Enhancing Learning and Teaching in Electronic Engineering:

A Digest of Research Findings and their Implications

Introduction and Background

The ETL Project is part of the Teaching and Learning Research Programme of the ESRC and was funded to carry out investigations of teaching and learning in four contrasting areas of university education – history, economics, biological sciences and electronic engineering. The four-year project involved working closely with course teams in each subject area and collecting information about students' approaches to studying and learning outcomes in relation to experiences of the teaching-learning environments being provided. In Electronic Engineering we worked with staff in seven course units in three universities and a college, collecting over 1000 questionnaires and interviewing over 150 students. In four of the settings, the analyses of data collected from one year-group were discussed with the course teams and led to *collaborative initiatives* designed to enhance student engagement and learning outcomes in the following year-group. A full report of the work in Electronic Engineering has been made available on both the project and the TLRP websites. Here we provide a brief indication of our main findings and consider their implications for enhancing teaching and learning.

Key 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 distinctive 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 in the subject with the most effective ways of teaching them. This formulation has direct implications for ways of teaching the subject more effectively.
- Many students in second-year analogue course units found 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 commented on their solutions to the problems set.
- Related to the difficulties with analogue was a more general tendency for students to report 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 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 further.
- Students in a new university reported favourably on having a single lecturer responsible for the teaching of analogue electronics throughout the degree course. Although this would be impracticable, or undesirable, in other contexts, the greater perceived continuity, coherence and connectedness in the teaching, along with a strong emphasis on professional applications, enhanced the students' engagement with the subject.

Enhancing Teaching-Learning Environments in Undergraduate Courses Project, Higher and Community Education, School of Education, University of Edinburgh, Paterson's Land, Holyrood Road, Edinburgh EH8 8AQ. Tel: +44 (0)131 651 666, email: etl@ed.ac.uk, URL: http://www.ed.ac.uk/etl

T·L·R·P Teaching & Learning Research Programme

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

The ETL Project as a Whole

The ETL project developed out of earlier research which had explored the link between the approaches to studying adopted by students and their perceptions of the teaching-learning environment provided by the staff. Students not only acquire knowledge directly through the teaching they experience, they are also, indirectly, developing particular ways of learning.

Approaches to learning and studying

Previous research has shown that some of the most important differences in the ways students learn and study involve the approaches they use. The main distinction is between a *deep approach* in which students have the intention to understand and use the learning processes necessary to achieve it, and a *surface approach* where the students' main concern is to complete the set work, but without much personal involvement with the subject.

The other main difference is in terms of the extent to which students are well organised in their study methods, use their time efficiently, and put concentrated effort into their work.

Congruence between aims, teaching and learning

The research into student learning over the last thirty years has increasingly emphasised the importance of seeing the outcomes of learning as the result of an interaction between the characteristics of the students and the whole teaching-learning environment; not just the teaching, but also the assessment procedures, the assignments, as well as the library resources, handouts and web materials that are available. The effects of that environment are not necessarily as the staff may expect because students differ in the ways in which they perceive what is provided.

It is important to set aims which require students to understand, and then to ensure that each aspect of the teaching-learning environment is designed to encourage students to adopt a deep approach. It has been found that even one important element suggesting a surface approach can be enough to undo other more positive influences.

While most course units now are required to list their formal *intended learning outcomes*, our interviews with staff showed that they were more concerned with encouraging students to develop the distinctive *ways of thinking and practising* (WTP), in their subject area, and that intended learning outcomes created too fragmented a picture of what they were trying to achieve.

Research on Electronic Engineering

We were advised to concentrate on one particular area of the subject as far as possible, and chose *analogue electronics* as it was considered to be difficult for students. But we wanted to ensure that evidence was collected across contrasting institutional settings, as well as from course units at different stages of the degree. In electronic engineering we also included a first-year HNC course in a city college to draw attention to the marked variations in electronic engineering taught in contrasting settings.

Contrasts between settings

In the city college, staff were teaching part-time day-release students working in industry, which created an entirely different set of problems. Relevance was demanded and yet difficult to ensure, given the contrasts in the contexts.

In a new university, the majority of students were less well prepared for the subject, and more support from staff was required. In one unit, the teaching of analogue was carried out by a single lecturer, and students had appreciated the continuity and coherence of that experience.

The specialist teaching and the choices provided for students in the research-intensive universities enabled high-level treatment of topics, but with the risk of discontinuity for the students, as the various staff emphasised different aspects and treatments of the subject.

In this project, we were able to demonstrate the value of collecting information from students about their experiences on specific course units in much greater detail than is possible with the usual evaluation forms. The main benefit was that they enabled us to highlight *specific difficulties* that students had encountered. Feeding that information back to the staff enabled us to discuss ways of enhancing student learning in their units.

Students' experiences of teaching and learning

Two questionnaires were designed to obtain detailed information from students about their experiences of the teaching of specific course units and how they were going about their studying.

As anticipated, initial difficulties with analogue were found among many students, who often reported substantially *delayed understanding.*

> 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].

Particularly in the second-year course units, up to a third of the students had experienced more difficulty in understanding analogue than digital. The main reasons given by students were the pace of lectures, the content being found rather boring, the demotivating effects of failing to arrive at correct solutions to tutorial examples, and needing more individual help with these difficulties.

> At the beginning I was all [at sea],… there was too much information at one time… We were given too many different concepts [in quick succession]… Once we'd gone over one specific network we weren't really given enough time to absorb it before we were given another one.

The difficulties reported in the specific units were not the same, but if any one of these aspects attracted low ratings from students, their progress in the subject was affected. There also appeared to be differences between year-groups of students, with even highly-rated teaching failing to achieve good results among students with negative attitudes that had developed earlier in the degree.

Attitudes to studying analogue

It was clear that the attitudes of a substantial proportion of students had been affected by the perceived difficulty of the subject. These students were using surface approaches because they felt they were not getting good results from the effort they had originally put into the work.

> You have to focus your energy where it's rewarded … You work through the problems and for the analogue ones, you don't get any answers out of them … I knew if I just followed these steps, then I could get an answer, but still have no idea what to do, yet scrape by. We probably would have got great marks had we actually understood what we were doing.

The collaborative initiative

From the information collected from students, discussions with staff led to a collaborative initiative designed to enhance student learning in each unit. It was decided that a deep approach to analogue could be strengthened in several ways – by putting more emphasis on demonstrating the processes of problem-solving during lectures, by encouraging discussions in tutorials, and by getting students to use a *tutorial workbook*. The idea was not just to ensure that students kept their solutions together in a systematic way, but also to encourage written comments on where they had gone wrong and what they should have done.

Results of the collaborative initiative

Where students had used the tutorial workbook as intended, they had found it valuable for revision work, and were more aware of the need to work systematically. The fact that tutors could easily see how many examples they had completed and look at the comments they had made, seemed to affect their attitudes to the work.

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

Enhancing Teaching and Learning in Electronic Engineering

Our discussions with staff and students led us to believe that we could identify a distinctive way of teaching in electronic engineering which reflected the ways of thinking and practising which staff expected students to acquire. It seemed, then, that there was an *inner logic of the subject and its pedagogy* which made certain ways of teaching, and specific learning activities, essential. Enhancing the overall teaching of electronic engineering would thus depend on identifying these distinctive ways of thinking and then finding better ways of teaching them and of supporting students.

The interviews with staff, together with the literature on teaching electronic engineering, enabled us to list what seemed to be the main WTPs, while discussing the students' experiences of teaching with staff helped us to identify a logical sequence which would support those ways of thinking.

Distinctive ways of thinking in analogue

- Appreciating the function of the circuit
- Identifying and integrating previous concepts
- Recognising salient groups of components
- Thinking logically about the circuit analysis
- Developing analytic tools for solutions
- Building up a memory bank of examples
- Thinking intuitively in designing new circuits

Teaching to encourage learning

- Create interest through professional links
- Show enthusiasm for analogue and its value
- Focus the course aims on understanding
- Explain the function of the circuit carefully
- Identify the main circuit groupings clearly
- Think out loud while working out examples
- Set tutorial problems graded in difficulty
- Provide worked examples with explanations
- Get students to use tutorial workbooks
- Encourage students to discuss problems
- Check individual progress regularly

How to help students learn analogue more easily

The project carried out an extensive review of the literature on teaching and learning in engineering and related disciplines. Combining these with the comments from students on what they had found particularly helpful in supporting their learning, we came up with the following suggestions. Most of these aspects do reflect current teaching practice, but we have stressed those which seem to be the best ways of supporting the main WTPs expected. The starting point has to be imagining what it is like not to understand the topic and think carefully about how to present it to students in that light.

◆ *Create interest through professional links*

Most of the students we talked to had a clear vocational aspiration to become electronic engineers and so they appreciated any links that were made between academic content and professional work. Anecdotes and examples brought the academic content to life in ways that reinforced the students' vocational commitment.

◆ *Show enthusiasm for analogue and its value*

Unless students believe that the lecturer is enthusiastic about what is being taught, they readily lose interest. Feedback from students stresses the importance in lecturing of seven main features: clarity, level, pace, and structure, with explanation, enthusiasm and empathy being the aspects most likely to encourage a deep approach to learning.

◆ *Focus course aims on understanding*

As students so readily revert to a surface approach in analogue, it is important regularly to explain why understanding is essential if they are to be effective electronic engineers. A checklist of the main aspects of the course that have to be understood helps the students to focus on understanding, as do explanations about how assessment tasks will test that understanding.

◆ *Explain the function of the circuit carefully*

The emphasis on understanding can be reinforced by careful explanations not just of the function of a circuit in theoretical terms, but also by mentioning its practical applications. Keep the language you use in the explanations as simple as possible

◆ *Identify the main circuit groupings clearly*

Students may find it difficult to follow explanations related to circuits shown on overheads, so overlays help to highlight specific groups of components. Alternatively, PowerPoint can be used to highlight specific groups of components successively. Explaining the logical progression in the analysis of the circuit in advance, and then bringing it out at each step, can be particularly helpful to students.

◆ *Think out loud while working out examples*

One of the most powerful ways of developing problem-solving skills is to explain your own thinking out loud as you work through problems. But keep it simple. Students find explanations that are expressed in complex language confusing, and prefer the simplest solution strategy. Such strategies are valuable in the early stages, even though they have to be superseded later on.

◆ *Set tutorial problems graded in difficulty*

Because of the strong feelings students have about initial failure when tackling problems, it is important to provide sufficient easy examples to start with, and then provide groups of examples, graded in difficulty. Encourage students to move on to the next level of problem once they feel sufficiently confident of their success in earlier ones.

◆ *Provide worked examples with explanations*

Although some staff are reluctant to provide worked examples in case it encourages mindless copying, in our study, most students used the examples to check their workings, and this proved an essential way of supporting their learning. Providing ongoing explanations within examples also helped, with an on-line tutorial which included step-by-step prompts being particularly effective.

◆ *Get students to use tutorial workbooks*

Left to their own devices, students are often disorganised in working on tutorial problems. The use of a tutorial workbook brings the solutions together, while encouraging students to note down any difficulties they encountered and how they were resolved forces them to think more deeply about solution strategies. Students also find their workbooks particularly helpful during revision.

◆ *Encourage students to discuss problems*

Students commented on how useful informal working groups had proved in tackling tutorial examples, suggesting that more systematic arrangements for collaborative working on problems might be well worth exploring. This approach has proved valuable in other subjects.

◆ *Check individual progress regularly*

Students criticised the lack of feedback on their work. Staff looking at workbooks during tutorials encourages students to do the examples, while periodic short tests, or required pieces of course work, will make students aware of any misunderstandings and encourage more responsible study methods.