledge and understanding that are formally assessed. In addition, there has been a shift away from assessments that compare student with student (norm referenced) to those that are based on pre-determined criteria (ie, criterion referenced). Such assessments can be made in relation to negotiated criteria (based on the active involvement of students), and/or on fixed criteria, such as those established by professional bodies, the NCVQ, or academic staff.

On engineering courses, it is now more common for there to be self and peer assessment, individual and group projects, presentations and panel assessments (often including employers), work based profiling (for sandwich years and shorter placements) and open book examinations.

At *Paisley College* on the honours course in Technology and Management offered by the Department of Mechanical and Manufacturing Engineering {158}, students are prepared for different approaches to assessment through a series of workshops:

***These allow the students to develop skills of self assessment and the students and staff will then discuss and agree the criteria to be used in the assessment of one of their Design case studies. The students will be asked to respond to this case study by submitting a report on how they have judged their achievement based on their own agreed criteria.{158}***

This recently developed course embeds progressively higher levels of learner responsibility and accountability over the three years:

***In year three it is proposed to assign each student a case study with no agreed programme of study. The staff members will assist the student in their work but will not act as experts or arbiters of the student's programme. It is expected that this will be the most difficult of tasks for the staff, to suppress the natural instinct to teach and be prescriptive.{158}***

On the *Polytechnic South West* HND in Civil Engineering Studies course {195}, intake students act as junior members of a consultancy reporting to a Partner' on the feasibility of constructing a motorway. A total of three reports are required for submission by each team - two essentially summarising group work and one drafted by individual students. Each submission includes a Project Diary as an Appendix.

***Students are informed at an early stage that they will be permitted to take a full set of reports together with notes they have generated during the unit - but no other literature, into the 'open book' end of unit assessment. The intention is both to focus the students' efforts on acquiring a comprehensive set of 'well shaped' notes and to ensure fairness of opportunity. An attempt to initiate peer assessment of submitted reports has also met with a positive student response. {195}***

The *Polytechnic of East London* HITECC course {43} aims to assess excellence of knowledge acquisition and skills of analysis in all four course components through the application of theory to practical situations and life examples. A clear stance on the purposes of assessment is taken:

***Breadth and depth of knowledge are not so important as the demonstration of understanding of the subject, its applications and relevance to work and life. Capability skills are seen as integral to this.{43}***

Various aspects of a student's capability are assessed through multiple sources:

- establishment of attainable goals: through the study contract

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book ([www.iclml.com](http://www.iclml.com))

- planing and organising skills: through the management of study and assessment submission
- explore and account for relevance of studies: through critical analysis of the role of new technology component studies, a specialist project and a work placement assessment
- self monitoring of progress against agreed criteria: based on negotiation of a timetable for goals and submission of feedback from continuous assessment
- evidence of achievement: through the completed portfolio of the year's work, the final critical review of the portfolio and laboratory notebooks
- acceptance of responsibility: meeting targets, observing agreed study timetable and receiving no penalty points for late submission.

### **Conclusion**

Recent developments in engineering education have much to offer colleagues within the field, as well as those in other disciplines. This is well illustrated by the examples submitted to the authors - only a fraction of which it has been possible to include.

Engineers face a complex and sometimes conflicting set of demands in terms of access, recruitment, employers needs, motivation, expansion of the subject base and the rapid pace of technological change. The shift from an elite to a mass system of higher education has posed particular challenges in engineering because of its resource intensive laboratory based disciplines.

Implicit in the examples is a recognition of changing priorities, in terms of the skills and qualities that a capable engineer in future will require and how these might best be developed.

The many examples of capability approaches now emerging in engineering education deserve widespread attention. In this chapter we have tried to pay tribute to some of the work that is not as widely published as it should be. The debate that we hope will ensue can in turn stimulate further developments that can continue to enhance the quality of engineering education in Britain.

### **Notes**

(1) See also Sparkes, J.J. (1989) Quality in Engineering Education Engineering Professors' Conference Occasional Paper No. 1; Sparkes, JJ (1991) The future Pattern of 1st Degree Courses in Engineering, Engineering Professors Conference Occasional Papers, No. 3. Entwistle, Noel; Hounsell D et al (1989) The Performance of Electrical Engineering Students in Scottish Higher Education, Department of Education, University of Edinburgh

(2) PCAS (1991) news release no.2 on 1991 entry; see also, Smithers, A, (199) Patterns of Participation in Engineering Higher Education' in Engineering Futures, The Engineering Council.

(3) See for example: Macaulay, Cathlin (1990) The experience and performance of Electrical Engineering students in Scottish Higher Education' in Engineering Futures

### **References**

HMSO 1980 The Finniston Report, Cmnd 7794

HMSO (1987) Higher Education: Meeting the Challenge, Cmnd 114

The Engineering Council (1985) Raising the Standard,

The Engineering Council and Standing Conference on University Entrance (1988) Admissions to Universities: Action to increase the supply of engineers

The Engineering Council.(1990) Continuing Education and Training Report 1990

From Quality in Learning, edited by John Stephenson and Susan Weil, published by Kogan Page, London in 1992.

Download the Quality in Learning Introduction file from the ICLML catalogue for details of other chapters in this book ([www.iclml.com](http://www.iclml.com))

Bonwitt, Barbara, (1990) Steps Courses in the Universities,' Engineering Futures, The Engineering Council, RSA and The Training Agency.

HMSO (1991) Higher Education: A New Framework London: HMSO, Com1541

Smithers, Alan (1990) Patterns of Participation in Engineering Higher Education,' in Engineering Futures, The Engineering Council.

Parry, Gareth (1990) Introduction and Conference Report, Engineering Futures, The Engineering Council.

Ball, Sir Christopher (1989) More Means Different London, RSA

Ball, Sir Christopher, (1991) Learning Pays, London, RSA

Cawley, Peter, The Introduction of a Problem-based Option into a Conventional Engineering Degree Course,' Vol 14, 1, (1989), pp. 83-95

(Higgins, JS, Maitland, GC, Perkins, JD and Richardson, SM, Identifying and Solving Problems in Engineering Design,' Studies in Higher Education, Vol 14, no. 2 p. 169, (1989)

Lower, B, Coulthurst, A, Blount, GN, and Elcock, David, 'Assessment of Group Projects' in European Journal of Engineering Education, 7 (1982), pp.171-187