Subject Overview Report

Electronic Engineering

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Subject Overview Report:

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EXECUTIVE SUMMARY

Background to the study

The ETL project is within the nationwide Teaching and Learning Programme of the ESRC and has been investigating ways of ‘Enhancing Teaching-Learning Environments in Undergraduate Courses’ in four main subject areas – Electronic Engineering, Biological Sciences, Economics, and History – chosen as popular undergraduate subjects with large intakes. We have been working with teaching staff to see what is working well in existing approaches, and to provide detailed feedback from students to see whether the teaching-learning environments can be made even more effective.

This report concentrates on our collaborative work with staff teaching on six course units from BEng degree programmes from three universities and a first-year unit from an HNC programme in a city college. Within the universities we selected second-, third- and fourth-year units on analogue electronics, as an area that students found difficult but which was an essential component of the degree course. The intention was to identify aspects of students’ experiences of the teaching which they found particularly helpful in their learning, and any experiences that impeded their progress.

The first phase of the study involved analysing sets of published reports on eight departments judged as excellent in the TQA and QAA reviews of teaching. These were followed up by telephone interviews with key teaching staff in four of those departments. Reviews of the literature and bench-mark statements were combined with analyses of these interviews to build up a picture of the nature of the subject area and its pedagogy.

Ways of thinking and practising. In the early stages of the main phase of the project, discussions with staff and students across all the subject areas made it clear that, over and above the description of intended learning outcomes, there were ways of thinking and practising (WTP) in each subject area which had guided the design and implementation of both teaching and learning activities and which could be used as a marker in considering how coherent and congruent that provision had been in our target settings.

Collaboration with departments was planned to last over two academic sessions. During the first year, preliminary discussions with staff and students across all the subject areas made it clear that, over and above the description of intended learning outcomes, there were ways of thinking and practising (WTP) in each subject area which had guided the design and implementation of both teaching and learning activities and which could be used as a marker in considering how coherent and congruent that provision had been in our target settings.

Feedback to course teams was based on analyses of these baseline data, identifying the most successful aspects of the course unit from the students’ perspective and any ways that their learning might be made more effective. In four of the settings, suggestions made by the research team were discussed with staff and led to a collaborative initiative through which the teaching-learning activities were fine-tuned to take account of difficulties reported by the students and focus on the ways of thinking and practising specific to electronic engineering. The initiative was implemented during the second year of the collaboration and the same data collection procedure and analyses were carried out to evaluate the outcome.
Main findings

- Most previous educational research on university teaching and learning has looked for generic principles, which could then be used to inform practice. By concentrating on specific disciplines and involving course teams, we identified specific forms of teaching within Electronic Engineering. Looking specifically at analogue electronics, we identified what seemed to be an inner logic of the subject and its pedagogy connecting characteristic ways of thinking and practising with the most effective ways of teaching them.

- A substantial proportion of students in second-year analogue course units found considerable initial difficulty in coping with circuit analysis problems. These students perceived the new material not only to be initially difficult to understand, but also as being presented at too fast a pace. Collaborative initiatives investigated the effectiveness of using tutorial workbooks in which students recorded and, where appropriate, commented on their solutions to the problems set.

- Related to the difficulties with analogue was a more general tendency, also reported in a Swedish study, for students to report a delayed understanding of new material being introduced. Although some such delay might be anticipated with abstract topics, this effect was not mentioned as frequently, or as strongly, in the other subject areas in our project. The extent to which this reaction is an inevitable consequence of the abstract nature of the subject, or depends on the methods of teaching, is well worth considering.

- Students in a new university reported favourably on having a single lecturer responsible for the teaching of analogue electronics through the degree course. Although this would be impracticable, or undesirable, in other contexts, the greater perceived continuity, coherence and congruence in the teaching, along with a strong emphasis on professional aspects, enhanced students’ engagement with the subject.

- In the city college, the day-release students were mainly concerned about the apparent mismatch between what they were being taught and their everyday work experiences. They felt the microprocessor they were being taught about was out-of-date, and the work they were doing on it was time-consuming, yet seemed irrelevant. Changing the choice of microprocessor allowed different teaching-learning activities to be introduced and these improved students’ reported experiences of the course unit.

- The use of questionnaires, designed on a conceptual basis to highlight aspects of teaching and learning that are directly involved in encouraging high level learning outcomes, provided important insights into those aspects of the teaching-learning environment that students reported had helped or hindered their learning, although a full understanding of their effects depended on analyses of students’ comments in the group interviews.

- What can I do to improve my course? Effective ways of providing support for learning were suggested for each of the following aspects.
  - Circuits linked to real-life illustrations from industry
  - Main circuit components clearly highlighted in diagrams
  - Ways of thinking about circuits explained and exemplified
  - Students required to work through sets of strategically varied examples
  - Ways of solving tutorial problems discussed
  - Worked examples provided at the appropriate time
  - Individual assistance with tutorial problems available
  - Progress monitored in tutorial work and tests

- While most of these essential components were found in the analogue units in one form or other, students in all settings felt that the feedback on their progress was neither sufficient nor timely, while in only one setting did students feel that the tutorial groups were small enough to allow their difficulties to be discussed individually.
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1. INTRODUCTION TO THE REPORT

The ETL project is within the nationwide Teaching and Learning Programme of the ESRC and has been investigating ways of ‘Enhancing Teaching-Learning Environments in Undergraduate Courses’ in four main subject areas – Electronic Engineering, Biological Sciences, Economics, and History – chosen as popular undergraduate subjects with large intakes. The term ‘enhancing’ was deliberately chosen to avoid the feeling that we had a concern about the general level of university teaching, or within these specific areas. Rather, our intention has been to work with teaching staff to see what makes existing approaches effective in that particular subject area, and to provide detailed feedback from students to see whether these teaching-learning environments could be made more effective. That feedback has enabled us to offer teaching staff a fuller picture of the student experience without implying that the student view should predominate. In thinking about enhancement, our departmental partners have naturally helped us to reach a balance between staff and student perspectives, and between the ideal and the practical.

One of the problems in introducing educational research findings to colleagues in other disciplines is that the nature of the data collected, the analyses carried out, and the ways in which conclusions are reached, can be very different to those adopted in other research areas. The contrast with the types of research carried out in engineering is particularly marked, leading to the following comment from engineers in the USA about attempts to encourage staff to use concepts and research findings from educational research to develop a scholarship of teaching within the subject.

> It is almost impossible to conduct an educational research study in which potentially confounding factors can be clearly identified and their influence eliminated... [Educational research does not use] the kind of reasoning engineering professors are accustomed to employing in their research... and most of them are skeptical of it. A large part of the challenge of legitimizing the scholarship of teaching in engineering education involves overcoming this skepticism. (Wankat et al., 2002, pp. 227-8)

The evidence collected in any educational research study can never be as precise as that engineers are used to, rather different kinds of evidence are used to lead towards sustainable conclusions. In spite of some understandable wariness about the nature of the research process, we generally had a great deal of help and support from both staff and students that allowed the study to progress in the ways intended.

This report is intended mainly for teachers of electronic engineering, but there are other audiences including educational developers and other educational researchers, and this creates problems in deciding how much detail to provide. Our solution has been to provide a moderate amount of detail about each phase of the study, but also to identify specific sections within the contents list to allow readers to navigate through the report more easily. It begins by looking broadly at engineering education, before moving on to deal specifically with electronic engineering and the types of teaching and learning that take place in that subject area. Next, the ETL project is introduced in enough detail to enable the reader to understand the overall research design and the kinds of data that were collected and analysed. The findings are then presented in order, starting with the preparatory Phase 1, and then moving on to the main part of the study (Phase 2) which involved two year-groups of students. Bringing together the findings from each Phase and from all the settings enables us to describe what seems to help students to learn more effectively, and to suggest how the teaching-learning environments might be enhanced.

2. ENGINEERING EDUCATION

2.1 Setting the scene

Although our subject area was electronic engineering, much of the published literature refers to engineering as a whole. We have, therefore, tried to set the more general scene before looking at electronic engineering specifically. Engineering, as a whole, is a subject designed to apply technical
principles from ‘engineering’ solutions to practical problems in society. It is seen by students applying for courses as an area which is much less theoretical than pure science, and yet their initial experience once at university is of a subject with a substantial theoretical and mathematical content.

There has been substantial criticism of conventional engineering education for more than two decades, not only in Britain, but world-wide. As Finniston said in 1980, “engineers have to work in teams with other relevant disciplines in which the total expertise is coordinated to achieve maximum efficiency towards the stated objective” (Finniston, 1980). He commented on the undue emphasis on theory in engineering education and stressed the need for engineers to make efficient use of manpower, finance and production processes to make competitive products. This had led, in some degree courses, to a substantial emphasis on the industrial context, but with a growing concern about its effects on the technical knowledge of students.

In Australia, a report commissioned by the Institution of Engineers (1996) argued that engineering education should become more outward looking, and more attuned to the real concerns of communities. The courses should promote environmental, economic and global awareness, problem solving ability, engagement with IT, self-directed learning and life long learning, communication, management and team-work skills, but on a sound basis of mathematics and engineering technology. In other words, the balance between technical knowledge and the skills required by industry has to be carefully judged.

In the UK, exemplar benchmarks describing the knowledge and skills to be expected of engineering graduates were developed from wide consultations through a working party of the Engineering Professors’ Council (2000). These were subsequently developed further to form the benchmarks specified by the QAA and the Engineering Council, with revised benchmarks currently being considered (ECUK, 2005). The benchmarks are presented in a general form, which then have to be reinterpreted within each of the major areas of engineering.

2.2 Changes in the engineering curriculum

Engineering education [in the past] was considerably more focused in terms of a narrow but deep curriculum compared with today where the requirement is for a balance between depth, breadth and change. Hence the dilemma facing educators is the provision of a suitable learning experience needed for potential and practising engineers in the face of rapid technological change. (M. Dodridge, LTSN Engineering, 2002a, p. 24)

The extensive requirements of engineering today when compared with other disciplines are depicted in models shown in Lee and Messerschmitt (1999) and Midwinter (2000). Both models use a layered approach. The first layer builds foundations such as core engineering principles and technology with the other layers built on the ones below. The second layer deals with systems, not just technical ones but others such as social, organisational and business. The top layer concentrates on applications and the effects the end use has on individuals and society as a whole. Engineering degrees are currently offered in a wide range of institutions and, as a result, the balance between technical and professional varies considerably. Recently, entry levels have been defined more closely, so that entry to Chartered Engineer status now depends more directly on entry qualifications.

In a recent paper, Edward (2002) reports on a longitudinal survey of the development of the professional engineer from career choice to practice. Prior to entry, the students surveyed did expect to have to learn theory and showed anxiety about the mathematics this would involve, but they were anticipating a practical approach with background theory. Instead, they reported finding what they viewed as highly abstract theory with occasional largely unconnected labs. Even after graduating, those surveyed had found it hard to see the relevance of much of what they learned and criticised much of the work as being unexciting, abstract and, at times, tedious. The graduates would have preferred more applications and project work, and a greater emphasis on professional skills.

The need to include professional knowledge and skills has been stressed in all these reports and in the benchmark statements in Britain, and has been implemented to varying extents through
redesigning curricula. It has, however, proved extremely difficult to balance the demands from industry with the professional and academic requirements to provide the technical knowledge and subject-based skills from which professional competence can be developed later on.

3. TEACHING AND LEARNING IN ELECTRONIC ENGINEERING

3.1 Overview of developments in teaching-learning environments

From the review of the descriptive literature, it appeared that there is a good deal of consistency in the teaching and learning experiences of students in electronic engineering. Students attend lectures, supported by examples classes and/or tutorials, together with ‘labs’ which may involve computer-based simulations. There are a higher number of contact hours in engineering, generally, than in most other subject areas which reduces the amount of time available for private study. The approaches to teaching and learning in other countries seem to be quite similar, and are often seen as being overly traditional compared with other degree courses. Writing from a Canadian perspective, Zywno (2003) concludes:

> Engineering classrooms in 2000 too often looked exactly as they did in 1970 or 1940. Little evidence of anything that has appeared in educational articles and conferences in the past half-century could be found. Faculty development is a particularly critical issue in engineering departments. (p. 59)

Similar points are made by Wellington (2004) on the basis of a survey of reports from Australia and the United States on the status quo in engineering education and the slow pace of pedagogical change. Within the UK, the Engineering Subject Centre of the Higher Education Academy (previously the LTSN) provides a ready source of innovative ideas about teaching and learning, as well as teaching and assessment materials. At the time of writing, there had been more than 25 learning and teaching projects in engineering, and many more applicable generic ones funded under a variety of HE funding initiatives, although the take up of these ideas within engineering departments has been said to be disappointing (LTSN Engineering, 2002b).

A recent report looking at problems in progression for the Higher Education Funding Council for England has provided examples of good practice across 42 electronic engineering departments (Cutler and Pulko, 2002). Respondents were asked to identify five subject areas which persistently proved problematic for students in years 1 and 2 of their electrical and electronic engineering (and related) programmes. The list of topics proved to be quite short, and was overwhelmingly dominated for both years by mathematics and by subjects with a high mathematical/abstract content, such as analogue electronics. Staff were also asked about how they had been trying to improve progression rates and, from their descriptions, a variety of possibilities emerged, including:

- harmonise module contents and attune programme content more directly to the labour market;
- review weekly a log of learning progress, compulsory tutorials, web-based tutorial response system;
- use up to 30% coursework assessment, as well as weekly progress tests, and mid-session diagnostic tests;
- move from exams to project–based learning, early exposure to hands-on design to enhance motivation, peer-assisted learning/collaboration, problem-based learning, and open-access laboratories;
- provide drop-in maths sessions (timetabled); dispersal of maths into engineering content, reduction of formal mathematical representation of content, supplementary tutorials for problematic areas, and dedicated engineer-as-maths-tutor with web support resources;
- provide study skills modules, personal development tutors, and counselling after a few weeks; and
- organise a staff-student liaison committee with input to course improvements, along with course evaluation feedback into course design.
This listing offers a variety of suggestions for dealing with the problems identified, although it must be emphasised that individual departments generally had introduced only one or two of these changes. The study also lacks any independent evaluation of the effectiveness of the actions taken to improve progression rates, which makes it impossible to judge the effects of the differing innovations.

3.2 Research into teaching and learning in engineering

In reviewing the research literature, the lack of major integrative studies, or reviews of research on teaching and learning was striking. Although a large number of local studies were traced, most focused on specific teaching topics, software or apparatus, and rather few were rooted in any principled consideration of teaching and learning. However, a recent edited book from Baillie and Moore (2004) contains articles from both engineers and educational researchers, showing how principles derived from educational research can fruitfully interact with reports of innovative teaching in engineering departments. One of the main reasons for the apparent lack of interest in new pedagogical ideas in engineering was seen by one of the lecturers in our project as being due to the apparent lack of relevance of the general literature of teaching and learning to electronic engineering.

I think that’s the problem from our point of view... Trying to sift out what would be relevant for our discipline is actually quite difficult… A lot of the techniques are aimed much more at psychology and those types of disciplines, and wouldn’t work for us - just wouldn’t be appropriate. So, some way of sifting out what would be useful for us is, potentially, very valuable… I think the experience has been that people have tried techniques in the past and it’s turned out that they don’t work because they really were intended for a different discipline.

The brief overview of relevant research literature, presented below, is intended to bring out, first, some general principles relating to student learning before moving on to studies that have looked at some of the specific forms of learning involved in electronic engineering and physics.

3.2.1 Approaches to learning and the development of understanding

In some of the most recent theoretical work on learning in educational contexts, Marton and his co-workers have identified contrasting ways in which students conceptualise the subject they are studying, and go about learning and studying. In their early work, they identified what has proved to be a crucial distinction between deep and surface approaches to learning. Both are driven by the student’s intention – either to understand the material for oneself or to cope with tasks in a mechanistic way and with little personal engagement. The deep intention leads to the learning processes necessary to reach understanding in a particular subject area, while the surface intention leads to the use of routine memorisation and reliance of procedural forms of learning (see Marton, Hounsell & Entwistle, 1997). The processes involved in a deep approach will necessarily vary between subject areas, and these, at times, will require some memorisation, but still with the intention to understand.

Subsequently, this area of research was extended to look at the very different ways in which students conceptualized both the subject matter they were learning and the tasks they were set (Marton & Booth, 1997). This work drew attention to the crucial importance of certain aspects of the subject in teaching and learning, which Booth (2004) has recently related specifically to engineering education.

A fundamental role of teaching is to bring critical aspects of the subject matter into focus… [Many studies have shown] that a deep approach is connected with grasping of critical features of subject matter, while a surface approach… gives knowledge that is easily misunderstood and quickly forgotten… [But] deep and surface approaches are generic terms and individual types of task (reading, solving problems, doing labs, undertaking projects in industry) all have their own peculiar forms which can be observed and analysed in situ (pp. 13, 17)

Other work with electronic engineering students has identified the notion of delayed understanding which is seen, in part, as a reaction to traditional forms of teaching (Scheja, in press). While delays can be expected between meeting new concepts or ideas and fully grasping them in most subject areas, the delay in electronic engineering has been found to cause considerable problems for students,
forcing them to adopt coping ploys and leaving them anxious about getting ‘out of phase’. And, again, in an engineering programme, students have been found to differ in the extent to which they feel in control of time, with students who feel out of control being less likely to adopt a conceptual approach to learning (Case & Gunstone, 2003).

Knight and Banks (2003) have commented on a similar phenomenon in differentiating between complex and complicated learning, as applied to the output standards of the Engineering Professors’ Council (EPC, 2000). They note that

It is known that complex learning takes time;… [it] usually takes a lot longer than a single module allows, sometimes appearing unexpectedly weeks, months or years after the stimulus that got it started. While information and inert knowledge can, in principle, be fixed in some form of memory in a fairly short time, and while the convergent use of formulae can also become quite quickly routinised,… complex social and academic practices can take years,… [and] slow learning means programme-level, not module-level, thinking. (p. 40)

Developing Marton’s work further, Booth and Ingerman (2002) have shown the importance of students’ perceptions of relevance not just of a specific topic, but of the degree programme as whole. From student interviews they concluded:

For the most part we hear of second-guessing the teachers’ intentions and trying to fit parts of an incoherent puzzle together… - students…scratch their heads over how some particular course is relevant to the rest or to their future careers,… but only some students demonstrated the capability to look away from their immediate puzzlement over the programme and focus, first on seeking points of contact in their understanding of the various fragments, and then bringing them into relation to a growing understanding of what constitutes engineering physics. (p. 20)

Of course, students cannot be expected to see the long-term benefit of skills they are required to develop, so an important part of an engineering degree programme or a course unit involves explaining the relevance of the various parts, and how they contribute towards the vocational goal towards which most of the students will be looking. And simply telling students about the broad aims is not sufficient. A large-scale research and development programme in Harvard introduced the notion of throughlines, presented initially as a written outline of the main purposes of a course and then mentioned each time new topics are introduced to show the links to the overview.

In physics education, two major research programmes in the USA have made a notable impact on thinking about teaching physics in undergraduate education (Dufresne et al., 1996; Mazur, 1997a, b). Mazur had, for some time, been trying to make sense of the reactions of students to introductory physics courses, and to discover why many students seemed to find them boring. He found that students were concentrating on learning ‘recipes’ or problem-solving routines which allowed them to arrive at solutions with little understanding of the underlying principles, but which led to inexplicable mistakes even by ‘bright’ students. He decided that traditional forms of lecture were the main cause of what can now be recognised as surface approaches to learning. He therefore tried to make students more actively involved in their own learning during lectures, and eventually devised what he called peer instruction. This approach is intended to transform lecture-based instruction by interspersing the lecturer’s presentation with occasional five-minute, short-answer or multiple-choice concept tests. Typically, students are required to write an individual answer and then justify their answers to other students sitting nearby. These discussions are designed to increase student activity and involvement, although the time involved reduces content coverage. Mazur puts any omitted material on the web and requires students to demonstrate that they have used it. This technique has been adapted to work with the Personal Response System (PRS) in which students can respond to questions using a hand-set (like a remote control), with computer analysis and display of the answers given by the whole class. The lecturer can then lead a more general discussion of any misconceptions.

There is evidence that this teaching strategy can lead to improvements in both student motivation and ways of learning physics (Mazur, 2001; Meltzer & Manivannan, 2002). The technique has also been tried in a variety of engineering and computing science classrooms (Hall et al., 2002; Nicol & Boyle, 2003; Cutts et al., 2004) with a generally positive response from students. There do seem to be
difficulties with the focus on specific concepts in other subject areas and in electronic engineering the specific questions may have to focus on crucial aspects that have been found to cause difficulty in, for example, analysing or designing circuits. Student responses can then be discussed and explored by the lecturer in the ways that Mazur and others have suggested.

Other innovations that involve systemic changes in the whole engineering curriculum have been based on the techniques of problem-based learning (PBL) that were developed first in medical education. Dissatisfaction among employers about graduates’ professional skills led three electrical and electronic engineering departments in England to explore the possibilities of developing PBL curricula towards the end of the degree course (Mitchell, Smith and Kenyon, 2005). In one department, the rationale for introducing PBL in a pilot phase drew attention to one of its strengths, namely the requirement for students to move away from the surface approach to learning and have greater depth. Any design-type question will require much greater understanding by the student of the constituent parts of the design. (p. 42.)

Introducing PBL late on in the degree programme was seen as overcoming some of the criticisms of far-reaching PBL revisions of the curriculum. However, students felt considerable uncertainty in adjusting to the lack of structure within the PBL approach, and it was concluded that much more thorough preparation and guidance was needed, as well as a choice of problems that closely matched the current knowledge base of the students. A recent review of evaluations of PBL courses, across a range of professional disciplines, found inconsistent evidence of their effectiveness (Newman, 2004), and considerable difficulties emerging in implementing the approach. In the EEE example mentioned above, some established principles of PBL had to be altered to fit both into the specific subject matter and into the realities of electronic engineering curricula. But, with these modifications, there was evidence from the pilot work that students particularly appreciated the emphasis on authentic problem-solving that PBL brings.

3.2.2 Developing problem-solving skills and expertise

There is a substantial research literature in psychology on how novices differ from experts in the problem-solving skills found in employment settings, and how such skills can best be developed (Sternberg, Grigorenko & Ferrari, 2002). The psychological research suggests that expertise depends on being able to see the nature of a problem intuitively, and recognize recurring patterns in differing types of problem, dealing with them conceptually and analytically once the nature of the problem has been established. There is no doubt that what has been called ‘intuition’ is often the result of accumulated experience, and the abstraction from that experience of their own guiding strategies and principles. But in the early stages of developing expertise, novices will still need the scaffolding provided by set routines or strategies suggested by the teacher, with that support gradually being removed as students develop in experience and confidence.

The metaphor of scaffolding is appropriate because scaffolding is an external structure that supports another structure under construction. As the new structure is completed and capable of standing on its own, the scaffolding is removed (McCormick & Pressley, 1997, p. 15).

Hearing experts solve problems out loud is also important for novices, as it makes explicit the ways of thinking used by them in reaching solutions, as is help in developing ways of reflecting on reasoning processes.

There is also a substantial literature on problem solving in the sciences, which is largely an untapped resource for engineers (Gabel and Bunce, 1994). Traditionally, problem solving has been taught by lecturers and tutors going through a problem-type and then asking students to do similar problems. But repetition of examples will not, in itself, lead to conceptual understanding, unless the examples are carefully chosen to provide appropriate variation and demand analytic thinking (Cowan, 1986). As we have mentioned, students often treat problem solving as depending on established routines, without the necessity of conceptual understanding (Hobden, 1998), and various attempts have been made to encourage students to reflect more consciously on the processes involved in problem-solving.
Schoenfeld (1992), for example, found in his own undergraduate mathematics teaching that process-based approaches to developing problem solving triggered students’ awareness of their own thinking processes, using questions such as “What exactly are you doing?” “Why are you doing it?” or “How does it help you?”. And more recently Cowan (2004) has argued the engineering students need encouragement and time to reflect on their own learning, with staff scaffolding the thinking process by providing simplifying strategies that students are encouraged to abandon once they feel sufficiently confident about their own problem-solving skills.

Virtual learning environments can be used to encourage such reflective thinking (McLoughlin et al., 2000), for example through providing

- access to procedural prompts and scaffolding which assists problem solving;
- models of effective and expert problem solving through video and audio clips;
- process-based reminders and reflective ‘time-outs’ during which students are asked to discuss the processes and strategies they are using while solving problems.

Reflection can also be encouraged through more traditional means. For example, Wellington and Collier (2002) report on the experience of using student workbooks in electrical and electronic engineering for Level 1 circuit theory as a way of providing more feedback on progress. Course work was increased to 60% and took the form of a tutorial workbook and a laboratory logbook. Students were, as usual, set examples to solve, but they were required to record their attempts at solving the example questions in the tutorial workbook, with the work assessed by a member of staff on a regular basis. The assessment process was used to confirm that students had attempted the set questions, obtained the correct answers, and that all appropriate working had been documented in the workbook. Workings for the examples were provided to allow students to initially check their own work, allowing assessment to take place within scheduled small group teaching sessions. The researchers concluded that:

Students were aware that the tutorial workbook made a significant contribution to the overall unit mark and the large majority directed their efforts accordingly. It is certainly possible for students to work collaboratively on their tutorial workbooks and seek assistance from other sources. For some students this is an effective way of learning and ultimately they are still required to pass the end-of-unit examination... Student motivation and performance... improved significantly. (pp. 267-8)

Drawing on the more theoretical work, it seems that problem-solving skills may be developed more effectively if students are encouraged to include their own explanations in the work-books of where they had gone wrong and why an alternative strategy would work better, as well as working more collaboratively.

In Finland, Savander-Ranne and Kolari (2003) have been using a worksheet as a scaffolding device for shaping problem-solving skills through a combination of strategy and discussion, following the sequence Predict-Discuss-Explain-Observe-Discuss-Explain. They have also advocated the use of visualisation aids to help students form mental images and visual interpretations of what concepts mean, combined with peer co-operation and collaborative learning.

### 3.2.3 Assessment and feedback

The larger classes currently found in some engineering courses are typically requiring lecturers to devote more time to assessment, and there is a growing problem in providing adequate feedback for students on their progress. According to Hussman and Smaill (2003):

In engineering, much of the learning needs to build on concepts that may take some time and practice to be appreciated. Therefore, one of the biggest problems is ensuring that students do enough work progressively throughout the course. This problem becomes more pronounced as increased staff workload can lead to fewer assessment instances. Since the final exam is regarded as essential, usually it is the formative assessment opportunities throughout the course that are cut back. As a result, students tend to put off most of their practice until much of the course has passed and the final exam is looming. (p.1)
On the other hand, the authors acknowledge the pivotal role of formative assessment and prompt, regular feedback. To provide this, the authors have introduced two web-based tools, CECIL and OASIS, in the teaching of first and second year courses in Australia. The authors conclude that computer-assisted assessment has the potential to allow an effective assessment regime to be maintained in this era of large classes... First, students receive virtually instant feedback. Second, regular assignments and formative testing are possible because the computer carries out the marking. Third, plagiarism in assignments and cheating in tests are largely ruled out because each student receives a numerically different version of each problem. [In addition] the database records all students’ activities,... enabling instructors to monitor the [overall] performance of students to modify the course delivery [as indicated by the findings] (pp. 3, 4).

In Britain, a survey of EPC members by the Assessment Working Group concluded that substantial changes in assessment practices would be necessary to meet the output standards set out by EPC. In reporting the conclusions of the survey, Knight and Banks (2003) found evidence of a wide range of assessment practices, the most common of which were examinations, time-constrained (class) tests, project reports, presentations, laboratory reports, design studies, vivas or orals, and poster presentations. They concluded that Engineering teachers are using a good range of appropriate techniques, although some may be disconcerted to realise how much needs to be done to get [those methods] in a coherent relationship that can stimulate complex learning... [implying the need for] a model of assessment that is itself complex and subtle... [involving] differentiated programme-level assessment arrangements based on a range of both formative and summative methods... These formative assessment arrangements, combined with a careers/employability support programme, should enable students to lay powerful claims to achievement that they could substantiate [for example, through portfolios]. (p. 46)

Writing in similar vein, Hamer (2001) argues that recent work on assessment has challenged the previous gold standard of examining and testing, suggesting that they do not provide the certainty that was once thought, and even where they are carried out effectively they may not assess what is most worthwhile.

This review of the literature has stressed the importance of encouraging a deep approach among engineering students as a way of shifting students away from a reliance on routine procedures in problem-solving and towards more thorough conceptualization. The emphasis can be helped by various technological and other innovations, but has also to be supported by adequate provision of feedback and a sophisticated strategy for assessment. This view of student learning, and ways of encouraging it, lies at the heart of the research carried out in the ETL project which is now introduced. We were not starting from the assumption that the teaching in electronic engineering was weak, even if it was largely traditional. In working with colleagues, we were seeking to understand how these methods were being used, and to explore the possibility of identifying additional ways of teaching and learning that seemed likely to offer potential, specifically in this subject area.

4. INTRODUCTION TO THE ETL PROJECT

4.1 The ETL project within the Teaching and Learning Research Programme

The Teaching and Learning Research Programme (TLRP) was set up in 2000 and invited bids for research studies designed to make educational research findings more relevant to practitioners and policy makers. The relevance was to be ensured by setting up projects in which educational researchers investigated ways of improving the engagement of learners and their attainments while working closely with colleagues directly involved in the design and teaching of courses. At university level, previous research on teaching and learning had tended to look for general principles that could be applied across subject areas, and had certainly managed to describe how students learn and study,
and to understand the main influences on their learning. However, colleagues in subject departments often saw the research findings as being too remote from their own experience and specialism. The ETL project was thus designed to look at teaching and learning across a range of subject areas.

Here, it is only possible to describe the research strategies in outline and indicate some of the main findings within the subject area, but further information about the work of the project, can be found on the project web site at http://www.ed.ac.uk/publications.html. Electronic documents relating to specific aspects of our work will be indicated in the subsequent sections and these are also available on the project web site, along with the questionnaires used in the project. A shortened version of one of these questionnaires is shown as Appendix A6.

So, what approaches to research are commonly found in research into teaching and learning? Given the nature of the subject area, the concepts used cannot be as precisely defined as in the physical sciences, nor can measurements relating to those concepts be carried out with the same validity and reliability found in those areas, or in engineering. As a result, educational researchers often use designs that come at the problem from several different directions and use complementary methods of measurement. While there are well-established methods of analysis for both large-scale surveys and small-scale interview studies, bringing results from the two approaches together depends on experience and judgment. Often, the researcher has to rely on developing an argument which draws on different strands of evidence, all of which contribute in differing ways to establishing a finding, rather in the way that a barrister uses evidence in a trial to establish a balance of probability in interpreting the evidence. That is the approach used in the ETL project.

4.2 Outline of the research design

The guidelines established for TLRP required projects to work collaboratively with potential ‘users’ of the eventual findings and also to draw on international expertise. We did this initially by appointing Subject Advisers who had extensive knowledge of the subject area (Professor Geoffrey Smith, succeeded by Professor Gordon Hayward and Dr Robert Kelly), and well-respected researchers into teaching and learning (Professor David Perkins of Harvard and Emeritus Professor John Biggs who had posts in Australia and Hong Kong).

During the first year of the study, the researchers examined Teaching Quality Assessment Reports (and the QAA equivalents) from 40 departments that had been rated as excellent, and followed up 18 of them with telephone interviews with staff. Analyses of these data provided a framework for describing differences between departments in terms of administration, research, professional liaison, teaching and student support, as well as indicating variations in the mix of students entering the courses in relation to the teaching (see Phase 1 Report).

In parallel with this work, the project team also developed two questionnaires for use with students (see Technical Report on Questionnaire Development). The first of these – Learning and Studying Questionnaire (LSQ) - was given at the start of each course unit and asked students about their reasons for coming into higher education and choosing that particular course unit, but with its main focus being on the ways in which the students had been going about their studying up to that point. The second questionnaire – Experiences of Teaching and Learning Questionnaire (ETLQ) - asked, first, about the ways students had approached their studying in that specific course unit, but concentrated on their experiences of the teaching-learning environment provided (i.e. all the various forms of teaching, learning resources, assignments and assessment they had encountered). It also asked about the demands they felt the unit had made on them and what gains in knowledge and skills they believed they had made. Students also gave self-ratings of their academic progress which would be used in conjunction with actual grades awarded by the institution.

In the main part of the project, we have been working with academic staff in departments, usually over a two-year period, looking at one first-year and one final-year course unit. During the first year of the collaboration, the research staff discussed with the course team the rationale for the course unit and the way it was taught. They then distributed the questionnaires at the beginning and the end of
the course unit, when they also interviewed groups of students about their experiences. Analyses of these baseline data allowed the research team to report back to the course team on how the students had responded to their experiences of the teaching-learning environment that had been provided.

Drawing on the pedagogic literature and previous experience of working with academic staff, the reports to the course teams suggested, where appropriate, possible ways in which the teaching-learning environment might be fine-tuned in line with the feedback from students. Discussions with the course team then determined whether a collaborative initiative could be agreed. If so, the following year was spent implementing the initiative and collecting data with that year group of students which could then be compared with the baseline data.

Key findings covering the project as a whole will be appearing on our web site as they emerge. Here we present a summary of the findings, and their implications, just for this subject area.

4.3 Conceptual bases of the analyses

Based on the existing literature on teaching and learning in higher education, the team selected an initial set of concepts as a starting point. As the project progressed other concepts were developed to describe aspects which had proved important and had not been used previously (see Occasional Report 2).

Our main intention was to find ways of improving the engagement and attainments of students. In our study, engagement was seen in terms of the balance between so-called deep and surface approaches to learning, that is the extent to which students were focusing on extracting the underlying meaning of what they were studying or were content generally to reproduce what they had been given. The LSQ questionnaire also described the extent to which students reported organised effort - organising their studying and using their time effectively, while putting concentrated effort into their work.

In looking at the course units, our starting point was to establish what staff felt were the main ways of thinking and practising (WTP) that students were being expected to develop, and how students perceived those aims.

The ETL team coined the phrase ‘ways of thinking and practising’ in a subject area (WTP) to describe the richness, depth and breadth of what students might learn through engagement with a given subject area in a specific context. This might include, for example, coming to terms with particular understandings, forms of discourse, values or ways of acting which are regarded as central to graduate-level mastery of a discipline or subject area. (McCune & Hounsell, 2005, p. 257)

The teaching-learning environments in the course units were described from the perspectives of both staff and students. Students described their experiences in terms of a set of questionnaire scales in the ETLQ questionnaire, and also in the group interviews. The scales covered clarity and coherence, choice allowed, encouraging learning, set work and feedback, staff enthusiasm and support, student support, and interest and enjoyment. The items describing teaching and set work were phrased in ways that indicated approaches likely to encourage deep approaches and well-developed ways of thinking and practising in the subject (WTPs).

The analyses in both the baseline year and the collaborative year considered the interplay between these two forms of data to reach the best possible reflection of the students’ experiences of each course unit. The descriptions of both staff and students were then considered in the light of what Biggs (2003) had called constructive alignment, which stressed the importance of establishing aims focused on understanding, and teaching and assessment aligned with those aims. This concept was used to focus our attention, in interpreting our analyses, on the range of contributions that a well-designed teaching-learning environment can make to students’ engagement in learning (a deep approach), and to high quality learning processes and outcomes.

Having looked at the literature and the design of the ETL project, we can now move on to the findings relating to Electronic Engineering, first looking at the preliminary work from Phase 1 and then at the
settings and samples for Phase 2, before discussing the collaborations that took place. Although the focus now will be almost entirely on electronic engineering, findings from the other subject areas will be briefly mentioned where they offer interesting comparisons.

5. PHASE 1 ANALYSES FOR ELECTRONIC ENGINEERING

The Phase 1 analyses looked first at the TQA/QAA reports on the quality of teaching for eight departments rated as ‘excellent’. These reports followed the various criteria for determining excellence, one of which was teaching provision, but the comments were more to do with justifying the ratings awarded, rather than providing details of the teaching that was being carried out. The analyses of the reports from the five subject areas we were looking at did help us to anticipate, in general terms, the variations in the teaching-learning environments we would be looking at within Phase 2, but a better understanding of the subject area and the ways teaching was carried out came from the telephone interviews we undertook with colleagues in half those departments. In Electronic Engineering two of the departments were in post-1992 universities with relatively small intakes, while the other two were research-intensive universities with large classes of highly qualified students.

The analyses of the telephone interviews focused on two aspects, what characterised these high quality teaching environments, and what were the ways of thinking and practising that staff believed were important in the subject area. Each of the main categories of response is indicated below, along with an indicative comment from the interviews. Comments made by staff in the new universities are coded ‘N’, while ‘O’ indicates an older university: for the purposes of this summary, individual lecturers have not been differentiated.

5.1 Characteristics of high quality teaching learning environments

**Emphasis on practical applications and professional experience**

There’s a temptation to teach the fundamentals first, so the minute they’re through the door we give them a good thrashing of mathematics, and engineering principles and everything else that’s fundamental and turgid, and then by the time they get to the final year, they do all the interesting stuff. They come to do electronics and all they do is mathematics, so they’ve no idea what electronics is by the end of the first year. One of the successes we’ve had this year is introducing a module ‘Build your own PC’. And they can buy it. So by the end of the first semester, they’ve got an achievement – they’ve come to do engineering and they’ve got a box in front of them. From a technological point of view, it’s not difficult, but it does engage them – they find that rewarding. They think, “Yes, that’s what I came to do”. (O)

**Enthusiastic and well-informed teaching**

I think you have to have a love of your subject and you have to have an interest in putting it across. I think if you’ve once lost that you suddenly lose your class in a strange way... We’ve had lecturers... who are very good researchers in their field but have no interest in teaching, are forced into teaching as part of the job, and the students perceive it very quickly. One thing you learn if you’re wise is that students are far more alert to these little points than a lot of lecturers give them credit for. (O)

**Demonstrating problem-solving**

With something that’s very mathematical, I’ve found it’s useful for them to see me go through how I’m building up an equation for example. And occasionally I’ll make mistakes, it’s also useful for that to happen, [because] then they see the thinking process. Occasionally I get to the end of an equation [and say], “Well looking at that, it’s wrong. Now why is it wrong? How do I know it’s wrong? How do I put it right? If I just put a slide where every equation is correct, it doesn’t quite seem to have the same beneficial effect of me actually going through the act of writing it on the board and going through it. As I write it I tend to talk about where each bit is coming from and I find that works better than putting up the equation - it sort of lacks a developmental flow. (O)
Using problem-based group learning

In this module on analogue electronics, with over 50 students, the intention is to allow them to do a design and build exercise. They are given a bad system – say, a wind-direction indicator – which provides five separable components or building blocks. They work together as a group..., although there is an individual component. They do simulation of the basic design and eventually move into the main lab. Each member of the group works on a separate element and then they put the parts together to produce something which hopefully works. It is good at bringing together theory and practice. (N)

Diagnostic testing and providing different learning paths

We do streaming in the first year and run three different maths streams in the hope of bringing everyone to a minimum level of attainment... With BTEC students, [the maths] will either make or break [them] in that they will either come around and find that they can develop the mathematical skills, or that it is just too much of a jump and they pursue a less analytic course. There is an increasing spread in maths ability and the mathematics department is going to have to respond to that by almost setting up like tailor made modules for groups of students. (N)

Systematic encouragement of peer support

This is a problem-solving module. The students are given a set of data, put together with circuit principles. Weak students are helped by getting students to talk through their solutions or their attempts, mixing up weak with bright students so that the weaker ones see that it’s possible. (O)

Individual support and encouragement within a congenial setting and with friendly staff

The personal tutor system is active across the first and second years. When it comes to the third year, basically the students know that they can come to the lecturer to discuss it. Now, I run six tutorial sessions associated with the course, but I dread to think the number of hours I actually do just talking to students outside those. You’ll typically get groups of three, four, five students coming along with a list of questions they’ve got and say can you help us through it - so that’s how it tends to work. (O)

Providing feedback on assignments

25% of the lab marks goes for a log book which they bring to the lab, 25% is for effort in the lab, 25% for clarity of recording of the results, 25 % for what’s been concluded. They get written feedback as well as their mark. Students get a half hour briefing on the lab as part of the tutorial system, and when that comes round again, they can use some of that time to ask questions about the previous lab. So we do give them lots of opportunity to improve. (N)

Assessment focused on testing understanding

I’m actually primarily trying to assess understanding of the subject. What I try and do is set questions in which the first part looks just for some regurgitation of information, just to get people into the question. I then typically set a problem that is going to actually require them to do some standard analysis.... Then, the third part of the question calls for a bit of lateral thinking, but primarily it’s mainly [depending on] understanding.... Something that uses facts and figures, I will provide them with a sheet in the exam with those facts and figures on. My argument is, if I was in industry doing this, I wouldn’t try and memorise these facts, but have them to hand. (O)

Variety of assessment methods focusing on understanding, including authentic tasks

Five assessment techniques are used. What are the different methods trying to get at? End of module exam, answer 4 out of 6, questions - some descriptive and explanations and problem-solving, several parts with increasing difficulty. Theory is embedded within a question which also has a practical part. Lab reports are marked with feedback. Capability of communicating is considered in context. They have peer assessment of the contribution of each member to the
product. Multiple-choice questions are detailed problem-solving which does involve background reading to find information. (N)

**Industrial placements and industrial support**

The industrial placements give general exposure to an industrial/commercial environment, so they’re no longer focused entirely on book learning. And the other thing you hope they take is a much greater understanding of what the equipment or products actually look like. They will have the most hazy understanding of some of the stuff we’re talking about because they will never have seen it and touched it and played with it. (And it affects their attitude); they will often come back and do stunningly well. (O)

**Obtaining and acting on student feedback on courses**

We have an organised system of student feedback through the supervisions (personal tutor meetings)... At the end of each module, we use feedback questionnaires, and these are very effective in identifying problems. We also have peer appraisal which means that every member of staff is seen at least once in each academic year... The student feedback is public – the data is on the reception desk and the students can pick it up and look at it... This was a painful step..., but people just accept it now. (O)

**5.2 Ways of thinking and practising in electronic engineering**

The notion of ways of thinking and practising in the subject (WTPs) came from an analysis of the telephone interviews during Phase 1 of the project and from preliminary discussions with colleagues in the various settings we had chosen for Phase 2. The outcomes of the analysis reflects what were seen to be central to an understanding of electronic engineering. Ways of thinking and practising in engineering were also found the QAA benchmark statements, but at too general a level to be related directly to electronic engineering. They did, however, provide an indication of the types of thinking and engineering practice that we should expect to find.

The categories established from the initial analyses were discussed with our Subject Adviser to produce a range of WTPs commonly found in Electronic Engineering. Figure 5.1 shows, at the top, the broad areas of knowledge to be found, and the very different emphases that were found across universities and, in particular, between old and new universities. The box below, at a more specific level, indicates some of the typical aspects covered.

These first two boxes describe general aspects of electronic engineering but, for the main part of the study, our Subject Adviser suggested that we concentrate on one specific area, wherever possible, with analogue electronics being the preferred choice. There is currently a shortage of analogue engineers in industry, and students often seem to find analogue course units particularly difficult, at least in the early stages of the degree. The ways and thinking and practising were thus chosen to cover what was typical of analogue courses.

It should be stressed that this was an early attempt to explore the WTPs involved and it was within the main phase of the project that it became possible to describe WTPs with greater certainty, at least within analogue electronics.

**6. SETTINGS AND SAMPLES WITHIN PHASE 2**

The intention in identifying departments which were willing to collaborate in the ETL project was to represent differing types of setting in which electronic engineering is currently being taught. We did not relate our choices to previous TQA/QAA ratings, but from the advice provided by our Subject Adviser, and accessibility from one of our three research centres – Edinburgh, Durham and Coventry. The idea was to sample course units being taught towards the beginning and towards the end of a programme. Within the resources available it was decided to work in about six settings. In electronic
engineering we finished up with four departments providing us with seven course units, all but one of which involved the teaching of analogue electronics. Description of the settings will be provided later on and outline summaries will be found in Appendices A1 and A2.

7. THE RANGE OF TEACHING-LEARNING ENVIRONMENTS PROVIDED

7.1 General approaches to teaching

There was general agreement about the way analogue electronics should be taught, namely through lectures in which the main principles of circuit functions and techniques of analysis were introduced. These lectures run in parallel with work carried out individually by students on tutorial problems through which students build up experience of the varieties of circuits involved and of determining the outputs from the circuits using standard transforms (to simplify the circuit) and algebraic manipulations of equations to make them solvable. Support for students comes in the form of tutorials and examples classes in which help is provided individually or to the class as a whole to explain general difficulties. Additional help comes from worked examples made available either in notes or on the intranet, while class tests are used to check on progress. Feedback comes partly in tutorials and also through self-help as students check their solutions against worked examples and informal peer help.
7.2 Teaching-learning environments provided

The term ‘teaching-learning environment’ has been used to describe all the teaching-learning activities and provision of resource materials and staff support that have been designed to help students achieve the WTPs for the course unit and the subject area. The settings involved in Phase 2 of the project showed the same overall characteristics as suggested in the review of the literature and in the Phase 1 investigation of a sample of departments rated as ‘excellent’ in TQA/QAA reports.

Figure 7.1 shows diagrammatically the components found within the teaching-learning environments provided in the settings we had selected, together with the function played by each of those elements in contributing to student learning. The teaching-learning environment experienced by the students is enclosed in the central ellipse, while above and below the ellipse are shown some of the main external and institutional influences on that environment. These influences have a marked effect on the ways in which teaching is carried out, often creating constraints due to competing pressures of other work, limited resources, and inadequate teaching rooms.

8. COMPARISONS OF ELECTRONIC ENGINEERING WITH WHOLE SAMPLE

The overall strategy for presenting the findings from our project involves looking first, and briefly, at analyses that compare those findings with those from other subject areas. Table 8.1 shows, first, the mean scores on the most important items and scales from the two questionnaires for the early years of the degree and later years, while Table 8.2 reports the relationships between a sub-set of those scales. We then move on to analyses relating to specific course units in Electronic engineering.
8.1 Responses to the questionnaires across subject areas

In Table 8.1, the mean scores for electronic engineering and the overall sample (all four subject areas) are shown in bold to facilitate comparison.

This section looks at the percentage responses across our four subject areas for first and final year samples over a range of the items asked in the LSQ, and the mean scores of scales in both questionnaires. (In Electronic Engineering, most of the distinctions were actually between second and final years.) A rating of 3 lies between agreeing and disagreeing with the statements in the questionnaire, so a score of 3.5 generally represents over half a standard deviation above neutrality, while 2.5 is equivalently below that level. As the sampling could not be controlled in ways that would ensure population

Table 8.1  Mean scores on scale scores by subject area

<table>
<thead>
<tr>
<th>Item or scale</th>
<th>Biosciences</th>
<th>Economics</th>
<th>Elec Eng</th>
<th>History</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
</tr>
<tr>
<td>Sample size</td>
<td>510</td>
<td>54</td>
<td>340</td>
<td>113</td>
<td>444</td>
</tr>
<tr>
<td></td>
<td>243</td>
<td>122</td>
<td>70</td>
<td>70</td>
<td>380</td>
</tr>
<tr>
<td>Mean scores on 1-5 scales (5 high) (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reasons for taking the degree</td>
<td>Interest</td>
<td>4.18</td>
<td>4.06</td>
<td>3.92</td>
<td>3.73</td>
</tr>
<tr>
<td></td>
<td>Social and personal</td>
<td>4.05</td>
<td>3.90</td>
<td>4.14</td>
<td>3.64</td>
</tr>
<tr>
<td></td>
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<td>3.85</td>
<td>4.09</td>
<td>3.77</td>
</tr>
<tr>
<td></td>
<td>Lack of purpose</td>
<td>1.96</td>
<td>1.74</td>
<td>1.79</td>
<td>1.78</td>
</tr>
<tr>
<td>Reasons for choosing the unit</td>
<td>Interest</td>
<td>4.26</td>
<td>4.46</td>
<td>3.86</td>
<td>3.91</td>
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<tr>
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<td>3.95</td>
<td>3.88</td>
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<td>1.93</td>
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<td>2.64</td>
<td>3.01</td>
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<td>3.86</td>
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<td>Easiness of perceived demands (note that low scores indicate perceived difficulty)</td>
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</tr>
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<td>Pace</td>
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<td>3.81</td>
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<td>Clarity and coherence</td>
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<td>4.00</td>
<td>3.94</td>
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</tr>
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<tr>
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<td>3.82</td>
<td>3.32</td>
<td>3.72</td>
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<tr>
<td></td>
<td>Staff enthusiasm &amp; support</td>
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<td>4.34</td>
<td>3.72</td>
<td>4.14</td>
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<tr>
<td></td>
<td>Student support</td>
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<td>3.91</td>
<td>3.81</td>
<td>3.44</td>
</tr>
<tr>
<td></td>
<td>Interest and enjoyment</td>
<td>3.66</td>
<td>4.12</td>
<td>3.39</td>
<td>3.69</td>
</tr>
<tr>
<td>Levels of achievement</td>
<td>Knowledge acquired</td>
<td>3.78</td>
<td>3.87</td>
<td>3.69</td>
<td>3.86</td>
</tr>
<tr>
<td></td>
<td>Generic &amp; info skills</td>
<td>3.71</td>
<td>3.99</td>
<td>3.45</td>
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<tr>
<td></td>
<td>Achievement on unit</td>
<td>3.57</td>
<td>3.74</td>
<td>3.54</td>
<td>3.80</td>
</tr>
</tbody>
</table>
estimates, and as many first year courses include students from a variety of degree programmes, the differences between subject areas should be treated with caution; they can be no more than indicative.

In Table 8.1, the aspects such as interest, deep approach, and the experiences of teaching and learning, which indicate positive reactions, show relatively high levels of endorsement. As we expected, therefore, our project was not finding indications of ineffective teaching-learning environments, but rather effective ones that might be open to ‘enhancement’ through ‘fine-tuning’ of some aspects of provision. That is true also for the pattern of means in Electronic Engineering, with levels of satisfaction with the course units being generally high. There are, nevertheless, some differences.

As expected, electronic engineering students rate ‘career’ more strongly than other groups when asked about their reasons for taking the degree, although the feeling of ‘lack of purpose’ was relatively higher among students in the third and fourth years than in such students in other subject areas. Both in the early years and later on, students were very clear that the unit would not be easy (they were mainly taking analogue). In the second-year units, students’ approaches to studying seemed to have deteriorated in the analogue units compared with their previous levels (i.e. deep and organised effort had declined, and surface had increased), while the opposite was found in the third and fourth year units, although the improvements for these students were not as marked as for students in some other subject areas.

The ‘experiences of teaching and learning’ section of the questionnaire (ETLQ) suggested that ‘interest and enjoyment’, ‘clarity and coherence’ of teaching in relation to aims, ‘encouraging learning’ and support of ‘set work and feedback’ were all rated slightly less highly than overall, but staff enthusiasm and general support were rated more highly. The pattern of these responses was more similar to Economics than to Biosciences or History.

8.2 Relationships between the questionnaire scales

Although multivariate analyses were carried out to look at the overall relationships across the whole set of scales, it is easier to make comparisons across subject areas by looking at the simple correlations between a selected set of the items and scales, designed to bring out the links between general attitudes, approaches to studying and self-ratings of academic progress, on the one hand, and students’ perceptions of the teaching-learning environment on the other. In the literature, there has been a great deal of discussion about the relationship between students’ approaches to studying and their perceptions of the teaching experienced.

At first sight, it seems obvious that it is the teaching which would affect approaches, but some studies have shown that students who enter a course with differing approaches perceive that course in contrasting ways. Of course, the approaches to studying cannot affect the way the course is actually delivered, but they do affect the way different students perceive it. In previous research, it had proved impossible to tease out these effects, but in the ETL project we had measures of reported approaches to studying before the course started and during the course. We also had indications of more general attitudes towards the experience of higher education, which would be expected to be more weakly related to approaches to studying, both before and during the target course unit.

The attitudes relate to a time prior to the unit and reflect the extent to which the students had chosen the degree course out of interest or had negative feelings about how worthwhile that choice had been. Prior to the unit students were asked how they had been going about studying on the course as a whole, while at the end of the unit they were asked how they had studied on the unit itself, and how well they thought they had been doing in terms of the knowledge and skills they had acquired and the levels of marks they had obtained. If the perceptions of the demands made by the unit, or of the experiences of teaching and learning, are a cause of changes in approach and to learning outcomes, then the level of correlations should increase from general to specific, and from the time before the unit to during the unit.

Table 8.2 presents the correlational matrices for these selected scales and items for Electronic Engineering, and the patterns of relationship were found to be broadly similar in the total sample.
The pattern for experiences of teaching and learning was somewhat different, because initial interest and established ways of studying were related to students’ reactions to the specific unit, although by no means as strongly as with approaches on the unit, where substantial correlations were found. There were indications that the deep approach was most strongly related to teaching which was specifically directed at encouraging understanding, while the support provided for set work and feedback, and the clarity of coherence of the link between aims and teaching also showed substantial correlations, as did enjoyment and interest.

The only noticeable difference in the pattern of relationships for the whole sample was that student support was more closely related to a deep approach than was staff support. Otherwise the consistent message coming from these analyses is that the positive teaching and learning experiences as identified in our scales (see Appendix A6 and Table 11.1) supported a deep approach and organised effort, as well as better learning outcomes as perceived by the students themselves. Our attempts to collect and equate grades from the different units proved unsuccessful, but students were specifically asked

Table 8.2  Correlations between perceptions of the teaching-learning environment and indicators of attitudes, approaches and learning outcomes

<table>
<thead>
<tr>
<th>Elec Eng sample (N = 365) General attitudes</th>
<th>Prior approaches</th>
<th>Approaches during</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easiness of demands made by unit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior knowledge required</td>
<td>.11</td>
<td>.11</td>
<td>.15</td>
</tr>
<tr>
<td>Pace introducing material</td>
<td>-.04</td>
<td>-.04</td>
<td>.14</td>
</tr>
<tr>
<td>Academic difficulty</td>
<td>-.03</td>
<td>.11</td>
<td>.15</td>
</tr>
<tr>
<td>Workload required</td>
<td>-.09</td>
<td>-.03</td>
<td>.06</td>
</tr>
<tr>
<td>Experiences of teaching and learning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enjoyment and interest</td>
<td>.23</td>
<td>.16</td>
<td>.31</td>
</tr>
<tr>
<td>Clarity and coherence</td>
<td>.13</td>
<td>-.14</td>
<td>.21</td>
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<td>Encouraging learning</td>
<td>.21</td>
<td>.30</td>
<td>.44</td>
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<td>Set work and feedback</td>
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<td>Staff support</td>
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<td>-.12</td>
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</tr>
<tr>
<td>Student support</td>
<td>.06</td>
<td>-.16</td>
<td>.21</td>
</tr>
</tbody>
</table>
to base their ‘achievement’ self-rating on the feedback and marks they had received by the time they filled in the second questionnaire.

Having looked at the general levels of means and patterns of relationships, we now move on to look at the analyses of the specific course units in Electronic Engineering, starting with the first year of our work with departments, and then considering the collaborative initiatives that took place in the second year. Finally, we present our conclusions about the teaching-learning environments that seemed to have best supported student learning in electronic engineering.

9. ANALYSES OF THE ‘BASELINE’ DATA FOR ELECTRONIC ENGINEERING

The purpose of the data collection during the first year of the collaboration with departments was to establish, through interviews with the teaching staff, the ways of thinking and practising which they believed to be most important within their course units and in the subject area generally. We also obtained the descriptions of the course units provided for the students. Information from the students came from both questionnaires and interviews. The data were analysed in ways designed to find convergence between the various forms of data and so establish a justifiable picture of the students’ experiences that could be offered to the teaching staff as a basis for the discussion of possible collaborative initiatives in the following year.

Within electronic engineering the settings that involved specialised units on analogue electronics proved to be sufficiently similar in the teaching approaches and students’ reactions to be considered together. The unit that brought together digital and analogue within a new university needed to be considered separately, as did the city college, where the level, as well as the content, was completely different from the others. The settings are described briefly in the following sections, with further details provided in Appendix Tables A1 and A2, along with information about the samples and data collection in Table A3.

9.1 Comparisons of students’ reactions across units in the baseline phase

To recap on the research design, the data came from a questionnaire (LSQ) taken at the start of each unit which asked students to indicate reasons for being at university and for taking the specific unit. It also asked students to respond to questions about their typical ways of studying in the subject area. The second questionnaire (ETLQ) asked about the demands the unit had made on them, how they had gone about studying in the specific unit, their experiences of the teaching, and what they felt they had gained from the unit. In both questionnaires they were asked to rate their academic performance, based on the marks and comments they had obtained up to that time. Group interviews were also held to explore students’ views about the teaching-learning environment more fully and transcripts of the interviews were analysed qualitatively to identify the main issues mentioned.

The questionnaire responses were analysed first by considering the means of the scale scores from grouped sets of related items, and then by looking at the percentage responses to individual items which showed the extent of satisfaction with specific aspects of the teaching. The data were collected within lecture periods, with inevitable variations in the nature of the samples obtained. As already indicated, most students viewed their experiences of the course unit positively, with most means being well above the average - 3 - but with some aspects being seen as problematic for a proportion of the students. There was substantial correspondence between the questionnaire responses and the interview comments, which allowed the findings to be discussed through an interplay between questionnaire and interview responses.

Appendix Tables A4 and A5 present the mean scores for both years of the collaboration on the scales, derived from the two questionnaires, along with some individual items. The main findings for the baseline year-groups are summarised for all seven settings, although the sample sizes for N2F for both year groups were too small to provide useful results.
Table A4 outlines the students’ responses at the start of the unit and this shows rather few marked differences among these units with the exception of N4L, a third-year course in which the students showed relatively less academic interest and also more regret about taking the degree: they also had the lowest mean score on deep approach combined with the highest surface approach and the lowest level of organised studying prior to taking the unit. This seems to have been a characteristic just of that particular year-group, as the subsequent year-group had scores close to the overall means.

Table A5 repeats the means for ‘intrinsic reasons’ and ‘deep approach’ to allow comparisons with the means taken from ETLQ. The next set of means indicates the differences in students’ descriptions of their general approaches to studying before taking the unit and during the unit, using exactly the same set of items. This difference is seen as a crucial indicator of the effects of subject content and the teaching-learning environment. Here, for the baseline year-groups, there were marked differences across the units. In both second-year units (N3F and N4F) and the final year unit N4E the deep approach and the organised effort shown by the students both decreased, while the surface approach increased. In the two third-year units (N1L and N4L) and the fourth-year unit (N3L) the deep approach increased with a corresponding decrease in the surface approach.

The next two sets of scales in Table A5 enable us to see differences in the ways in which students perceived the teaching-learning environments and here there was a high proportion of statistically significant differences. The students were asked first about the relative easiness of the demands made of them, and then how they rated different aspects of the teaching and learning they had experienced. The knowledge required and the demands related to generic skills were found to be relatively undemanding, but a substantial proportion of students in some units found the pace at which new material had been introduced, the academic difficulty, and the workload all troublesome.

9.2 Descriptions of the settings in the research-intensive universities

9.2.1 Ancient research-intensive university teaching specialist analogue units

The course units chosen were from the second and final year of an undergraduate programme leading to single and joint Honours degrees. Students were working towards a Chartered Engineer qualification and, after an additional year, to the MEng, and most would be aiming for research and development positions in industry. The courses recruit well-qualified students from across the UK: entrants with appropriate ‘A’ Level subjects are taken directly into the second year.

Analogue is taught as a substantial element of the first-year course and continues with compulsory course units in each of the following years. The curriculum was about to be revised due to university-wide changes, but at the time of the project there was a marked discontinuity in the way analogue was presented between the first and second years, from a functional, broad-brush approach to a more detailed analytic one in the second-year course unit that was one of our target units. In the second year, besides lectures and tutorials (every fortnight to groups of 20-25), there were examples classes in which over 100 students worked on the same problem together in a lecture hall, with the lecturer going through the example in the second half of the period. Laboratory work was carried out in a separate course unit which covered aspects of both analogue and digital electronics. Two class tests were given during the unit. These could count 10% towards the overall grade, but this was discounted if the exam mark was higher than the class test result.

The other target unit was final year analogue for some 60 students, which was one of six taught intensively through lectures and tutorials in the first term, with Finals following at the beginning of the next term. This arrangement had been introduced to allow students to carry out a major project in the last two terms. Assessment in the unit was based on the end of unit examination, but final examinations contributed only 40% to Honours classifications.

9.2.2 Technological research-intensive university

Three specialist analogue units were included in our project, from the second, third and fourth years of undergraduate programmes in engineering leading to single Honours in electrical and electronic
engineering, as well as joint degrees with other engineering specialisms and computing. Students here were also working towards a Chartered Engineer qualification while appropriately qualified students were admitted to the MEng programme which required an additional year of study. Most of the students in BEng and MEng programmes would be aiming for research and development positions in industry.

The second-year course was in the first semester with most of the teaching to a class of over 80 students being in a single three-hour session that involved a lecture, an examples class, and tutorial time for those students who had questions. In both the baseline year and the collaborative year a single lecturer did all the teaching, even when there were over 100 students enrolled. Laboratory work was carried out in a separate course unit which covered all areas of the syllabus. 20% of assessment was through set work, with the remainder being end of unit examination.

The third-year course unit was taught in the second semester. In the baseline year the class of around 60 was taught (lecture and tutorial) by a single lecturer, while in the collaborative year, a different lecturer was involved, but was supported by teaching assistants to help with a larger class (75) and form tutorial groups of around 10-12. The optional final year course on analogue was taught to 28 students by two lecturers.

9.3 Analyses of baseline data in the research intensive universities

In the next sections the analyses of the data carried out will be illustrated through the three units which were included in the collaborative phase of the project. Our general strategy was to try to identify the aspects of the teaching-learning environment that seemed to be most important in encouraging students to adopt deep approaches and so direct their energies towards developing the ways of thinking and practising (WTP) that staff had identified for us. In doing that, we had in mind the notion of constructive alignment or congruence as it has come to be described within the project – the extent to which all aspects of the teaching-learning environment are acting together to link teaching and assessment with the main aims of the unit and the current knowledge and aspirations of the students. Through the design of the questionnaires and in discussions with students, we were looking at the teaching through the eyes of the students, but we then discussed the students’ experiences with staff. In this way we built up a picture of the teaching-learning activities that students found most helpful, and these could then be used in conjunction with findings from previous research to suggest ways of enhancing teaching-learning environments in electronic engineering more generally.

9.3.1 The nature of analogue electronics and its WTPs

In our initial discussions with staff and interviews with students, we began by exploring the nature of topics within analogue electronic engineering. Previous research had suggested that one of the specific difficulties students encounter in electronics is that they are faced with contrasting representations or models of a circuit – the actual circuit, the circuit diagram, simplifying transforms of it, algebraic solutions, and computer simulations (Entwistle et al., 1989). Students have to move between these different representations in solving problems or designing circuits and they also need to understand the function of a circuit in both practical and theoretical ways – the engineering applications and the physics of how it behaves.

In analogue electronics, an additional difficulty seems to be that understanding involves both analytic skills and an ‘intuitive’ grasp of circuit characteristics - intuitive in the sense that the characteristics of analogue circuits are less transparent and predictable than digital ones. Students thus have to build up substantial experience of the properties of many different kinds of circuit before they can ‘see’ what lies behind any new circuit diagram they meet or can decide what type of circuit will be required in a design problem.

Lecturers seem to vary in the relative emphasis they put on the functional and the analytic aspects of the subject, but there is general agreement that many students find the early stages of learning analogue
difficult, for reasons that seem to be intrinsic in the nature of the subject, but may also be due to less effective preparation in the mathematical skills required.

The following extracts come from the lecturers interviewed at various stages in the project

Analogue just doesn’t come naturally to most people… Many of the concepts are mind-boggling [when they are first met]. Quite abstract ideas, also a lot of lateral thought… You’ve got to understand how a circuit works; you’ve got to understand the model that is behind that transistor and small signal model, and how that behaves… That doesn’t stick out in a circuit diagram and hit you in the face. You’ve got to know what’s beyond that. And that’s tricky. You’ve got to understand things like how a transistor is biased, what points they operate at, how you can use the characteristics of the transistor path and the linear region that you get… There are all sorts of issues. It’s just a lot more airy than digital. [Second year lecturer]

[Analogue is quite different from] the digital side, in that everything is inexact, there is no parameter that is accurate. The very best we can do … might be to get 1% accuracy: often [it can be much less]. So there’s not a lot of point in calculating things to the last decimal place, assuming you know the various parameters, when those parameters have this huge variation behind them. So, instead, it’s more important to have an understanding, a conceptual, intuitive understanding of what’s going on. [Final year lecturer]

In terms of analogue system design, the most difficult [aspect] is… understanding how the transistor works and how it operates in a circuit… The gap between the semi-conductor physics of a transistor and the transistor operating in a circuit is a very subtle and important one. And that link often is very difficult for the students to comprehend… [A concept] that students [also] find difficult… is feedback. That’s the real world feedback, as opposed to academic feedback analysis. Where they find the most difficulty… of all in analogue is actually figuring out how to tap off the output and apply it to the input – negative feedback… In an analogue course, once you’ve got feedback in the circuit, you really start to introduce complexity, and one of the tools that you can use is… reduce your circuit to a block diagram, and analyse it using classical feedback systems analysis… But going from the real circuit to a block diagram is very difficult [for the students]. (Third year lecturer)

In terms of teaching analogue, some people take the view that you are trying to teach an intrinsic understanding of circuits, how a circuit operates, and once you understand how a circuit operates, you can then form the analysis, and understand it in greater depth. But in order to get to that level you need to have the sort of intuitive understanding at a top level, in order to get below the surface… Other people treat it as a systems approach and you just have a style of analysis and you just turn the handle. As long as you put in the, right figures at the front end, the answer comes out at the back end, treating it as a system. And in a sense it doesn’t matter what the circuit is, you’ve got this analytical technique for the system that will give you the right answer [Final year lecturer]

Some students never achieve that level of intuitive understanding and that’s one of the reasons why there’s such a shortage of analogue designers, because to get that level of understanding you need to work at it and in the beginning it isn’t easy. It is quite tricky to do that and some students take the strategic view that – well, analogue is just a small part of the course, there are lots of other things which they can do much more easily, so they back-pedal on the analogue… They learn enough to get them through the course but they make the decision fairly early on that analogue is not something they want any professional [involvement]. [Final year lecturer]

The students are changing, I don’t think it is just me [getting older]. They cannot deal with mathematical things the way they used to. Particularly in the first year, we have to devote almost a lecture to very basic algebra. They’re really struggling with that… The inability to deal with maths is right through the course… [The maths people] produce revision notes … and if you were to read these revision notes, you would think they are quite insulting, but they are what is required… (Final year lecturer)

In other discussions with staff, another aspect of the difficulty of analogue was mentioned, namely that it drew on knowledge from several other areas of electronics. In other words, understanding in analogue depends on the integration of concepts coming from other areas of the degree course. If not sufficiently well grasped, or if students cannot bring them together effectively, then a thorough understanding of analogue circuits is impossible.
Most of the students interviewed did find analogue difficult because of the range of operations they had to master and also a confusing uncertainty that they hadn’t met in digital. During the interviews, students were asked why they found it difficult, and what the main thought processes involved, but it proved difficult to get students to focus on ways of thinking and practising. Only in a few groups did developed explanations emerge.

I: Do you feel that you have been developing certain ways of thinking and practising that will help you in your future jobs?

S: I’ve not thought about it too much. I think the skills that are required to be an analogue engineer are your understanding and problem solving, just like any other engineering class that you do. I couldn’t really say any more on that. Quite simply, you’ve got to know what you are doing… You are given a specification and you’ve got to meet that specification in terms of the circuit design or whatever. (N4E)

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[I think analogue] requires a different kind of mind-set than digital, which seems to be more to do with computer science. For analogue, I think it is much more mathematical and analytical. Even just a little difference in a circuit can make a big difference to how it operates, so you have to realise that and go back to first principles and work out how it works. (N3F)

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I think probably [it has] a lot to do with logical thought. Just thinking through things properly helps you foresee the problems that are coming up. So the thought process [involves]… getting everything organised so that it will make sense, rather than just [thinking what] you need to know… You’ve got to get it in the right order,.. because things can seem scary [when] you see the original problem and the final solution. You are like “Oh, how do you get [there]: it’s just thinking through the wee steps is kind of [difficult]… You need to know what your start- and end-product is. So you need to identify them. (N4E)

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S: I suppose it’s kind of like patterns. I mean you are looking for certain things that you expect to see. And if you can find them, maybe the most important things, fundamental to what the circuit is going to be doing. So you find the most important things and [once you] can identify them and make sure you understand the way everything is set up, [then you can] kind of understand it all.

I: That’s very interesting. Have you thought about this before?
S: No: not at all. [all laugh] (N4E)

Taking these various responses together, it seems that an understanding of electronic circuits depends on intuition about the functions of circuits built up from the experience of a wide range of different examples, the ability to bring in concepts and ideas from other topic areas to think about analogue circuits and their functions in an integrated way, detailed circuit analysis using problem-solving skills that involve algebraic knowledge and dexterity, and imagination in designing new circuits to meet requirements. That combination of skills, not surprisingly, creates more difficulty than many other areas of electronic engineering, and yet it represents the essential WTP for analogue electronics. Some of the students, even towards the end of the degree, had apparently not thought consciously about the processes of problem-solving that were involved, and that became a particular focus for our later work.

9.4 Detailed analyses of students’ reactions across three contrasting units

An important function of the analyses of these data involved looking for aspects of the students’ experiences that were found less than ideal, and considering ways of developing a collaborative initiative that might improve the level of satisfaction reported. However, it was equally important to draw from them evidence about the teaching and learning activities that students found most helpful and had appreciated most.
Looking at the three illustrative units in turn, the student interviews will be used to indicate both the support they valued and the perceived difficulties reported by the students, as well as some of the additional aspects of each setting that affected the students’ experiences.

Table 9.1 summarises a selection of responses to the questionnaire. Most of the analyses are based on the percentage agreement with individual items. This makes clear the specific comment to which students were responding. However, the important differences in approaches to studying between

<table>
<thead>
<tr>
<th>Scales and items</th>
<th>Course unit</th>
<th>N3F 2nd year</th>
<th>N4F 2nd year</th>
<th>N4L 3rd year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitudes towards the degree course prior to the unit</td>
<td>(Scale)</td>
<td>Percentage agreement with item</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I want to study the subject in depth</td>
<td>(intrinsic)</td>
<td>87.2</td>
<td>77.9</td>
<td>61.1</td>
</tr>
<tr>
<td>I sometimes wonder why I ever decided to come here</td>
<td>(lack of purpose)</td>
<td>5.2</td>
<td>14.7</td>
<td>29.6</td>
</tr>
<tr>
<td>Difference in mean scores for approaches to studying between those prior to unit and those during unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep approach (scale scores)</td>
<td>-0.22</td>
<td>-0.09</td>
<td>0.34</td>
<td></td>
</tr>
<tr>
<td>Surface approach (scale scores)</td>
<td>0.40</td>
<td>0.05</td>
<td>-0.49</td>
<td></td>
</tr>
<tr>
<td>Organised effort in studying (scale scores)</td>
<td>-0.20</td>
<td>-0.16</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Approaches to studying during the unit</td>
<td>Percentage agreement with item</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I usually set out to understand what we had to learn</td>
<td>(deep)</td>
<td>72.1</td>
<td>82.5</td>
<td>75.0</td>
</tr>
<tr>
<td>I've often had trouble in making sense of the things</td>
<td>(surface)</td>
<td>61.8</td>
<td>55.0</td>
<td>34.4</td>
</tr>
<tr>
<td>I have generally put a lot of effort into my studying</td>
<td>(effort)</td>
<td>51.5</td>
<td>60.0</td>
<td>40.6</td>
</tr>
<tr>
<td>Relative easiness of demands made by course unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What I was expected to know to begin with</td>
<td>(knowledge)</td>
<td>65.3</td>
<td>71.4</td>
<td>62.5</td>
</tr>
<tr>
<td>The ideas and problems I had to deal with</td>
<td>(academic difficulty)</td>
<td>16.0</td>
<td>34.7</td>
<td>42.5</td>
</tr>
<tr>
<td>The rate at which new material was introduced</td>
<td>(pace)</td>
<td>25.3</td>
<td>46.9</td>
<td>72.5</td>
</tr>
<tr>
<td>The amount of work I was expected to do</td>
<td>(workload)</td>
<td>33.3</td>
<td>34.7</td>
<td>52.5</td>
</tr>
<tr>
<td>Experiences of the teaching provided in the course unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How this unit was taught fitted in with what we were supposed to learn</td>
<td>72.0</td>
<td>67.3</td>
<td>97.5</td>
<td></td>
</tr>
<tr>
<td>I found most of what I learned in this course unit really interesting</td>
<td>45.3</td>
<td>34.7</td>
<td>82.5</td>
<td></td>
</tr>
<tr>
<td>Plenty of examples illustrations were given to help us to grasp things</td>
<td>66.7</td>
<td>51.0</td>
<td>95.0</td>
<td></td>
</tr>
<tr>
<td>The teaching encouraged me to rethink my understanding of some aspects</td>
<td>60.0</td>
<td>67.3</td>
<td>72.5</td>
<td></td>
</tr>
<tr>
<td>Staff tried to share their enthusiasm about the subject with us</td>
<td>88.0</td>
<td>91.8</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Staff were patient in explaining things which seemed difficult to grasp</td>
<td>81.3</td>
<td>81.6</td>
<td>92.5</td>
<td></td>
</tr>
<tr>
<td>Staff gave me the support I needed to help me complete the set work</td>
<td>69.3</td>
<td>51.0</td>
<td>75.0</td>
<td></td>
</tr>
<tr>
<td>The feedback given on my set work helped to clarify things</td>
<td>63.7</td>
<td>30.6</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td>The feedback on my work helped me to improve my ways of learning</td>
<td>52.0</td>
<td>22.4</td>
<td>50.0</td>
<td></td>
</tr>
<tr>
<td>Talking with other students helped me to develop my understanding</td>
<td>81.3</td>
<td>71.4</td>
<td>72.5</td>
<td></td>
</tr>
<tr>
<td>Knowledge and subject-specific skills acquired</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge and understanding about the topics covered</td>
<td>73.3</td>
<td>69.4</td>
<td>92.5</td>
<td></td>
</tr>
<tr>
<td>Ability to think about ideas or to solve problems</td>
<td>77.3</td>
<td>71.4</td>
<td>92.5</td>
<td></td>
</tr>
<tr>
<td>Skills or technical procedures specific to the subject</td>
<td>70.7</td>
<td>61.2</td>
<td>95.0</td>
<td></td>
</tr>
</tbody>
</table>
the general approaches prior to taking the unit and the specific approaches taken during the unit are presented as differences in the mean scores to show the extent to which students had moved towards or away from a deep, active approach while studying in that unit. These results will be discussed separately for each of the three units.

9.4.1 Second-year course unit at the ancient research-intensive university (N3F)

From Appendix Tables A5, the students’ experiences suggest a strongly positive overall reaction to the course unit, with assessing understanding, staff enthusiasm and support, and student mutual support being particularly highly rated, along with clear aims and teaching that was congruent with them. Table 9.1 above draws attention to more specific aspects of the responses, while students’ comments during the group interviews help to explain the reasons for those responses.

Looking first at aspects that were specific to this particular setting, one of the striking features of the students’ experience was an apparent ‘phase change’ between the way analogue electronics had been introduced during the first year and the students’ experiences in second year. The first year had focused on the functions of the circuits with practical illustrations of their use in equipment in everyday use, while the second-year started with a challenge to the simplifications used previously and a strong focus on the detailed analysis of amplifier circuits using feedback.

[In first year the lecturer] introduced op-amps, not as a complicated electrical system, but the ideal of it… just so that students can understand what an ideal op-amp is… It was taught like it related back to something in the physical world, that most people knew of… The second year course to me was a bit jumping in at the deep end;… it felt like it jumped into Chapter 10.

An initial problem for some of the direct-entry students (who had not taken the first-year course) was a lack of the basic knowledge about analogue electronics provided in the first year. Although an additional set of lectures was provided, these ran in parallel with the analogue course, leaving these students very much ‘at sea’ for the first few weeks.

About 15 of us joined directly in second year, so we had catch-up classes… [At] the beginning it was quite hard to deal with… [It] would be halfway through the first term [when we] started linking the two things together - the catch-up classes and things were presented in the lectures. It required some more work over the Christmas holidays, but [afterwards] we were all moving along with the other people.

Finally, students were concerned about what they saw as additional topics towards the end of the unit which were related to work that was to come in the third year and was not examined. They would have preferred more time to have been available for the examined part of the syllabus, but the analogue course team had deliberately planned the content with this longer time perspective in mind.

As already mentioned, the majority of students showed a strong appreciation of most aspects of the course with the following comments illustrating their views.

I thought [the lecturer] was … enthusiastic, … putting 110% into it. It was obvious … that he was actually interested in the subject and was trying to make us interested, and also realised that it’s difficult [for us]…

What [was done] in one lecture was to try and explain the way of deriving that every time we do a problem instead of memorising it. I found that lecture particularly important and very good and understood some bits. Before that I was just trying to memorise and it took a lot of time.

The notes we were given were quite thorough, so if you start at the beginning and read through then there were proper explanations and paragraphs and so on to read almost like a text book. The way the notes were written and presented, you did actually realise that, although they were completely different areas, they were held together by the same underlying theory, which was good.

The examples class … was really quite helpful to put the knowledge that we were being taught in lectures into context… The lecturer would show you exactly how to answer the problem. And,
when we did get tutorial solutions, they were thoroughly worked solutions, they weren’t just the final answers, so you could follow through the work and understand better yourself.

There were, however, aspects of some students’ experiences which were less positive and Table 9.1 suggests a particular problem in that, in spite of high levels of intrinsic interest in the subject, there was an overall decrease during the unit in both deep approach and organised effort, while surface approaches increased markedly. The individual items suggest the extent of this effect, with about a quarter of the class not setting out to understand the material, a third having difficulty in making sense of it, and only a half indicating that they had put a lot of effort into their studying.

The causes of this effect are inevitably complex, but the ‘phase change’ from first to second year and the initial difficulty faced by ‘direct entrants’ must have contributed, but the perceived academic difficulty level (only 16% found the demands easy) and the pace with which material was introduced (25% easy) seem to have affected the self-confidence of a substantial proportion of the students and led to some redirection of effort to course units where rewards could be obtained more easily. The following comments illustrate this effect.

These lectures were… the most difficult part of the course in the second year… During the autumn term I honestly didn’t really grasp what was going on… I’d been putting in as much effort into analogue as… other courses but it really needed special attention and I probably should have given it more at the start of the year… The way the lecturer explained it, I never really could relate the circuit to his diagrams or the voltages that he was telling us that were there.

At the beginning I was all [at sea], sort of too much information at one time. But… when he went back to it later on to revise it, it was a lot easier to understand… I just think that we’re given too many different concepts at one time… It seemed that once we’d gone over one specific network that we weren’t really given enough time to absorb the information before we were given another one, and the difficulty level increased as you went onwards… If you hadn’t taken the first couple of steps, it was harder to grasp the more difficult ones…

You work through the tutorial problems and, for the analogue ones, you don’t get any answers out of them. You… sit down and work through the problems and realise you’ve done all of them wrong… and you can’t see how in the world you got from point ‘a’ to point ‘b’… I tended to [work] blindly. I knew if I [just] followed these steps, then I could come to an answer… We can teach ourselves… to do an example and have no idea what to do and we scrape by. But we probably would have got great marks had we actually understood what we were doing.

The final comment offers an explanation of the observed lower levels of both effort and deep approach in analogue, as well as higher levels of the surface approach compared with earlier studying, while the other extracts, taken with many of the other interview comments, suggest that the pace and perceived difficulty level had affected the ways of studying. But looking at the setting as a whole, the ‘phase change’ in the approach to analogue, the lack of prior knowledge of the direct entry students, and the pressure to include third-year content will have exacerbated any effects created by the actual teaching.

9.4.2 Second-year course unit at the 1960s research-intensive university (N4F)

This unit was taught in a three-hour block, alternating between a lecture, an example class and a tutorial in an large 19th century lecture hall which was uncomfortable and sometimes cold. Some students thought that the three-hour slot was convenient, but others found it difficult to keep their mind on the work for that time and under those conditions.

I thought Friday morning was not a great time to have it… It’s the end of the week, and it’s three hours in the morning - you’re knackered… [And] if you miss one week, say you’re ill, you’ve missed a whole… week’s work, just for missing one day. Most other subjects, an hour here and there or two hours, unless it’s the labs… It’s a bad idea. You lose interest as well ‘cause you don’t get a break for two hours.

The questionnaire, as in the previous setting, showed a high level of overall satisfaction, along with some specific areas of discontent. This lecturer seems to have been particularly effective in sharing
his enthusiasm for the subject and bringing it to life with anecdotes related to his own professional experience: he was also patient in explaining aspects the students found difficult.

He started off quite nicely with a very thorough introduction, he said in the first lecture I will assume you don’t know anything, so that was helpful… I think he was very good on the transistors… It’s all a bit confusing… but I thought … that was fairly clearly explained.

He was very good at relating to applications, real world stuff. Like, we were talking about aiming for efficiency, you were trying to minimise bandwidth noise. He might give a hi-fi applications example or something, so that certainly helped in understanding concepts.

I think he put across concepts well and he referred back to a lot of stuff from his own career before he went into teaching, like problems that he came across which get put into a practical situation, which made it easier to understand.

In this second-year class, the students showed little change in either deep or surface approaches but they reported putting less effort into this unit compared with their previous studying. Academic difficulty, workload and pace were again found demanding by a majority of the class, with comments similar to those in the previous unit described, but the main problems in this setting lay in their work on the tutorial problems where they felt they had not had enough worked examples or feedback, and where the tutorials (whole class with a single lecturer) were judged to be impracticable.

His notes consist basically of bullet points…, an A4 sheet with four small slide prints and there’s quite a limit to what you can get into a slide print. He does have extra notes at the back with that, but sometimes it’s very hard to follow them… If you’ve worked through the maths, you would see where the next bits come from, but there’s about five lines [of the working] missing, so if your maths is a bit shaky then it’s going to lead to problems.

[Also there were] no tutorial solutions. We were refused any. We were told we had to approach the lecturer and ask for help rather than get solutions. But there’s 80 students for that course and… it’s not so easy, especially if you live away from [town]… I think our lecturer’s opposed to giving solutions actually ‘cause he thinks we’ll just learn it [parrot fashion].

I’d quite like it if maybe the lecturer provided some extra… problems for you and then put the solutions up… online. Even worked examples that weren’t from the tutorials [would help], so [even if] we’re not given tutorial solutions, we can still see how to implement things, not just being taught theory and expected to figure out how to implement it.

When you got help it was fine. That was my experience of it. Good explanation, but just a matter of getting help [with so many people there]… You don’t really want to hang about and ask him for anything - not if there’s a big massive queue… There’s only one tutor per tutorial group, and there are several people asking questions at the same time and he can’t get round you all, so I find that a bit of a waste of that hour.

9.4.3 Third-year course unit at the 1960s research-intensive university (N4L)

Whereas the vast majority of students across the project as whole were happy with being in higher education, some 30% of this year group agreed that “I sometimes wonder why I ever decided to come here”. This negative attitude was recognised by both staff and students in other years, and seemed to have originated with a group of disaffected students in first year who influenced the attitudes and behaviour of the class right through into third year. Nevertheless, these students gave some of the highest ratings of satisfaction with this unit obtained anywhere in the project, with every student indicating that the lecturer was trying to share his enthusiasm with them, and over 80% finding it “really interesting”. The only critical comments related to wanting more feedback and easier access to help during tutorials, again with a large group (over 60) and a single tutor.

The lecturer (this year) is really good… When you’ve got a good lecturer that is trying to actually make you learn rather than just make you pass, I think that’s good. …I mean, he’s taken time in the lectures to actually tell us… what we can achieve from [analogue], in terms of salaries and things like that. And his enthusiasm for us to do well, makes you more enthusiastic about everything…
Basically he wants us to learn it: he doesn’t just want us to pass, he wants us to pass well. He wants us to know stuff for when we go to interviews... And even coming down the stairs with us, he says “You guys, you can all pass on that, just put your work in and you’ll pass”. He just seems to want us to pass. He pushes you on a wee bit more as well.

He tried to make it so we understood what was going on rather than just learning what it was. Probably it did help... He’d say why you were trying to learn something, trying to make sure that everyone understood in the class, rather than just saying it and [us] just kind of memorising it. I think he’s looking for us to take something and try to remember it and actually use it, as opposed to other classes where you just revise, pass the exam and then that’s it done. I think he’s trying to get into our heads that we actually need to know it.

He understands that ... obviously there are people that are not going to study till two weeks before the exam and there are people who study all the way through it. And he can cater for that because he ... comes across as a decent guy, you know. He’s not, he’s not always on your back, but he lets you know, you’ve got to understand this...

The tone of his voice is kind of chatty and he actually walks up the class and he comes to someone and goes, “Do you understand that?” He’s in their face, but it’s not like a lecture kind of like, “Do you understand that now?” It’s more like, “Do you understand; just tell me if there’s something you don’t understand”. And some people do come up, other people do go “I don’t understand it”; it’s great... His enthusiasm - he runs his own company, so he knows how to handle [people] as employees, and I think that filters back in the ... lectures, you know. He does good man management I think...

In spite of this emphasis on understanding, a quarter of the class still disagreed that they had sought understanding. Over 90% of the students felt their knowledge and skills had improved, and yet the exam performance for the class proved disappointingly low, which seems to reflect their initial ‘lack of purpose’ and the fact that only some 40% of them had “generally put a lot of effort into their studying”. The students themselves suggested that they needed to have been ‘pushed’ a bit more, although the lecturer was insistent that, as third-year students, they had to take responsibility for their own effort and working practices.

It would be nice to force us to do the tutorials, because it’s optional. We’ve had other classes where we’ve handed tutorials in and it forces you to do it, but if you don’t have to, you don’t do them... I think they should make us hand something in... to make us do something. Most of my best classes have been classes that needed a lot of work throughout the year, rather than just leaving us to do what we want.

9.4.4 Comparisons between the responses to the three units

Although some of the more striking differences between the three units have been pointed out, the interpretation is more complex than might seem at first sight. The second-year unit in N4 maintained much the same level of deep approach, a reduced level of organised effort. Over 80% of the students said they usually set out to understand, but over half had trouble making sense of things and under two-thirds said they had put a lot effort in studying. Students felt that both the pace and the difficulty level were problematic, as were the lack of worked examples and feedback, leading to the least satisfactory learning outcomes of the three units.

The second-year unit in N3 showed the most significant drop in deep approach, but they were coming from a higher initial level, and three-quarters of the students still indicated they were setting out to understand. The real problem was in the increase in surface approaches with over 60% of students saying that they had often had trouble making sense of things. The link between this reaction and fast pace and high difficulty level, based on previous research, seems understandable, and yet the ratings on the experience of teaching were generally favourable, and the feedback given on work was rated more highly than the other two units. So there is a mixed message coming from the students which, from interview comments not reported here, might be explained by the students remembering the initial difficulty they had, rather than the fact that they had subsequently developed a good
understanding of the material. Three-quarters of the students thought they had achieved a good grasp of the knowledge and skills covered in the course unit.

However, the reliance on self-ratings on achievement can be problematic in some instances. We asked students to base their judgments on the grades they had been given, but in the third-year course in N4 there had been no class exams or formal feedback on course work from which to judge progress. Moreover the level of encouragement given had perhaps led the students to become overconfident about their understanding. The enjoyment reported by these students, and the very high ratings, was counteracted by the proportion of the class who had negative attitudes and the fact that only 40% of the students said they had generally put a lot of effort into their studying. So, the high-self-ratings on achievement were not reflected in the exam results, which were as disappointing as they were in the other units.

It seems that specific aspects of the students’ experiences of teaching may affect them more strongly at different stages of the course unit. Thus, experiencing a fast pace linked with perceptions of a high degree of difficulty at the start of a unit may well have a strong effect on the self-confidence of some students and their willingness to spend time working on examples that they are getting wrong. Later in the unit, as students in N3 specifically mentioned, understanding became stronger, leading them to rate their knowledge and skills quite favourably on the whole.

The comparison of these three units showed that students in all three classes found the analogue course difficult, and in all of the units one or more aspect of the teaching was found somewhat problematic. As Eizenberg (1988) commented, after trying to develop deep approaches in students of anatomy:

> Inappropriate approaches (to learning) are simply induced (by teaching): just one piece in the ‘jigsaw’ that is out of place ... may interfere with the relation between the learner and the content. Encouraging students consistently to adopt deep approaches and employ them holistically is ... difficult because ... all the pieces need to fit together. (pp.196-7)

### 9.5 Delayed understanding

As we have seen, many of the students taking analogue commented that the subject matter was more difficult than other course units, and there was a general feeling that understanding came only uncomfortably late on in the course. This phenomenon had been reported previously, and more generally, in both electronic engineering and computer studies courses, and referred to as delayed understanding (Scheja, in press). Of course, some delay in understanding can be expected with some topics in all subject areas, but the delay in electronic engineering seems to be more widely shared, and much greater in extent, than in subjects where the ideas can be expressed in everyday language. Besides blaming the difficulty of the subject or their lecturers, students often recognised their own responsibility for this lack of understanding:

> [With] new topics that were introduced [in analogue], especially in the second year,... understanding [came late]. It wasn’t until the third year that I thought, “Ah, yeah”. And that was even though I’d done electronics before as a technician. So... delay does happen.

> I tended to do [the tutorial problems] blindly. I just knew if I did that, did that, did that, follow these steps then I could come to an answer... I learned a routine. It wasn’t so much understanding what it meant,... We scraped by but we probably would have got great marks had we actually understood what we were doing.

> Something I think I’m guilty of is actually memorising how these work and not understanding, which I don’t think is the right thing to do, but I think for me it works. I memorise how it works, so the problem-solving factor is not [coming in]. If you see a [different] circuit,... you’re quite stumped, because you’ve committed to memory how [one] thing works, and [then] you see something totally different. I think more emphasis should be on understanding the circuit analysis behind it. Trying to understand how to analyse the circuit the way it is. And then that means you can adapt that to different examples.
In second year I got a better understanding of what I learnt in first year. Now in third year I’ve kind of learnt what I was supposed to know in second year… It’s a shame that I’ve never felt that I’ve learned it in the actual year [it was taught].

As we shall see, there was general agreement from staff that the analyses suggested a clear problem in the ways a substantial proportion of students were approaching the tutorial problems and that ways of encouraging a deeper approach to problem-solving should be sought through the collaborative initiatives. But first we need to look at the two other settings, the first a new university that was teaching analogue electronics (along with digital) across all years of the degree and, in complete contrast, a city college at which day-release students were being introduced to the study of microelectronics.

9.6 New university teaching a final-year unit

9.6.1 The setting

This institution developed from a technical college to a polytechnic, before becoming a post-1992 university. The course unit chosen was in the final year of a B.Eng. (Honours) degree in Electrical and Electronic Engineering. Attendance is full-time over three years, or four years with a paid, work-based placement. The degree leads to Incorporated Engineer status and is therefore more practical and less theoretical in orientation than some other degrees. Students enter with a variety of qualifications, including the equivalent of 3Cs at ‘A’ Level, BTEC and an Access course. The department is in a purpose-built building with rooms mainly designed for groups of under fifty.

The degree programme has a systems approach to electrical and electronic engineering. Circuits are taught from first year, with increased complexity being introduced in each successive year. The degree is well supported by industry with placement support, real life projects, case studies and occasional guest lectures. Teaching time is distributed between lectures, tutorials and labs, and using actual circuits. In the final year there were some 40 students in the class.

The main focus in the analysis of the baseline data in this unit was on staff and student perceptions of the teaching-learning environment in this final-year unit which combined digital and analogue electronics. The findings have already been described more fully elsewhere (Nisbet et. al., 2005). Unusually, all of the teaching of analogue, including lab supervision, was carried out by the same lecturer, who had responsibility for that subject throughout all three years of the degree.

9.6.2 The lecturer’s perspective

The lecturer had considerable experience both in HE teaching and in industry. In his interview comments he emphasised the practical nature of the degree, together with the coherence, continuity and increasing complexity of the teaching and learning over the three years. Asked what he wanted the students to get out of the course, he emphasised the importance of teaching for understanding. He described how he tried to keep things simple, particularly with the maths, using repetition to promote understanding and drawing on a mixture of methods to encourage active participation, including gapped notes and diagrams. Above all, he emphasised the importance of hard work for the achievement of real understanding. He actively looked out for evidence of understanding, for example from his continuous assessment of laboratory work. He openly acknowledged that his approach was determined both by the changing nature of the student intake and a reduction in class contact time. He described his approach as one that started where the students were and led them gradually towards increasing confidence and self reliance. He also highlighted the influence of the lecturer in the encouragement of student learning by his own approach and behaviour towards students: conveying his own enthusiasm; being approachable and available outside timetabled classes; and being well organised and prepared.

9.6.3 The students’ perspective

Frequency distributions of items from the second questionnaire showed a high level of satisfaction with the experiences of this course unit, and this was supported by the student interview data. Those
interviewed were particularly appreciative of the lecturer’s organisation, approachability, availability, patient explanation and general supportiveness, all of which were perceived as having positive benefits for learning (see N1L in Appendix Table A5). Asked how they went about learning analogue electronics, students described a particular way of thinking that depended on memorisation for understanding, especially with regard to mathematical equations. In terms of doing well in analogue, they demonstrated awareness of their own responsibilities as learners in terms of maintaining interest and enthusiasm and putting in the work. This, they felt, was particularly important given that analogue continued throughout the three years of the degree, unlike other one-semester units where ‘you never look at it again’.

The students also talked about the incremental nature of the subject, how it built on learning and knowledge from previous years and the importance of mastering the ‘building blocks’ and keeping up with the work. Another aspect referred specifically to the importance of learning how to apply the theory; demonstrating applications to the world of work; learning to think like a professional engineer. Some would have liked even more in the way of practical application, seeing the skills they were developing as related mainly to academic theory rather than to professional practice. Students who had done a placement year were enthusiastic about their experience of placement and emphatic that the course theory and concepts should be even more closely linked to applications met in industry, with more practical, hands-on experience. They also referred specifically to the benefits of the placement experience when tackling their final year project and to the positive motivational impact of the placement on their approach to their final year studies.

To sum up, both lecturer and students commented on the perceived advantages of continuity, coherence and congruence over the degree programme as a whole, which indicated substantial alignment of the teaching and assessment both to the aims of the course and to the students. While this alignment stemmed here from the unusual situation of having one lecturer teaching analogue electronics throughout the degree course, it does at least raise the issue of how best to ensure such coherence, given the growing recognition of the difficulties which students experience within a modular system without built-in connections between modules. Given the consistently positive responses of students in both interviews and questionnaire, no collaborative initiative was sought.

9.7  City college teaching an introduction to microprocessors

9.7.1  Setting

This setting was chosen to ensure that the project examined a higher education setting within the further education sector. The college is a multi-site institution in an inner-city setting. One of the aims of this college is to increase activities that support wider participation in higher education by developing foundation programmes such as the HNC.

The selected course unit was a first-year module entitled ‘Microprocessor Systems’, part of a two-year HNC engineering course run in partnership with the local university, a former polytechnic. The main focus of the module is on using microprocessors in problem-solving systems, which is also the main focus of the ‘outcomes based’ Edexcel syllabus. Teaching is in small groups (the class size was around 10) and moves from lecturer presentations to discussion as appropriate and also involves practical work.

In a typical year, around ten students, most of them on day-release, undertook the module, the majority having progressed from national certificate courses that were also run at the college. Subject to their performance on the module, those students who wish to can progress to the second year of an engineering degree at the university. To this extent the HNC can be seen as the first year of the degree for ‘non traditional’ students seeking a route into higher education. Most of the students are in their late teens and work in factory maintenance, attending college on day-release, which is a compressed and tiring experience of being actively involved all day, coupled in many cases with a lengthy commute to college.
9.7.2 The tutor’s perspective

The unit introduced students to key computer programming concepts and their role in enabling a basic microprocessor to drive simple systems of peripheral hardware. The tutor was clear about the main aim of the module, which was to help students understand the function of microprocessor systems to drive peripheral equipment, anything from factory machinery to a printer, for defined purposes. This distinctive picture of ‘ways of thinking and practise’ essentially represents the broadest level of understanding the students have to grasp - the microprocessor systems’ ‘lens on the world’.

The main method of teaching was by lectures with electronic visual aids supported by a course handbook, and the course work involved exercises in programming. The tutor explained that the course description specified that it should be largely practice-based and so he deploys programming exercises to reinforce the theoretical aspects of the module. The microchip deployed in the baseline year was the obsolete Z80, chosen because of its simplicity and architectural similarity to modern chips, built into the ‘BECCA-Plus’ handheld computer. With this equipment, the programming aspect involves writing a ‘mnemonic code’, which approximates natural language, and looking up the equivalent ‘machine code’ (the numeric programming language for the chip) from a table and writing it up as a programme. This is embedded within a hands-on programming task.

9.7.3 The students’ perspective

Analyses of both questionnaire responses and interviews with the whole year-group indicated that while the exercises associated with programming the microprocessor were a logical way of making connections between theory and the operation of the microprocessor, the students perceptions were that the module’s aim was to teach them how to programme the Z80, and felt that the connections with practice should be more direct, developing their understanding ‘top-down’ in terms of applications of the technology, rather than bottom-up in terms of how the technology operates.

There was thus a mismatch between how the tutor viewed the module’s aims and organisation and the students’ perceptions of them. These perceptions exerted a profoundly negative influence on the students’ attention and attitudes to the learning experience. This was exacerbated by the students’ feeling that they should be working with the microprocessors found in their work places rather than the obsolete Z80, and compounded by physical weariness from lengthy commuting combined with intense day-long learning activities. More details of the analyses have again already been published (Bromage and Whitaker, 2005).

It seems that while the tutor’s broad notion of microprocessor systems explains the approach taken to teaching and learning on the module, the students were so closely bound into their daily work experiences that they found it difficult to see that much broader view. They first have to understand how a microprocessor itself functions, and then how microprocessors are ‘embedded’ with other components within a system. Each level interacts with the others and can act as threshold concepts that open up a greater understanding of microprocessor systems, or alternatively become blocks to further progress.

Perhaps the most interesting outcome of the analyses of the baseline data in this setting was how the choice of the Z80 microprocessor as the focus for the module affected the teaching-learning activities that were then required. The programming exercises necessary for the students to be able to operate the device were found boring and irrelevant. The collaborative initiative led to a replacement of the Z80 with a far more ‘user friendly’ microprocessor, with important consequences for teaching and learning, as we shall see in the next section.

10. DESIGN AND IMPLEMENTATION OF THE COLLABORATIVE INITIATIVES

The discussions we had with colleagues in the seven settings for electronic engineering meant that we were able to identify suitable collaborative initiatives in four of them. One was in the city college
(N2), while essentially a common initiative was agreed for the three analogue course units in research-intensive universities. These initiatives are now discussed in turn.

10.1 The collaborative initiative in the city college

10.1.1 Baseline year

In discussing the findings from the baseline year, the central issue identified was the module’s ‘perceived relevance’ for the students, and this was traced to the equipment deployed in the module and its alignment with technologies visible in the students’ occupational milieu. Arguably, a precipitating factor was the students’ work colleagues’ minimal understanding of what the students had learned and how theory related to their working practices. The influence of this ‘community of practice’ (Wenger, 1999) apparently precipitated a crisis of confidence among the ‘baseline’ students. Their occupational milieu emphasized the practicalities of ‘engineering technologists’, whereas the occupational model built into the module is arguably that of the ‘holistic professional engineer’ (Robinson and Bramhall, 2001).

10.1.2 The agreed initiative and its implementation

At the core of the agreed intervention was the replacement of the Z80 microprocessor chip with the PIC chip. The reasons for this were, firstly, the technical difficulties of working with the Z80, in terms of its poor user-friendliness, and its perceived relevance, long obsolete for contemporary industrial contexts.

Secondly, the change would also enable more ‘hands on’ learning activities to be developed. PIC programming code is very complex and for the collaborative year the students were not required to hand assemble code, a move intended to reduce the confusion they had experienced in the balance between the ‘programming’ aspect of the module and the ‘systems’ aspect. More ‘realistic’ and ‘hands on’ learning activities were developed for the students. For example, the module tutor developed a ‘pelican crossing’ exercise, where the students develop a control system that works the crossing lights in response to crossing user input.

In the proposed collaborative initiative, it was suggested that links that the college has with a major car manufacturer might be exploited to arrange field trips so the students would see a complex computer operated assembly process, intended to demonstrate the relevance of microprocessor systems in a manufacturing context. However, logistical issues associated with making the necessary arrangements precluded any such visits.

10.1.3 Responses to the collaborative initiative

Early in the module, the students saw examples of everyday objects that are controlled by microchips, such as toasters and computer hard discs. The students understood that microprocessors are used in everyday appliances. However, this did not stop them from questioning the relevance of the PIC processor in particular to their own professional lives. The question of relevance has been less prominent since the change from the Z80, but it has still been an issue for students. Those working in electrical maintenance felt that they should learn to program the latest chip that they will encounter in industrial settings, the PLC. On the other hand, the students were considerably less critical of the PIC than the previous cohort were of the Z80.

As with the ‘baseline’ cohort, the purposeful end of a program seemed to appeal to the students, and they found the tutor-led sessions and example programs important in fostering their achievement. Teaching the difficult programming concept of ‘interrupts’ was facilitated by the use of ‘macro’ sub-routines modules that the students can incorporate into their programs using the PIC. This facilitated the teaching at a more conceptual level, as the students did not have to grapple with the complexities of programming as well. The students commented that they couldn’t do it without the example programs provided by tutor, to set up the ‘banks’, the PIC and the program.
There was, however, still some confusion as to what the tutor expects the students to gain from the module, some think it is an overview, others to learn programming skills. With regard to possible ‘ways of thinking and practising’ within the discipline, those students who had progressed from the ONC comment that despite now using a different processor with different logic commands to those they had previously deployed on the ONC, the task was very similar, giving them an advantage. These students commented that three aspects - thinking about a program step-by-step, mapping the program in a flowchart, and knowing the commands to translate map into code - were crucial to their success in these tasks. It seems that these generic skills together may form important ways of thinking and practising in this field.

Interestingly, the previous cohort made no similar comments. It is possible that the changes made since the baseline year have helped to reinforce this conceptualization, as the students were no longer distracted from such tasks by the difficulties inherent in mastering BECCA Plus, or an unhealthy preoccupation with the irrelevance of the Z80.

In summary, the changes facilitated by replacing the Z80 with the PIC processor system highlight how the equipment used can condition and constrain teaching and learning possibilities. The benefits were twofold. Firstly, the change allowed a greater alignment between the visible technologies deployed in the module and those in the students’ workplaces, although several students still expressed reservations about the new processor. Secondly, while the baseline cohort had complained about the user-friendliness of the BECCA-plus from the start, the following cohort had no similar complaints about the PIC-based single board computer. There is some evidence to suggest that this may have helped them to focus more on ways of thinking and practising within software systems engineering. However, several students again complained about the module’s emphasis on theory. It may be that the recognition of the role of theory in understanding aspects of the working practices of the ‘holistic professional’ is the main ‘threshold concept’ that these students need to grasp.

10.2 The collaborative initiative in the two research-intensive universities

Students interviewed generally agreed that they were, at first, not at all clear how to solve tutorial problems. They were looking for clear strategies to be offered within the lectures that would guide them more easily towards the solutions. They also wanted more worked examples to be provided to offer additional guidance. Although recognising that worked examples could be helpful, some of the staff were wary of what they saw as ‘spoon-feeding’ in case it encouraged the mindless following of routines. As we have seen, both staff and students agreed that there was a way of thinking associated with the analysis of analogue circuits that had to be mastered, but achieving this competence proved difficult for a substantial proportion of the students. The tendency for surface approaches to be adopted by these students made any through understanding unlikely.

In considering the possibilities, it was realised that only relatively minor changes could be implemented within the timescale and the formal procedures involved in making any substantial changes in the syllabus or teaching arrangements. It was thus decided to seek ways of encouraging a deep approach more directly. Besides drawing on the analyses of the baseline data, we also drew on previous findings from research into student learning and from psychology.

10.2.1 Previous research used suggesting a collaborative initiative

Expert and novice learning

The literature on problem-solving was described in the review section of the report (Section 3.2.2) and indicated the importance of providing appropriate ‘scaffolding’ for students’ early attempts at developing the skills involved. Although problem-solving in electronic engineering clearly has aspects which are specific, there should still be elements in common with other contexts. The main features highlighted in the psychological research were found in the teaching of analogue electronics, although not always in a fully developed form.
All the units gave students a large number of examples chosen to cover the most salient differences in the problems, but novices also have to be encouraged to look for recurring patterns and to develop systematic strategies. While students asked to be given clear guidelines for solution strategies, lecturers were aware of possible pitfalls. They wanted students to realise that mindless following of such guidelines would not get them very far in analogue electronics. Hearing experts solve problems out loud is also important for novices, as it makes explicit the ways of thinking used by them in reaching solutions: staff did this quite regularly but students wanted rather more of this activity. Finally, the research suggested ways of encouraging novices to internalise their reasoning processes, for example, by making notes about mistakes made and better ways of tackling the problems. Some students seemed to be doing this, but others were not working so systematically.

Collaborative learning

There is a good deal of emphasis in the current research literature, and in classroom practice, on the value of various forms of collaborative learning and how this can be used to facilitate thinking about problem-solving processes, both in engineering (Nicol & Boyle, 2003) and in other subject areas (Biggs, 2003). Students we interviewed had generally not been given such opportunities in class, although some of them had formed self-help groups in their own time. In some departments, students are allocated to groups of around four and often stay with that group, unless there are difficulties, throughout the course. This not only provides the experience of collaborative working but can easily be adapted to working on problems and on projects. These experiences not only contribute to social skills but also offer continuing opportunities to discuss the processes of learning, studying and problem solving. These methods can also be used to plan group presentations and to provide feedback on each others’ work. Where staff resources make it increasingly difficult to provide individual feedback and small-group tutorial discussions, it becomes increasingly important to capitalise on the collaborative learning which students generally enjoy and find beneficial.

10.2.2 The agreed initiative and its implementations in three settings

In all three course units, there was ready agreement to put more direct emphasis on the need for students to adopt a deep approach to problem-solving. It was suggested that one way of doing that would be to ask students to carry out the work on tutorial problems in a ‘logbook’ and, as in some industrial settings, to use the logbook to write down their own comments about problems they had met and how they had overcome them. Using the logbook would also make the students more aware of the need to work through a substantial number of examples in order to build up their understanding of analogue electronics, as well as encouraging explicit consideration of the solution strategies involved. At the time of developing the initiative, the previous use of such tutorial workbooks (see Section 3.2.2) had not been identified in the literature, but our intentions were similar to those described there.

The possibility of setting up collaborative working groups of students to encourage discussions about solution strategies was also discussed, but the logistics of that proved impossible to organise at short notice.

David Perkins, one of our international consultants, had shared with us the notion of ‘blow-up factors’ from his own experience of carrying out similar research. These are unanticipated events that blow the research off its designed course. It should be stressed that while these are ‘blow-up factors’ for those who designed the research study, the events are very much part of the everyday experience of university staff.

In one unit (N3F), the lead lecturer was off ill for some four weeks at the very start of the course. As a result, the students were not introduced to the idea of using logbooks until well after the unit had started. There was also some redistribution of teaching which affected the overall coherence of the unit from the students’ perspective. In another unit (N4F), the lecturer had set up the initiative from the start, stressing the value of both logbooks and collaborative working, and had wanted to assess the workings in the logbook within the coursework mark, but this proved impossible in a large lecture-
room based class. As a result, the initiative was dropped after a few weeks, although some students continued using the logbooks for their own benefit.

In the remaining unit, the initiative was fully implemented and there were tutorial assistants allocated to help with the tutorials. But the lecturer from the baseline year had taken sabbatical leave, and a colleague who was new to teaching took it over, thus preventing any direct comparison between the two year-groups. The extent to which the effect of the collaborative initiative could be evaluated was thus extremely limited. Nevertheless, the data did provide some indications of how students had used the logbooks and what they thought of them, while discussions with our Subject Advisers helped us to assess the value of the initiative.

10.2.3 Responses to the collaborative initiative

As a result of the analyses in the previous year, we had a good idea of the teaching-learning activities that students believed to help their studying, and so we devised some additional items to include in the ETLQ with two of the items being specifically related to the collaborative initiative (see Appendix). Comparing the mean scores on these items provides an indication of students’ reactions to the teaching they experienced during the collaborative initiative.

In the main analyses (Table A5) the patterns of response from students in the two second-year classes (N3F and N4F) were very similar to those found in the previous year groups. Table 10.1 adds to these findings using additional items designed to be specific to teaching and learning in analogue electronics, using means and standard deviations on seven-point scales to show how much each of the aspects was believed to contribute to their understanding of analogue electronics.

N3F was perceived by the students responding as being very strong in the provision of worked examples and in enabling students to work on problems on their own, supported by effective help in tutorials, although the explanations in lectures were rated less highly. The logbook idea was introduced and some students worked with the idea, but there was a feeling that it ought to have counted for

<table>
<thead>
<tr>
<th>Course unit</th>
<th>Teaching-learning activity</th>
<th>Mean scores on a 1–7 scale</th>
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<tr>
<td></td>
<td></td>
<td>N3F (SD)</td>
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<tr>
<td></td>
<td></td>
<td>Mean (SD) N = 59</td>
</tr>
<tr>
<td>The way diagrams presented</td>
<td></td>
<td>5.0 (1.3)</td>
</tr>
<tr>
<td>The way ideas explained in lectures</td>
<td></td>
<td>4.3 (1.6)</td>
</tr>
<tr>
<td>Lecture explanations of problems</td>
<td></td>
<td>4.2 (1.8)</td>
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<tr>
<td>Worked examples provided</td>
<td></td>
<td>5.0 (1.4)</td>
</tr>
<tr>
<td>Working on problems on own</td>
<td></td>
<td>5.2 (1.3)</td>
</tr>
<tr>
<td>Using the log-book</td>
<td></td>
<td>4.2 (1.7)</td>
</tr>
<tr>
<td>Staff help in tutorials</td>
<td></td>
<td>5.0 (1.7)</td>
</tr>
<tr>
<td>Discussions with other students</td>
<td></td>
<td>4.8 (2.1)</td>
</tr>
<tr>
<td>Feedback on work submitted</td>
<td></td>
<td>3.5 (2.1)</td>
</tr>
<tr>
<td>Class tests and the results</td>
<td></td>
<td>4.3 (1.8)</td>
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assessment purposes, given the work involved. N4F was almost the converse, with the explanations appreciated, but worked examples and the tutorial help less highly regarded. The introduction of logbooks was introduced thoroughly with the idea that the work would be assessed: students who had been putting a good deal of effort into their logbooks were understandably annoyed when they found that these would not, after all, be included in the assessment. In neither unit was the feedback on work submitted felt to be very helpful, and similar views were expressed during the interviews, and this reaction by students seems to have been common across most of the units we have looked at.

In N4L, the way the diagrams were presented (through PowerPoint slides) was strongly appreciated, as were the worked examples (provided through an interactive program on the web which gave hints rather than actual solutions). The staff help in tutorials was also strongly rated in the small-group tutorials that had been provided (at considerable additional cost). The logbooks were included in the coursework mark and the intention was that it would be marked according to the quality of the comments as well as correct solutions, but the students were far from clear what emphasis was to be put on the various aspects or how the different tutors were interpreting the guidelines. Tutors certainly looked at the logbooks but their underlying purpose does not seem to have been clearly understood.

The use of logbooks was the main innovation in the teaching in all three units and it was hardly surprising that students rated that activity highly only where it had been fully implemented. In the interviews, reactions to the logbooks varied. Initial reservations about an additional task were expected, and found, but there were also positive comments.

I think when [the lecturer] mentioned the logbook and how you can look back and it will be helpful - at the time I thought, “Helpful, my bum”! I’m going to realise I’m not any good at all. But later we were answering questions in class, and everybody was looking through their notes, and [my friend] says to me – “That’s in your logbook” and I say, “Oh, so it is”, and we worked everything out really good. So, that’s when I thought a logbook was going to be a ‘must’ then. (N4F)

The idea was good but I think they never bothered [about them] … It was the first year, you know, they can’t get everything right first time. (N4L)

I think the logbook has been good, because, I can look back at this stuff I did at the start and I’ve actually written wee bits on the tutorials in the side, … and if I’m having difficulties with anything…. I look back on my logbook and [find what I need]. I wouldn’t have kept [my own] logbook - no way…. there would have been bits of paper everywhere! (N4F)

I got used to writing down all the problems in the logbook and then you can sort of look back and read through it and understand what you have done… At first I’d just look at a couple of tutorial questions and write down what I thought. But now I’ve got, like, pages of stuff written down, so I think the logbook now is really important to my understanding. (N3F)

A common reaction to the experience of the logbooks was that the idea was good, but there had been problems in implementing it.

I think probably we got the mechanics wrong but the notion was [good] - to get you thinking about the process of problem solving and actually commenting to yourselves about where things were tricky and what the way out was. So then when you came to revise you’d have your own comments there. (N4L)

I had [worked with] that to a lesser degree before but instead of leaving a whole spare page [which had been suggested] I just wrote myself little notes under different problems I was doing. So that when I was revising it was just right in front of me, I didn’t need to have to skip over to the next page. (N3F)

The logbook was good and bad… It’ll be great because you’ve got the work we did and… you’ve got little comments, so you can think, “How is it that works again?”, ’cause it’s maybe got a wee bit of explaining in it. That’s the good bit. But the bad point is, it can make things look jumbled it
‘cause, say you get to a question and you’re stuck, so you miss it out and do the next one, and you’re stuck at that one, … and pages with like one wee kind of section on the side of the page that’s actually right. The rest of the page is scribbled out. So it can end up a bit messy. (N4L)

Having it in the log book’s good, but we’d need to work out a better way of using them. Maybe you can do your calculation in your bog-standard blue, comments can be written in red, and then even when it comes to diagram, like you see having different colours on it, could make it so much easier. (N4L)

It became clear from the feedback that students who had put an effort into using the logbook had found the exercise beneficial, but the suggested way of doing it was not effective. Students wanted to be able to adapt the general idea to their own established ways of studying. Moreover, several students commented that they had found it difficult to know what type of comments to make, and that is not surprising. Reflecting on learning processes does not come naturally; it will require a good deal of explanation and continuing tutorial support until the idea has been fully grasped.

Overall, there was thus general agreement that the idea of what could probably be better described as a tutorial workbook, was a good one. To work well, however, it would probably have to be introduced as a matter of general departmental policy across all units where it was appropriate and as part of the assessment procedure, so that students would feel that the effort was being rewarded. In the study described in the literature review (Section 3.2.2), Wellington and Collier (2002) found that the assessment weighting had clearly affected the effort put into a tutorial workbook and that the innovation had proved effective in improving motivation and academic performance. From our own study, it seems that students need a full and clear explanation of the purposes of introducing a workbook - keeping workings together and commenting on the solution strategies that worked and the difficulties encountered – and help with understanding the type of comments they might include. The different ways of recording comments would need to be mentioned, and students being encouraged to find the way that suited them best.

11. TEACHING TO ENHANCE LEARNING

11.1 Conceptual mapping of general influences on student learning

Figure 11.1 maps some of the influences on the quality of learning achieved within course settings in higher education, based partly on the findings of the ETL project across the four subject areas, and partly on the more general research and development literature on teaching and learning.

The top half of the diagram involves the individual students’ characteristics, starting at the top with their previous educational and personal histories, their existing stage of epistemological development, and their current knowledge and aspirations. Perry (1970) described a developmental trend among university students as they progressed from believing that there are ‘right’ and ‘wrong’ answers to everything (dualism) to a gradual realization that knowledge is ultimately relative and is built up from interpretations of evidence (relativism). Within the sciences, this development is seen more in terms of the readiness of students to use evidence effectively and to see how theories depend on it. The stage of development reached, as well as other aspects of prior experience, all affect students’ approaches to learning and studying, and also their perceptions of the teaching-learning environments they experience.

The bottom half of the diagram describes the teaching-learning environment that staff have provided for the students, and the influences on its design. The teaching policies of the department, and its teaching ethos, are affected by institutional policies about assessment procedures, as well as a whole range of other policies. The content of any course unit is determined to some extent by the departmental teaching ethos, but also by the general views about content and pedagogy held by the wider academic community and by the validating Institution. It is here that the nature of the subject content is paramount, and where the ‘inner logic’ of the subject and its pedagogy is most likely to be seen.
The lower set of linked boxes emerging from ‘departmental teaching ethos’ describes the aspects of the teaching-learning environment which the ETL project has found to be important in influencing student learning across the four subject areas with which we have worked.

We started our research looking at the extent to which the teaching and assessment was ‘constructively aligned’ with the aims of the course, but realised that other aspects, such as student support and feedback, were also important. The term *congruence* was thus preferred to the narrower sense of ‘alignment’, and has proved a fruitful way of considering the relative effectiveness of course units in

*Figure 11.1 A conceptual map of the influences on learning in higher education*
focusing on the main WTPs identified. The higher set of linked boxes is based partly on the demands that we found were affecting student approaches to learning, but also on previous research, which had identified what students believed to be the main characteristics of ‘good’ lecturing (Entwistle, 1998).

High quality teaching-learning environments appear to be congruent not just with the main aims and WTPs, but also with the students’ backgrounds, prior knowledge and aspirations. Moreover, the congruence exists within each of the various elements identified, so that the differing forms of assessment and feedback, or of teaching-learning activities, for example, have to be congruent between themselves, as well as with the other aspects of the whole teaching-learning environment. Of course, this is an idealistic description, but the project has found, across the four subject areas, that any serious lack of congruence will affect the ability of students to learn effectively, and even some relatively minor disruption of coherence can create difficulties for some students. As discussed earlier (§ 9.4.4), the work of Eizenberg (1988) and our own analyses of teaching and learning in analogue electronics have suggested that any one element of a teaching-learning environment that is seriously incongruent with the main WTPs that staff are aiming at can disrupt student learning and shift a proportion of the class as a whole away from deep approaches and towards surface approaches to learning.

11.2 Aspects of teaching and learning specific to electronic engineering

The final analysis brings us more directly to the main aim of the project – to identify ways of enhancing the quality of student learning. It seemed important to link the items that specifically asked students about the teaching-learning activities that had helped their understanding of analogue electronics with the more general items rating their experiences of the teaching-learning environment from ETLQ. This analysis was carried out with all the students with complete data from ETLQ and the additional items (N =129). Maximum likelihood factor analysis of this set of items produced seven identifiable groupings of items. Of these, three factors included items students had rated for their helpfulness in understanding, and these are shown in Table 11.1 showing the items from the two sets of items that defined each factor.

The first group of items describes teaching that is perceived by the students to be coherently organised and which is seen as providing good explanations and examples, emphasising the need to think more deeply about the subject. The second group indicates the types of support that students appreciated in working on the tutorial problems, while the third suggested the ways in which collaborating with other students had helped.

12 CONCLUSIONS AND IMPLICATIONS

12.1 General impressions of the teaching-learning environment

In all the settings, a majority of students were satisfied with most aspects of their experiences of teaching and learning electronic engineering but with the strong proviso from some students that the overall experience was not sufficiently varied, at least in analogue. The repeated emphasis on the analysis on formal examples of different circuits, although necessary, led to criticism of that aspect of their experiences, especially from MEng students looking back over the whole of their BEng experience. As one of the students commented:

[In the learning, you’re repeatedly] reading it, hearing it, talking about it, doing it, doing it, doing it… Personally for me that system doesn’t work. And I don’t know, I guess that’s probably why, for first, second and part of third year, it was a case of scraping by. Except for in the case of projects, I’ve tried to go through the motions; it’s the sameness. It’s [the same] pattern, and each day is that pattern.

In several of the settings, the BEng students seemed to find the way circuit analysis had been taught rather boring. The MEng students felt that there were ways in which more variety could be introduced


**TABLE 11.1  Items defining three factors related to ratings of helping students to understand**

| Items are presented in the order of the size (above 0.35) of factor loadings in each set of items. |
| Well-organised teaching providing good explanations, examples, emphasising thinking |
| Items describing what specifically helped in learning analogue |
| The way the lecturer(s) explained how to think about problems |
| The way ideas and concepts were explained in the lectures |
| The way diagrams were presented and used in lectures |
| General items rating experiences of teaching and learning related to the analogue items |
| Staff helped us to see how you are supposed to think and reach conclusions in this subject |
| Staff tried to share their enthusiasm about the subject with us |
| We weren’t just given information; staff explained how knowledge is developed in this subject |
| The course unit was well organised and ran smoothly |
| The teaching encouraged me to rethink my understanding of some aspects of the subject |
| We were given a good deal of choice over how we went about learning |
| How this unit was taught fitted in well with what we were supposed to learn |
| Plenty of examples and illustrations were given to help us grasp things better |
| Supporting students’ work on tutorial examples |
| Items describing what specifically helped in learning analogue |
| The help give by staff as you worked on tutorial problems |
| Feedback and comments from staff on the work submitted |
| Worked examples provided in handouts or on the web |
| The class tests and the results you were given |
| Working on the tutorial problems on your own |
| General items rating experiences of teaching and learning related to the analogue items |
| The feedback given on my work helped me to improve my ways of learning and studying |
| Staff gave me the support I needed to help me complete the set work for this unit |
| The feedback given on my set work helped to clarify things I hadn’t fully understood |
| The different types of teaching (lectures, tutorials, labs., etc.) supported each other well |
| On this unit, I was prompted to think about how well I was learning and how I might improve |
| Doing the set work helped me to think about how evidence is used in this subject |
| I was encouraged to think about how best to tackle the set work |
| Working collaboratively with other students |
| Items describing what specifically helped in learning analogue |
| Group discussions with other students on doing the problems |
| General items rating experiences of teaching and learning related to the analogue items |
| Talking with other students helped me to develop my understanding |
| Students supported each other and tried to give help when it was needed |
| I found I could generally work comfortably with other students on this unit. |

into the teaching-learning activities, using, for example, simulations and interactive materials on the web. It was, in fact, surprising to find rather little use being made of computer-based advances in the presentation of lectures or in interactive e-learning in the settings with which we worked, although the review of the literature indicated that such techniques were being used within electronic engineering in other universities.
The MEng students also felt that not enough emphasis had been put, until the final year, on demonstrating the professional relevance of what was being taught. Students who had just completed analogue units also asked for more emphasis on the professional aspects and applications of circuits, but generally gave high ratings for the efforts that staff had made in lectures to explain difficult areas to them patiently and thoroughly. The limited feedback provided to students on their work and the large size of tutorial groups did, however, prompt regular criticism.

12.2 The inner logic of analogue electronics and its pedagogy

The process of reading through the transcripts of interviews with staff and students opened up an important question for the project as a whole about how the nature of a specific subject area affects the teaching and learning of it. In analogue electronics we found certain teaching-learning activities which were present in all the course units, and which were rated highly by students as contributing to their understanding when they had, in the students’ view, been carried out effectively. This led to the notion of their being an inner logic of the subject and its pedagogy, reflecting its distinctive ways of thinking and practising, and indicating some of the necessary conditions for learning analogue electronics. To some extent an effective pedagogy will have elements in common across most subject areas, but the nature of the subject must affect the particular forms of teaching and learning which suit that subject best, and in particular the way in which common teaching methods are implemented.

This idea of an inner logic has something in common with the notion of signature pedagogies of the professions introduced in a recent talk given by Shulman (2005). He and his colleagues have been investigating several professional areas, including engineering, and have been struck by the existence of methods of teaching that have evolved to encourage the specific kinds of thinking that are characteristic of each profession.

What I mean by ‘signature pedagogy’ is a mode of teaching that has become inextricably identified with preparing people for a particular profession. This means it has three characteristics: one, it’s distinctive of that [specific] profession... Second that it is pervasive within the curriculum, so that there are certain continuities that thread through the program that are part of what it means to “think like a lawyer” or “think like a physician”... There are certain kinds of thinking that are called for in the rules of engagement of each course, even as you go from subject to subject. The third feature is another aspect of pervasiveness, which cuts across institutions and not only courses. Signature pedagogies have become essential to general pedagogy of an entire profession, as elements of instruction and of socialization.

Although this description is somewhat similar to the link we have been trying to establish between WTPs and essential elements of pedagogy, Shulman was focusing on much more distinctive methods of teaching – small group teaching such as clinical rounds in medicine or disputation sessions for lawyers. The teaching of analogue electronics was not distinctive in that way, being lectures, tutorials and lab sessions, but the teaching-learning activities used had evolved into specific forms to encourage particular ways of thinking; hence, the idea of an inner logic of the subject and its pedagogy.

Table 12.1 Main WTPs identified for analogue electronics

| ♦ Appreciating the overall function of a circuit |
| ♦ Drawing on previous concepts and integrating them |
| ♦ Recognising the salient groups of components |
| ♦ Thinking logically in setting about circuit analysis |
| ♦ Developing the necessary analytic tools for solutions |
| ♦ Building up a memory bank of contrasting examples |
| ♦ Thinking intuitively in designing new circuits |
Here we attempt to tease out from the review of the literature and our empirical findings what this inner logic of the subject and its pedagogy involves, linking what seem to be the main WTPs to the teaching-learning activities that staff and students believed most directly supported those ways of thinking. The starting point is to summarise in Table 12.1 the main ways of thinking and practising in analogue electronics as described earlier in Section 9.3.1.

The next step is to use the Phase 1 analysis of high quality teaching-learning environments from electronic engineering departments, described in Section 5.1, together with the teaching-learning activities identified in Phase 2 as having a particularly important role in supporting student learning of analogue electronics, to suggest the main features of its pedagogy. This review produced a set of teaching-learning activities which appeared to be essential for supporting effective learning in electronic engineering.

The presence of these teaching-learning activities in a basic form may be sufficient for the most motivated and best-prepared students, but other students will need more support under these headings if they are to maintain motivation and persevere with the difficulties they encounter. And each of the essential characteristics listed in Table 12.2 can be offered in ways which provide additional support. The review of the literature and our own study offered a variety of possibilities, and provides a more complete picture of a supportive teaching-learning environment in electronic engineering. Much of this picture will be familiar, even obvious, to teachers of the subject but it is hoped that seeing how the elements fit into a logical whole, and how each of the elements can be made more supportive of student learning will prove helpful and provoke further discussion.

### Table 12.2 A pedagogy for developing WTPs in analogue electronics

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuits linked to real-life illustrations from industry</td>
<td></td>
</tr>
<tr>
<td>Main circuit components clearly highlighted in diagrams</td>
<td></td>
</tr>
<tr>
<td>Ways of thinking about circuits explained and exemplified</td>
<td></td>
</tr>
<tr>
<td>Students work through sets of strategically varied examples</td>
<td></td>
</tr>
<tr>
<td>Ways of solving tutorial problems discussed</td>
<td></td>
</tr>
<tr>
<td>Worked examples provided at the appropriate time</td>
<td></td>
</tr>
<tr>
<td>Individual assistance with tutorial problems available</td>
<td></td>
</tr>
<tr>
<td>Progress monitored in tutorial work and tests</td>
<td></td>
</tr>
</tbody>
</table>

### 12.3 Essential and supportive aspects of a pedagogy for analogue electronics

#### Circuits linked to real-life illustrations from industry

Lecturers varied considerably in the extent to which they used their own industrial experience to enliven their presentations but most of the students we talked to had a clear vocational aspiration to become electronic engineers and appreciated any links that were made between academic content and professional work. Anecdotes and examples brought the academic content to life for them in ways that they felt helped to reinforce their vocational commitment.

#### Main circuit components clearly highlighted in diagrams

Unless students were able to see clearly which particular set of components was being described on an overhead or slide, they could not easily make sense of the explanations. Overheads with an overlay used to highlight specific groups of components can be effective, but a particularly successful approach
used PowerPoint slides that highlighted successive groups of components to bring out their specific functions. Explaining the logical progression in the analysis of the circuit in advance, and bringing it out at each step, can be particularly helpful to students. However, such technology is not essential: students also liked a more traditional approach in which circuits were built up step-by-step on an overhead or blackboard as the lecturer’s explanation evolved, as the explanation and the diagram were again closely linked.

Ways of thinking about circuits explained and exemplified

One of the most powerful ways of developing problem-solving skills involves experts explaining their own thinking as they work on problems. This was commonly used, but sometimes the explanations, from the students’ perspective, jumped steps by making unjustified assumptions about their prior knowledge. Students liked explanations that were expressed in simple language and laced with enthusiasm and humour. In general research on lecturing, feedback from students has stressed the importance of seven main aspects: clarity, level, pace, and structure as the basic components, with explanation, enthusiasm and empathy being the aspects most likely to encourage a deep approach to learning (Entwistle, 1998). The review (§ 3.2.1) described the use of periodic concept tests in lectures to emphasise and monitor understanding (Mazur, 1997b), and this method has been developed into the computer-based Personal Response System which has been used in some engineering classrooms.

Students work through sets of varied examples

In all our settings, sets of varied examples were provided. Students suggested that the difficulty gradient be initially gradual to allow sufficient experience of success before meeting more difficult examples. As students vary markedly in what they see as easy or difficult, it may be necessary to provide sets of examples at explicitly graded difficulty levels, with students being encouraged to do enough of each set to confirm their understanding before moving on to the next level of difficulty. The collaborative initiatives in our project (§ 10.2.3) suggested the value of getting students to use tutorial workbooks to ensure that their workings were kept together, to encourage them to think about the process of problem-solving more explicitly, and to make their workings more accessible to tutors.

Ways of solving tutorial problems discussed

Students repeatedly asked for set procedures for tackling problems to be provided, but staff were reluctant to provide them, given the nature of analogue electronics. However, such solution frameworks would act as ‘scaffolding’ (§ 3.2.2) to guide students through the early stages of developing problem-solving skills, and so would support the development of problem-solving skills. Students would then have to be weaned off these supports to ensure more independent ways of working, but without such support skill development in the early stages can be slow and discouraging for the student. Our collaborative initiatives had sought to set up collaborative student groups to work on tutorial problems, but this proved impossible to organise. However, students did comment on how useful informal working groups had proved, suggesting that more systematic arrangements for collaborative working on problems might be worth exploring, as has been used in other contexts (§ 10.2.1).

Worked examples provided at the appropriate time

Staff differed in their attitudes to providing worked examples of the tutorial problems set, with some of them suggesting that students would then not do the initial workings themselves. However, the students we talked to found the worked examples invaluable; the general lack of other forms of feedback made worked examples an essential part of their experience. Students were particularly appreciative of staff who included explanations for the key steps in the solutions they provided. In one of our settings an on-line tutorial had been set up which took students through the stages in working through problems with prompts provided. Students who actually used this program found
it helpful, but it would have to be seen as an essential part of their work before its effects could become general.

**Individual assistance with tutorial problems available**

In all but one of our settings, students found considerable difficulty in obtaining individual advice, as tutorial groups were much too large: students resented wasting their time waiting for their difficulties to be resolved. Using graduate students in one of our settings was much appreciated by the students, although it did have serious resource implications. Offering e-mail access to staff did not seem to be taken up much by students, perhaps because they found difficulty in formulating their difficulties.

**Progress monitored in tutorial work and tests**

Although feedback on work done is generally accepted to be crucial in student learning, there was a general lack of feedback in the settings we looked at. Tutors only saw students’ work intermittently in tutorials and, even where class tests were given, there was no individual feedback. The resource implications of individual feedback may now be impossibly high, but without either worked examples or feedback it is difficult to see how students can learn effectively. Although each of our settings provided some combination of worked examples and feedback, students generally felt that it was inadequate in some respects. The assessment procedures also relied heavily on examinations, whereas in the literature there was an emphasis on developing mixed methods of assessment, recognising and integrating their differing strengths into coherent assessment strategies (§ 3.2.3).

12.4 Introducing and justifying change in teaching and learning practices

One of the great difficulties in interpreting the findings from this kind of research is the impossibility of controlling possible influences on the outcomes of learning. We have been able to identify some apparent effects of teaching on learning, as perceived by students, but often what the students experience is also a consequence of past events or circumstances about which students are unaware, such as the comments of previous generations of students, earlier attempts to change teaching arrangements, departmental timetabling arrangements, availability of rooms that allow alternative teaching methods, departmental decisions on what has to be covered in the course units and at which stage of the course. The ability of any individual lecturer or course team to make changes is more limited than students may realise, while the competing pressures on staff from research and administration can severely limit both preparation time and, in particular, the additional time and resources needed to introduce major changes into the existing degree programme.

The main incentives for considering changes in teaching practices within departments come from recognising that certain topics have been regularly found to be difficult by successive cohorts of students. Other incentives will come from high failure rates in specific course units, or worrying levels of drop-out from the degree course as a whole. In Section 3.1 we summarised a study by Cutler and Pulko (2002) which had surveyed programme-level innovations of teaching provision in electronic engineering designed to improve the progression rates in those departments. These provide suggestions that may well be worth considering in other departments, while our project focused more narrowly on the teaching-learning activities within individual course units.

The experience of students in the new university showed the value of having the analogue component of the degree course taught by the same lecturer. The continuity, coherence and congruence of that area of teaching was commented on very favourably by the students, while these elements were not commented on specifically by students in the other units. The students also appreciated the emphasis given to professional applications. Where analogue is taught by several different lecturers, it is difficult to be sure how previous topics have been treated, and students may meet somewhat different notations or solution strategies. Course teams could well give these aspects greater consideration in planning their teaching and ensuring agreement about the main treatments of the subject, communicating with each other more fully about what is being taught.
In the city college, the experience of day-release students was strongly influenced by the comments made to them at work about the relevance, or otherwise, of their course at college. It also raised the issue of using equipment that was markedly out-of-date compared with what students were seeing in the workplace. The effects of introducing more up-to-date equipment for the collaborative initiative not only improved the students’ attitudes, but also allowed important changes to be made in the pedagogy employed, by removing some repetitive work students had found boring, and introducing a more conceptual approach with a much clearer focus on ways of thinking and practising in microelectronics.

The use of tutorial workbooks in the collaborative initiative for three analogue units was broadly supported by both staff and students, even though the evidence of changed approaches was much weaker than had been anticipated, due to the unexpected events affecting the implementation. The workbook encouraged students not only to be more systematic in recording their solutions, but also to make written notes of difficulties encountered and how they were overcome, and so offers considerable advantages in analogue electronics, and in other areas where problem-solving skills are important. If students are also encouraged to work collaboratively on specific problems, and are required to reflect from time to time on the thinking processes and solution strategies involved (by, for example, calling for ‘time-outs’), deep approaches are likely to be strengthened overall. The use of ‘scaffolding’ – for instance, offering deliberately oversimplified solution frameworks from which students are later systematically ‘weaned’ – is also widely recognised in the literature as being helpful in learning problem-solving skills.

Our project has been exploring the use of questionnaires designed on a clear conceptual basis to provide detailed feedback on the effects on student learning of the various teaching and learning activities currently being used. The findings suggest that a revised version of our ETLQ questionnaire (see Appendix A6) could be used periodically (perhaps during course review) to obtain much more detailed information about students’ reactions to specific course units than comes from normal evaluation forms. Typical feedback questionnaires indicate levels of satisfaction but rarely provide much indication of the causes of any dissatisfaction. Not only does our questionnaire provide such information, but the scales also represent a coherent view, within a theoretical framework, of some important components of supportive teaching-learning environments. The questionnaire shown in Appendix A7 is a much shorter instrument that concentrates specifically on what were found in the current study to be essential aspects of teaching and learning in analogue electronics, and with some minor amendments probably in other areas of electronic engineering.

How the analyses of our questionnaires and interviews were carried out and interpreted also suggests a way of thinking about teaching and learning that relies more heavily than seems to be typical at present on detailed feedback from students about their experiences. Discussion of the meaning of feedback that focuses on teaching-learning activities also creates opportunities for considering pedagogical issues that might otherwise be overlooked. The interpretation of the findings is by no means straightforward, as was seen in considering the pattern of results for the three analogue units (§9.4.4), and discussions over possible interpretations and implications can arouse interest and provoke pedagogical debate.

The analyses we carried out in this project enabled us to discuss aspects of teaching provision that have been found to be strongly supportive of student learning in electronic engineering, and also to indicate some innovations which sound promising. It is hoped that these ideas will provoke discussion by course teams about ways of enhancing the teaching-learning environments they are currently offering. It is recognised that these suggestions cannot reach the level of specificity that point to specific teaching arrangements: each course unit has individual aims, makes a specific contribution to a degree programme, and involves students of differing backgrounds and aspirations. Although the project cannot offer direct answers to ‘what works’ in teaching electronics, it has offered evidence and ideas that can be considered in the light of the particular circumstances in other settings.
ACKNOWLEDGEMENTS

Although the contributors to the analyses and the writing of the report are indicated on the title page, the research is part of the larger ETL project and many of the underlying ideas have been developed within the team as a whole, as well as with staff in the seven settings with which we worked collaboratively. Besides the authors of this report, the other members of the research team at the end of the project were Dai Hounsell (Co-director), Charles Anderson, Kate Day, Jenny Hounsell, Ray Land, Judith Litjens, Velda McCune, Erik Meyer, and Nicola Reimann. Special thanks are due to our collaborators in electronic engineering departments: Roy Chapman, Tony Gachagan, Alister Hamilton, Les Haworth, Gordon Hayward, Robert Kelly, Brian McQuillan, Martin Reekie, and Peter Whitaker, without whose patient help the project could not have been carried out. We are also grateful to others who discussed particular aspects of the project with us, namely Sherri Johnstone, Tim Mulroy, David Renshaw, and Ian Robinson.

REFERENCES MENTIONED IN THE TEXT


<table>
<thead>
<tr>
<th>Unit code and theme</th>
<th>N2F Introduction to Microprocessors</th>
<th>N3F Second-Year Analogue Circuits</th>
<th>N4F Second-Year Analogue Electronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional setting</td>
<td>City college working extensively with day-release students towards ONC, HNC and HND</td>
<td>Ancient research-intensive university offering BEng at Chartered Engineer level, and MEng</td>
<td>1960s research-intensive university, offering BEng at Chartered Engineer level, and MEng</td>
</tr>
<tr>
<td>Prerequisites for unit</td>
<td>Preferred: National certificate courses run by the college</td>
<td>First-year analogue course or Direct Entry to second-year based on 'A' level grades</td>
<td>First-year analogue course or Direct Entry to second-year based on 'A' level grades</td>
</tr>
<tr>
<td>Status of unit</td>
<td>Introductory module within the HNC programme 30 one hour-long sessions</td>
<td>Compulsory course taught in the first half of the second year of a four-year programme 24 lectures, 5 fortnightly tutorials and 5 examples classes</td>
<td>Compulsory module in the first semester 12 three-hour morning sessions for the whole semester involving a mixture of lecture, tutorial and examples classes</td>
</tr>
<tr>
<td>Indicative admission requirements</td>
<td>3 GCSEs grade C or above, incl. English, Maths. &amp; Science, or equivalent qualification, e.g. BTEC First Diploma or GNVQ Intermediate in a related subject. Students without these qualifications are considered on an individual basis</td>
<td>Typically 3 good 'A' level grades or Scottish Higher with 5 good grades, although some students use their 'A' level to obtain Direct Entry into the second year, &amp; other students come into first year with alternative qualifications</td>
<td>Typically 3 good 'A' level grades or Scottish Higher with 5 good grades, although some students use their 'A' level to obtain Direct Entry into the second year, &amp; other students come into first year with alternative qualifications</td>
</tr>
<tr>
<td>Student enrolment</td>
<td>Pre-collaborative initiative: 10 Collaborative initiative: 11</td>
<td>Pre-collaborative initiative: 105 Collaborative initiative: 81</td>
<td>Pre-collaborative initiative: 84 Collaborative initiative: 111</td>
</tr>
<tr>
<td>Core teaching provision</td>
<td>Lecture Tutorial Practical work All occurring within the unit</td>
<td>Lectures Tutorials Examples classes Analogue practical tasks within other unit</td>
<td>Lectures Tutorials Examples classes Analogue practical tasks within other unit</td>
</tr>
<tr>
<td>Assessment (including weightings)</td>
<td>60% coursework 40% examinations</td>
<td>Notionally 90% examinations, 10% class tests, but stronger exam performance allows lower test marks to be discounted</td>
<td>80% examination 20% coursework</td>
</tr>
<tr>
<td>Guidance / learning support</td>
<td>Extensive written guidance in course handbook Software available for students to use at home In-class support from the module lecturer</td>
<td>Detailed notes provided at the start of unit Worked examples provided after related tutorials with up to 25 students and 1 lecturer</td>
<td>Detailed notes provided at start of module with some worked examples provided Tutorials carried out in the lecture by a single lecturer in the pre-collaborative initiative year</td>
</tr>
<tr>
<td>Staffing input</td>
<td>1 lecturer</td>
<td>2 lecturers</td>
<td>1 lecturer with 1 tutorial assistant in the collaborative initiative year</td>
</tr>
</tbody>
</table>
### Appendix Table A2: Summary of Third- and Fourth-Year Course Unit Settings, Electronic Engineering

<table>
<thead>
<tr>
<th>Unit code and theme</th>
<th>N1L Analogue and Digital Electronics</th>
<th>N3L Analogue Electronics 4</th>
<th>N4L Analogue Electronics 3</th>
<th>N4E Analogue Electronics 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Institutional setting</strong></td>
<td>Post-1992 university</td>
<td>Ancient research-intensive university</td>
<td>1960s research-intensive university</td>
<td>1960s research-intensive university</td>
</tr>
<tr>
<td><strong>Status of Unit</strong></td>
<td>Final-year module lasting the whole session of 24 weeks</td>
<td>Compulsory final-year course taught in the first term along with five other units and a project. 18 lectures and 12 tutorials</td>
<td>Compulsory third-year module</td>
<td>Optional final year module provided at the request of third-year students ?? lectures</td>
</tr>
<tr>
<td><strong>Student enrolment</strong></td>
<td>Pre-collaborative initiative: 38 Entry level to the degree course is 3 ‘C’s at ‘A’ level, BTEC, GNVQ or through access courses</td>
<td>Pre-collaborative initiative: 64</td>
<td>Pre-collaborative initiative: 63 Collaborative initiative: 75</td>
<td>Pre-collaborative initiative: 28</td>
</tr>
<tr>
<td><strong>Core teaching provision</strong></td>
<td>Lectures Tutorials Practical work</td>
<td>Lectures Tutorials</td>
<td>Lectures Tutorials</td>
<td>Lectures</td>
</tr>
<tr>
<td><strong>Assessment including weightings</strong></td>
<td>50% examination 50% coursework</td>
<td>100% examination within the unit, but the 6 exams constitute only 40% of the final mark, with dissertation and second-year marks also being included</td>
<td>100% examination in pre-collaborative initiative year 20% coursework introduced for the collaborative initiative year</td>
<td>100% examination</td>
</tr>
<tr>
<td><strong>Guidance/learning support</strong></td>
<td>Website provided and handouts of powerpoint slides</td>
<td>Website provided including an interactive tutorial on problem-solving</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Staffing input</strong></td>
<td>2 lecturers (1 teaching digital)</td>
<td>2 lecturers</td>
<td>1 lecturer with 6 tutorial assistants in the collaborative initiative year</td>
<td>2 lecturers</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>Optional paid year in industry</td>
<td></td>
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Enhancing Teaching-Learning Environments in Undergraduate Courses Project
### Appendix Table A3: Sample Sizes Across the Whole Project and In Electronic Engineering Settings

#### Total sample across the project

<table>
<thead>
<tr>
<th></th>
<th>Biology</th>
<th>Economics</th>
<th>Engineering</th>
<th>History</th>
<th>Media</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of units</strong></td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>31</td>
</tr>
</tbody>
</table>

**Students**

<table>
<thead>
<tr>
<th></th>
<th>Biology</th>
<th>Economics</th>
<th>Engineering</th>
<th>History</th>
<th>Media</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LSQ</strong></td>
<td>939</td>
<td>1084</td>
<td>623</td>
<td>882</td>
<td>250</td>
<td>3778</td>
</tr>
<tr>
<td><strong>ETLQ</strong></td>
<td>887</td>
<td>580</td>
<td>417</td>
<td>742</td>
<td>84</td>
<td>2710</td>
</tr>
<tr>
<td><strong>Complete data</strong></td>
<td>564</td>
<td>453</td>
<td>365</td>
<td>514</td>
<td>54</td>
<td>1950</td>
</tr>
<tr>
<td><strong>Interviewed (in groups of 2-6)</strong></td>
<td>117</td>
<td>263</td>
<td>104</td>
<td>166</td>
<td>18</td>
<td>668</td>
</tr>
</tbody>
</table>

**Staff**

<table>
<thead>
<tr>
<th></th>
<th>Biology</th>
<th>Economics</th>
<th>Engineering</th>
<th>History</th>
<th>Media</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interviewed</strong></td>
<td>32</td>
<td>25</td>
<td>13</td>
<td>19</td>
<td>1</td>
<td>90</td>
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</tbody>
</table>

#### Samples and response rates* in the Electronic Engineering settings

<table>
<thead>
<tr>
<th></th>
<th>N1L (%)</th>
<th>N2F (%)</th>
<th>N3F (%)</th>
<th>N3L (%)</th>
<th>N4F (%)</th>
<th>N4L (%)</th>
<th>N4E (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline year</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Number of students</td>
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<td>10</td>
<td>105</td>
<td>60</td>
<td>84</td>
<td>63</td>
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<td>Number of staff</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Completing LSQ</td>
<td>37 (97%)</td>
<td>9 (90%)</td>
<td>94 (90%)</td>
<td>46 (77%)</td>
<td>68 (81%)</td>
<td>54 (86%)</td>
<td>27 (96%)</td>
</tr>
<tr>
<td>Completing ETLQ</td>
<td>26 (68%)</td>
<td>6 (60%)</td>
<td>75 (71%)</td>
<td>39 (65%)</td>
<td>49 (58%)</td>
<td>40 (63%)</td>
<td>17 (61%)</td>
</tr>
<tr>
<td>Both LSQ &amp; ETLQ</td>
<td>24 (63%)</td>
<td>6 (60%)</td>
<td>68 (65%)</td>
<td>39 (65%)</td>
<td>40 (48%)</td>
<td>32 (51%)</td>
<td>15 (54%)</td>
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<td>Staff interviewed</td>
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<td>1</td>
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<td>1</td>
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<td>Student groups</td>
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<td>5</td>
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<td>10</td>
<td>6</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>N1L (%)</th>
<th>N2F (%)</th>
<th>N3F (%)</th>
<th>N3L (%)</th>
<th>N4F (%)</th>
<th>N4L (%)</th>
<th>N4E (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Collaborative year</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of students</td>
<td>11</td>
<td>81</td>
<td>111</td>
<td>75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of staff</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completing LSQ</td>
<td>10 (91%)</td>
<td>79 (98%)</td>
<td>93 (84%)</td>
<td>34 (45%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completing ETLQ</td>
<td>8 (73%)</td>
<td>56 (69%)</td>
<td>77 (69%)</td>
<td>7 (9**)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both LSQ &amp; ETLQ</td>
<td>7 (64%)</td>
<td>54 (67%)</td>
<td>68 (61%)</td>
<td>3 (4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff interviewed</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student groups</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students interviewed</td>
<td>9</td>
<td>6</td>
<td>10</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Collaborative initiatives were not carried out in every setting

* Response rates are the percentage of the number of students registered in the class at the time of the examination

** The very low response rate, caused by an incorrect version being used, makes the results for this group invalid
Appendix Table A4: Mean scale scores * on the LSQ questionnaire for electronic engineering by course unit

<table>
<thead>
<tr>
<th></th>
<th>N1L Baseline</th>
<th>N2F Base</th>
<th>N3F Col.</th>
<th>N3L Baseline</th>
<th>N4F Base</th>
<th>N4L Col.</th>
<th>N4E Baseline</th>
<th>Analysis of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>37</td>
<td>9</td>
<td>10</td>
<td>94</td>
<td>79</td>
<td>46</td>
<td>68</td>
<td>93</td>
</tr>
<tr>
<td>Level of Significance</td>
<td>&lt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scales from Learning and Studying Questionnaire (filled in at the start of the course unit)

### Reasons for taking the degree

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Col.</th>
<th>Significance</th>
<th>NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic</td>
<td>3.96</td>
<td>3.70</td>
<td>3.50</td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>3.54</td>
<td>3.39</td>
<td>3.30</td>
<td></td>
</tr>
<tr>
<td>Career</td>
<td>4.14</td>
<td>4.56</td>
<td>4.60</td>
<td></td>
</tr>
<tr>
<td>Regretting decision</td>
<td>2.59</td>
<td>2.78</td>
<td>1.70</td>
<td></td>
</tr>
</tbody>
</table>

### Reasons for taking the course unit

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Col.</th>
<th>Significance</th>
<th>NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest</td>
<td>4.19</td>
<td>3.56</td>
<td>3.80</td>
<td></td>
</tr>
<tr>
<td>Importance</td>
<td>4.19</td>
<td>3.33</td>
<td>4.25</td>
<td></td>
</tr>
<tr>
<td>Expected easiness</td>
<td>1.97</td>
<td>2.00</td>
<td>2.30</td>
<td></td>
</tr>
<tr>
<td>Needed for career</td>
<td>3.43</td>
<td>3.89</td>
<td>3.70</td>
<td></td>
</tr>
</tbody>
</table>

### Approaches to studying prior to unit (full scale)

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Col.</th>
<th>Significance</th>
<th>NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep</td>
<td>3.58</td>
<td>3.45</td>
<td>3.88</td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>2.98</td>
<td>2.84</td>
<td>2.18</td>
<td></td>
</tr>
<tr>
<td>Organised</td>
<td>3.19</td>
<td>3.07</td>
<td>3.76</td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>4.01</td>
<td>3.74</td>
<td>4.17</td>
<td></td>
</tr>
<tr>
<td>Concentration</td>
<td>3.45</td>
<td>3.11</td>
<td>3.65</td>
<td></td>
</tr>
</tbody>
</table>

* All scales have been converted on to a scale running from 1 (low) to 5 (high) with a mid point of 3
### Appendix Table A5: Mean scale scores on the ETLQ questionnaires for electronic engineering by course unit (Scales all 1 – 5 high)

<table>
<thead>
<tr>
<th>N1L Baseline</th>
<th>N2F Base</th>
<th>N3F Col.</th>
<th>N3L Baseline</th>
<th>N4F Base</th>
<th>N4L Col.</th>
<th>N4E Baseline</th>
<th>Total Base</th>
<th>Col.</th>
<th>Analysis of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample size (matched/ETLQ)</strong></td>
<td>24/26</td>
<td>6/6 **</td>
<td>7/8 **</td>
<td>68/75</td>
<td>54/56</td>
<td>39/39</td>
<td>40/49</td>
<td>68/77</td>
<td>32/40</td>
</tr>
<tr>
<td><strong>Intrinsic reasons for choosing degree (LSQ)</strong></td>
<td>3.96</td>
<td>3.70</td>
<td>3.50</td>
<td>4.08</td>
<td>3.88</td>
<td>3.99</td>
<td>3.87</td>
<td>3.88</td>
<td>3.70</td>
</tr>
<tr>
<td><strong>Deep approach prior to unit (LSQ)</strong></td>
<td>3.58</td>
<td>3.45</td>
<td>3.88</td>
<td>3.76</td>
<td>3.72</td>
<td>3.71</td>
<td>3.55</td>
<td>3.64</td>
<td>3.41</td>
</tr>
<tr>
<td><strong>Difference in approaches to studying between those prior to unit and those during unit (matched items and samples from LSQ and ETLQ)</strong></td>
<td>0.23</td>
<td>0.23 - 0.50</td>
<td>-0.22 - 0.11</td>
<td>0.23</td>
<td>-0.09 - 0.12</td>
<td>0.34</td>
<td>0.36</td>
<td>-0.07</td>
<td>0.07 - 0.09</td>
</tr>
<tr>
<td><strong>Surface approach</strong></td>
<td>-0.14</td>
<td>0.11</td>
<td>0.61</td>
<td>0.40</td>
<td>0.31</td>
<td>-0.29</td>
<td>0.05</td>
<td>0.15</td>
<td>-0.49</td>
</tr>
<tr>
<td><strong>Organised effort in studying</strong></td>
<td>-0.13</td>
<td>0.95</td>
<td>0.20</td>
<td>-0.20</td>
<td>-0.19</td>
<td>0.44</td>
<td>-0.16</td>
<td>-0.08</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>Perceived easiness of demands made by unit (ETLQ)</strong></td>
<td>3.65</td>
<td>3.67</td>
<td>3.13</td>
<td>3.41</td>
<td>3.50</td>
<td>3.54</td>
<td>3.73</td>
<td>3.83</td>
<td>3.35</td>
</tr>
<tr>
<td><strong>Knowledge</strong></td>
<td>3.69</td>
<td>3.67</td>
<td>3.75</td>
<td>2.40</td>
<td>255</td>
<td>2.77</td>
<td>3.02</td>
<td>3.34</td>
<td>3.63</td>
</tr>
<tr>
<td><strong>Pace</strong></td>
<td>3.42</td>
<td>3.75</td>
<td>4.06</td>
<td>2.62</td>
<td>2.63</td>
<td>2.78</td>
<td>2.89</td>
<td>3.03</td>
<td>2.99</td>
</tr>
<tr>
<td><strong>Academic difficulty</strong></td>
<td>3.27</td>
<td>3.50</td>
<td>3.88</td>
<td>2.57</td>
<td>2.73</td>
<td>2.72</td>
<td>2.92</td>
<td>3.23</td>
<td>3.30</td>
</tr>
<tr>
<td><strong>Workload</strong></td>
<td>3.60</td>
<td>3.89</td>
<td>4.17</td>
<td>3.32</td>
<td>3.36</td>
<td>3.45</td>
<td>3.31</td>
<td>3.77</td>
<td>3.61</td>
</tr>
<tr>
<td><strong>Generic skills</strong></td>
<td>4.05</td>
<td>3.57</td>
<td>3.78</td>
<td>3.86</td>
<td>3.64</td>
<td>4.01</td>
<td>3.71</td>
<td>3.99</td>
<td>4.47</td>
</tr>
<tr>
<td><strong>Experiences of teaching and learning (ETLQ)</strong></td>
<td>3.44</td>
<td>3.10</td>
<td>2.50</td>
<td>3.17</td>
<td>3.05</td>
<td>3.36</td>
<td>3.39</td>
<td>3.37</td>
<td>3.69</td>
</tr>
<tr>
<td><strong>Clear aims and curricular congruence</strong></td>
<td>3.99</td>
<td>3.53</td>
<td>3.28</td>
<td>3.52</td>
<td>3.28</td>
<td>3.54</td>
<td>3.05</td>
<td>3.52</td>
<td>3.87</td>
</tr>
<tr>
<td><strong>Set work &amp; feedback - clear and supportive</strong></td>
<td>3.94</td>
<td>3.67</td>
<td>3.75</td>
<td>4.13</td>
<td>4.08</td>
<td>3.79</td>
<td>3.98</td>
<td>4.00</td>
<td>4.28</td>
</tr>
<tr>
<td><strong>Assessing understanding &amp; critical thinking</strong></td>
<td>4.10</td>
<td>3.00</td>
<td>3.69</td>
<td>4.10</td>
<td>3.84</td>
<td>4.44</td>
<td>4.24</td>
<td>4.47</td>
<td>4.66</td>
</tr>
<tr>
<td><strong>Staff enthusiasm and support</strong></td>
<td>3.82</td>
<td>4.00</td>
<td>4.38</td>
<td>3.95</td>
<td>3.86</td>
<td>4.21</td>
<td>3.89</td>
<td>4.18</td>
<td>3.96</td>
</tr>
<tr>
<td><strong>Student support</strong></td>
<td>3.92</td>
<td>2.58</td>
<td>3.25</td>
<td>3.03</td>
<td>3.04</td>
<td>3.56</td>
<td>3.05</td>
<td>3.45</td>
<td>4.19</td>
</tr>
<tr>
<td><strong>Knowledge and enjoyment from the course unit</strong></td>
<td>4.01</td>
<td>3.78</td>
<td>3.63</td>
<td>3.63</td>
<td>3.54</td>
<td>3.97</td>
<td>3.62</td>
<td>3.90</td>
<td>4.13</td>
</tr>
<tr>
<td><strong>Knowledge and skills acquired (ETLQ)</strong></td>
<td>3.71</td>
<td>3.89</td>
<td>4.17</td>
<td>3.35</td>
<td>3.26</td>
<td>3.43</td>
<td>3.39</td>
<td>3.57</td>
<td>3.53</td>
</tr>
</tbody>
</table>

** Due to problems in the distribution of the ETLQ in this class, the proportion of the class sampled was unacceptably low and the values must be treated with caution.

Note: To judge the size of the difference scores, note that their overall standard deviations were 0.60 (deep), 0.84 (surface) and 0.81 (organised study) respectively.
Appendix A6

Shortened Experiences of Teaching and Learning Questionnaire (SETLQ)

This questionnaire has been designed to allow you to describe, in a systematic way, your reactions to the course you have been studying and how you have gone about learning it. We will be asking you a series of questions, some of which overlap so as to provide good overall coverage of different experiences. Most of the items are based on comments made by other students. Please respond truthfully, so that your answers will describe your actual ways of studying, and work your way through the questionnaire quite quickly. It is important that you respond to every item, even if that means using the ‘unsure’ category. Your answers will be confidential. Please put a cross in the appropriate box to indicate how strongly you agree with each of the following statements.

1 What do you expect to get from the experience of higher education?

a. I hope the things I learn will help me to develop as a person and broaden my horizons.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

b. I’m focused on the opportunities here for an active social life and/or sport.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

c. I hope the whole experience here will make me more independent and self-confident.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

d. I want to learn things which might let me help people, and/or make a difference in the world.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

e. I want to study the subject in depth by taking interesting and stimulating courses.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

f. I mainly need the qualification to enable me to get a good job when I finish.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

g. When I look back, I sometimes wonder why I ever decided to come here.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

2 Reasons for taking this particular course

a. It’s something I expect to find interesting.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

b. It’s supposed to be a fairly easy course unit.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

c. I thought it would look good on my CV.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

d. It should help me to understand the subject better.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

e. It’s an area I will need to know about for my career.
   
   
   very strongly  fairly strongly  somewhat not sure  rather weakly  very weakly/ not at all

3 Approaches to learning and studying

Next we are interested in the ways you have been going about studying in this particular course. The responses in this section mean

✓ = agree  ✓? = agree somewhat  x? = disagree somewhat  x = disagree

Try not to use ?? = unsure unless you really have to, or if it cannot apply to you or your course unit.

1. I’ve often had trouble in making sense of the things I have to remember.
   
   
   ✓  ✓?  ??  x?  x

2. I’ve been over the work I’ve done to check my reasoning and see that it makes sense.
   
   
   ✓  ✓?  ??  x?  x

3. I have generally put a lot of effort into my studying.
   
   
   ✓  ✓?  ??  x?  x

4. Much of what I’ve learned seems no more than lots of unrelated bits and pieces in my mind.
   
   
   ✓  ✓?  ??  x?  x

5. In making sense of new ideas, I have often related them to practical or real life contexts.
   
   
   ✓  ✓?  ??  x?  x

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<table>
<thead>
<tr>
<th>Experience Area</th>
<th>Question</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4 Experiences of teaching and learning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Aims and congruence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. It was clear to me what I was supposed to learn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. The topics seemed to follow each other in a way</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. What we were taught seemed to match what we</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. The handouts and other materials we were given</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I could see how the set work fitted in with what</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. We were given a good deal of choice over how we</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. We were allowed some choice over what aspects of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. On this unit, I was prompted to think about how</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. The teaching encouraged me to rethink my</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. This unit has given me a sense of what goes on</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. The teaching in this unit helped me to think</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. This unit encouraged me to relate what I learned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. It was clear to me what was expected in the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. I was encouraged to think about how best to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. The feedback given on my work helped me to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Staff gave me the support I needed to help me</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. The feedback given on my set work helped to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. You had really to understand the subject to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. To do well in this course unit, you had to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. Staff tried to share their enthusiasm about the</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Staff enthusiasm and support from both staff and students** | |
| 21. Staff tried to share their enthusiasm about the subject with us.
21. Staff were patient in explaining things which seemed difficult to grasp.
22. Students supported each other and tried to give help when it was needed.
23. Talking with other students helped me to develop my understanding.

Interest and enjoyment generated by the course
24. I found most of what I learned in this course unit really interesting.
25. I enjoyed being involved in this course unit.

5 Demands made by the course unit
In this section, please tell us how easy or difficult you found different aspects of this course unit.

a. What I was expected to know to begin with.
b. The rate at which new material was introduced.
c. The ideas and problems I had to deal with.
d. The skills or technical procedures needed in this subject.
e. The amount of work I was expected to do.
f. Working with other students.
g. Organising and being responsible for my own learning.
h. Communicating knowledge and ideas effectively.
i. Tracking down information for myself.
j. Information technology/computing skills (e.g. WWW, email, word processing).

6 What you learned from this course unit
Now we would like to know how much you feel you have gained from studying this course unit.

a. Knowledge and understanding about the topics covered
b. Ability to think about ideas or to solve problems.
c. Skills or technical procedures specific to the subject.
d. Ability to work with other students.
e. Organising and being responsible for my own learning.
f. Ability to communicate knowledge and ideas effectively.
g. Ability to track down information in this subject area.
h. Information technology/computing skills (e.g. WWW, email, word processing).

Finally, how well do you think you’re doing in this course unit as a whole? Please try to rate yourself objectively, based on any marks, grades or comments you have been given.

Please check back to make sure that you have answered every question.
Thank you very much for spending time completing this questionnaire: it is much appreciated.

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Appendix A7: Experiences of Studying Electronic Engineering Questionnaire

Experiences of studying electronic engineering

These additional questions are based on the work we did with last year’s students on this course unit and so are more specific to the subject you have been studying.

How helpful did you find each of the following in learning and understanding the material you have covered in this course unit?

Please use the seven-point scale to indicate the relative helpfulness of the different aspects.

---

1. The way diagrams were presented and used in the lectures
2. The way ideas and concepts were explained in the lectures
3. The way the lecturer(s) explained how to think about problems
4. Worked examples provided in handouts or on the web
5. Working on the tutorial problems on your own
6. Using your log / tutorial book to think about your own solutions
7. The help given by staff as you worked on the tutorial problems
8. Group discussions with other students on doing the problems
9. Feedback and comments from staff on the work submitted
10. The class tests and the results you were given

---

Please use this box to explain your responses or to make your own comments.

---

If you need more space, please use the back of the sheet.

We are very grateful to you for spending time completing this questionnaire.