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Ways of thinking and ways of teaching across contrasting subject areas

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Introduction

The ETL project is within the nationwide Teaching and Learning Programme of the ESRC (www.tlrp.org) and has been investigating ways of 'Enhancing Teaching-Learning Environments in Undergraduate Courses' (ETL project) in four main subject areas – Electronic Engineering, Biological Sciences, Economics, History and, for the first phase only, Media Studies – chosen as popular undergraduate subjects with large intakes. In the programme as a whole, there has been an emphasis on ensuring that the research is conducted, as far as possible, in collaboration with the potential users of the research findings – in our case mainly the academic staff involved in teaching. We have sought to involve staff in the progress of the research, firstly through detailed feedback on students reports about their ways of studying and experiences of teaching and learning in chosen course units, and then in discussing with them possible ways of enhancing that teaching-learning experience to encourage more effective learning outcomes.

The term 'enhancing' was deliberately chosen to avoid the feeling that we any preconceived concern about the general level of university teaching, or teaching within these specific areas. Rather, our intention has been to work with teaching staff who are already providing good experiences for students, to see what makes them effective in that particular subject area, and to provide more detailed feedback from students to see whether those strong teaching-learning environments could be further enhanced. The feedback provided to the teaching staff offered 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. This paper will present a brief outline of the project as whole, indicating the research design, conceptualisation, and emerging findings. These descriptions will be brief as detailed reports are accumulating in published articles (McCune & Hounsell, 2005; Anderson & Day, 2005), and extensive reports for each subject area are being provided on the project website (www.ed.ac.uk/etl). The project is so wide-ranging that no single paper can do justice to the four subject areas together: this paper thus uses Electronic Engineering to illustrate the type of analyses that have been carried out and how conclusions have converged from different sources of data.

Research design

The project was conceived in terms of three main phases – preliminary, main and dissemination – and began in 2001. The preliminary phase, lasting about a year, involved an extensive review of the general literature on teaching and learning in the subject areas chosen, and the development of an initial conceptual framework, but also detailed analyses, in each subject area, of the published Teaching Quality Assessment or QAA Reports on eight departments rated as 'excellent' and selected from the full range of universities. As these reports were stronger in their justification of the grades awarded than in their explanations of what, specifically, was excellent about their teaching, telephone interviews were conducted with around four members of staff in half those departments who were substantially involved in organising and delivering undergraduate degree programmes. Analysis of these interviews provided a much better indication of the range of teaching methods and learning activities being used, and immediately made clear the wide variety of settings we had to cover. It also indicated what the main educational aims of staff in these departments were for their students. These analyses, along with an extensive review of the nature of undergraduate teaching-learning environments, and ways of evaluating them, helped us to design the questionnaires which represented one of the main data sources in the ETL project.

The main phase began in the 2001-02 academic session with pilot work involving the development and testing of two questionnaires – the *Learning and Studying Questionnaire (LSQ)* and the *Experiences of Teaching and Learning Questionnaire (ETLQ).* The early part of the main phase also involved discussing with our Subject Advisers (experts drawn from the five subject areas) our choice of departments to approach. After that, discussions were held in those departments and arrangements were made with selected teaching staff to work with the project for up to two years. The first year of the collaboration involved interviews and discussions with staff in the selected course units, usually one in the first (or second) year, and one in the third or fourth year.

During lectures or practical sessions early in the course unit, students were asked to complete the LSQ, which covered their reasons for being at university and for choosing the course unit. They then completed a set of items indicating the ways in which they were currently approaching their studying in the degree course as whole and, finally, a self-rating on their academic performance until then. Towards the end of the course unit the students were asked to complete the ETLQ that contained items relating to the demands being made on them in the course unit, an abbreviated version on approaches to studying but specifically focused on work within the unit, a set of items rating the teaching-learning activities they had experienced, and self-ratings of the extent to which their knowledge and skills had improved through the unit, and a further rating of their academic progress, this time on the unit itself. Additional information about students' experiences of the unit were obtained from series of small-group interviews that focused on the areas covered in the ETLQ, and on the project's research questions, but also on any additional issues raised by the students themselves. Where possible, the grades awarded for the unit by the department were also collected.

As the collaboration with the departments was quite lengthy, we were dependent on the goodwill of departments, staff and students, and the quality of the collaboration largely determined the extent to which the project could successfully meet the requirements of the research design. Given that there was a range of differing reasons for staff agreeing to be involved in the project, the extent of commitment was similarly variable, but in most of our settings the commitment was wholehearted, even within the severe time constraints currently affecting all university staff. Indeed, where the members of staff became particularly interested in the research, the problem became our own limited time, particularly for travelling, that restricted the degree of involvement some staff would have welcomed.

The final phase of the project is still ongoing and involves more extensive dissemination of the findings to the potential users of the findings. Besides the usual conference presentations, this involves the preparation of two *Research Briefings* through the TLRP offices, one for educational developers and one for academic managers. As our main audiences are within the subject areas, we are also preparing a *Research Digest* for each subject area, and workshops and seminars have been arranged through the relevant Subject Centres of the Higher Education Academy and/or subject organisations. Finally, the project will be producing a general book summarising the project as a whole, within the TLRP *Gateway Series.*

Conceptual frameworks

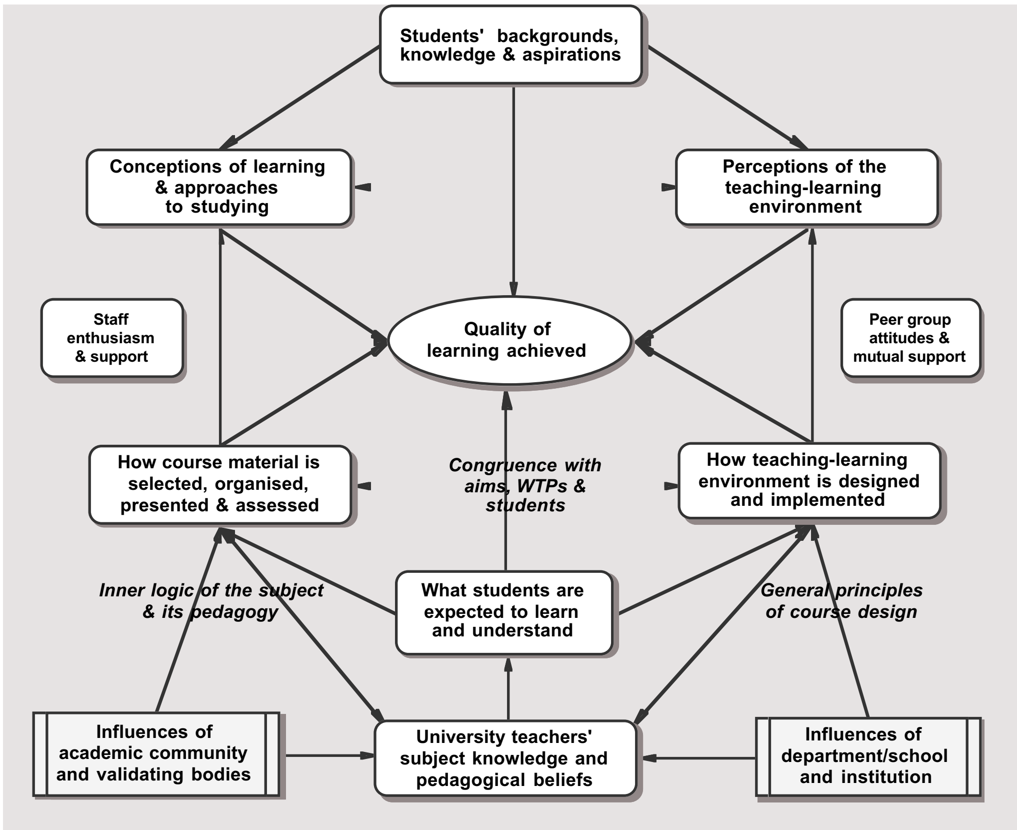
The development of the conceptual framework has been assisted through the involvement of our International Consultants, Professor Emeritus John Biggs from Australia and Professor David Perkins from Harvard Graduate School of Education. The conceptual framing of our research proposal relied substantially on the notion of *constructive alignment* (Biggs, 1996), which, in turn, drew on the earlier work leading up to the *Teaching for Understanding* framework introduced by Perkins and his colleagues to use in school teaching (Wiske, 1998). The wider framing of the proposal was based on the more general discussions of teaching-learning environments as *systems* within which the prior characteristics of students interact with their experiences of teaching, learning and assessment (Biggs, 1993; Entwistle, 1987, 1998).

The early stages of the project used the notion of *constructive alignment* to consider the links between aims and the teaching and learning environments provided. We asked staff what were the primary aims of their teaching in both in their discipline generally and in our target course unit. We then considered the way staff described their units and students' reactions to their experiences in relation to the idea of encouraging *deep approaches* to learning through the type of constructivist approaches to teaching and learning that accumulating evidence has suggested encourage the development of conceptual understanding (Prosser & Trigwell, 1999; Ramsden, 2003). From the literature, we identified the aspects of general teaching-learning environments which seemed most important in providing support for the broad aims that staff had indicated, and incorporated these ideas as scales within *ETLQ*. From the analyses of the pilot work, we decided that conceptual understanding was only part of what was involved, and that a more complete way of describing the commonality of staff aims was *ways of thinking and practising in the discipline,* shortened to WTPs in our discussions. McCune and Hounsell (2005) have described WTPs in terms of

> *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… WTP can potentially encompass anything that students learn which helps them to develop a sense of what it might mean to be part of a particular disciplinary community… We are using the notion of WTP to enhance our understanding of high-quality learning as understood and experienced by staff and students in particular contexts. By building up a richer picture of the kinds of learning sought in each setting, we will be better placed to consider the strengths and weaknesses of each teaching–learning environment. (McCune & Hounsell, 2005, p. 257-8)*

These, then, were some of the most important ideas used to frame our analyses of the data subsequently collected, along with the other concepts included in a general conceptual framework. This is shown in Figure 1 and described in outline below: further details can be found on the project web site (Entwistle, 2003). At the centre is the quality of the learning achieved, with the remaining concepts forming part of an explanation of the interaction between student characteristics, shown in the top half of the conceptual map, and the teaching-learning activities and staff involvement indicated towards the bottom of the diagram.

Figure 1 A general conceptual framework for the ETL project



Student characteristics are defined in terms of what students bring to the learning, including their existing knowledge and aspirations, as well as the whole gamut of their individual background and prior experiences. One line of research on student learning has concentrated on describing conceptions of knowledge and learning, and how these relate to approaches to studying (Vermunt & Vermetten, 2004; Entwistle, in press), while the relationships of these to background characteristics to conceptions and study strategies have also been demonstrated empirically (Vermunt, 2005). Earlier research had already indicated the close links between approaches to studying and perceptions of teaching (Entwistle & Ramsden, 1983; Meyer, 1991), and this inter-relationship has recently been explored further (Richardson, 2005). Evidence of the associations of both approaches and perceptions with the quality of learning achieved has been summarised by several authors, including Ramsden (2003). Between the two halves of the diagram, evidence from the ETL project justifies the separate identification of the encouragement and support for learning provided by staff, on the left, and peer group attitudes and the mutual support of the students in the class, on the right.

The bottom half indicates three general concepts (without boxes) used in the ETL project for thinking about the teaching-learning system as a whole. The idea of *congruence* of teaching-learning activities with aims comes directly from the description of constructive alignment, but the new term has been introduced both to avoid the linearity of relationship implied by the term 'alignment' and to recognise the need to ensure linkage with the aspirations of students as well as the aims of staff. This version of the conceptual map also divides the teaching-learning environment into those aspects that are more directly related to the teaching of the subject content (on the left) from those that are influenced more by *general principles of course design*. Although the two aspects overlap substantially, one advantage in making the separation is to bring out the link between the nature of the discipline and the methods of teaching adopted, through the notion of an *inner logic of the subject and its pedagogy.* The connections shown between the approaches to teaching and approaches to studying have been demonstrated empirically (Trigwell & Prosser, 2004), but the other links shown are more conceptual and inferential than directly empirical (Entwistle & Walker, 2002; Hativa & Goodyear, 2002).

The remaining boxes, bottom left and bottom right, are included to keep in mind some of the broader influences on student learning. In the subject areas there is a wealth of tradition affecting the ways these subjects are taught at university level, and in the professional areas validating bodies retain a strong influence. Within the institution and school or department, there are decisions about resource and room allocation, timetabling, and assessment procedures that all constrain, as well as support, the teaching-learning activities that staff can choose in implementing their course designs.

Samples and data collection in the main phase of the study

The data collected were designed to enable us to understand the nature of the discipline as described by both staff and students, the aims of the staff in designing each course unit in our sample, the content of the unit, the methods of teaching and assessment, as well as the various forms of support for learning, students' perceptions of the teaching-learning environment they experienced, their reasons for being at university and choosing the unit, their approaches to studying both before and during the target course unit, and their self-ratings of their increasing in knowledge and skills. We collected all the relevant documentation relating to the course unit, including examples of handouts to students, interviewed staff and groups of students, and asked students to complete our two questionnaires, the SLQ at the beginning of the unit and the ETLQ at the end. Local logistical factors determined the timing and context for questionnaires to be completed during various teaching sessions, but these provided few, if any, opportunities for following-up non-attenders. As a result, the SLQ and ETLQ samples were by no means identical and where the complete data set was being analysed the sample sizes were reduced. Table 1 indicates the samples obtained, while Table 2 shows the main scales derived from the questionnaires, as well as certain individual items chosen for the analyses. Details of scale development work, alpha reliabilities, and listings of scale items can be found on the web site.

All the individual interviews with staff were recorded and transcribed when members of staff were happy with this procedure. Where recording was not possible, full notes were taken. The group interviews with students were all recorded (with the groups' permission) and transcribed. The interviews were guided by a set of broad issues to be covered, but the interviews were allowed to flow freely to ensure that all aspects of importance to the respondents were covered. The interview analyses sought to identify the main themes being discussed and to group reponses under those categories. Summary reports were then produced, integrating the qualitative and quantitative analyses, to provide feedback to the staff and a stimulus for discussions about possible collaborative initiatives.

Table 1 Samples of respondents completing questionnaires and attending interviews

	Biology	Economics	Engineering	History	Media	Total
Number of units	6	7	8	6	4	31
Students						
LSQ	939	1084	623	882	250	**3778**
ETLQ	887	580	417	742	84	**2710**
Complete data	564	453	365	514	54	**1950**
Interviewed	117	263	104	166	18	**668**
(in groups of 2-6)						
Staff						
Interviewed	32	25	13	19	1	**90**

Analyses of the questionnaire data

The questionnaire data were analysed in various ways, including means and standard deviations of scale scores and also the percentage agreement with individual items. The main purpose of these analyses of each individual course unit was to provide indicative feedback to the course teams, rather than statistical significance in statistical tests (given the variable nature of the sampling). The quantitative and the qualitative analyses were brought together, looking for convergent trends in the conclusions being reached, which could then be discussed with the course teams for each of the units included. Towards the end of the project, the complete set of unit reports in each subject area, from both the baseline and the collaborative years, were brought together and to provide the *Subject Area Research Briefings* that will be found on the project website.

Other analyses of the questionnaires also looked across the units to examine similarities and differences among the four subject areas. The relationships between the scales, along with a selection of individual items, were investigated initially through factor analyses (maximum likelihood with rotation to simple structure), with differing combinations of variables and several solutions for each before choosing the ones which represented the best balance between explaining variance and obtaining a clear and informative factor pattern. These factor analyses were carried out for the whole sample and also for each of the four subject areas. Other multivariate analyses have been planned, but are yet to be carried out.

Here, we report the factor structure for the whole sample with complete data and comment on the extent to which analyses of the separate subject areas were similar or different. After that we use the example of electronic engineering to illustrate some of the ways in which the data were used within course units to suggest, implement and evaluate collaborative initiatives.

Of particular interest in the analyses are the links between the students' reactions to the course unit and any changes in their approaches to studying and the self-rated learning outcomes. Factor I shows a link between the whole set of experiences of teaching and learning (describing what were taken to be constructivist approaches to providing a teaching-learning environment) and, importantly, shows much higher loadings on deep approach during the unit than in that approach previously. It also includes substantial loadings on the self-ratings of knowledge and skills acquired during the unit. Factor II describes the deep approach itself both prior to and during the unit with links to intrinsic reasons for attending

Table 2 **Maximum likelihood factor analysis of questionnaire scales for whole sample**

Scales and individual items (*) (N = 1950) — Factors	I *Exper Teach*	II *Deep App*	III *Surf App*	IV *Org Effort*	V *Acad Self-Conf*	VI *Inter Enjoy*	VII *Generic Skills*
Reasons for attending university							
Intrinsic reasons related to content		**.40**					
Lack of purpose now experienced *			**.43**				
Reasons for choosing the unit							
Expected level of interest *						**.40**	
Expected easiness *					.25		
Approaches to studying prior to unit							
Deep approach to learning		**.80**					
Surface approach to learning			**.77**				
Organised effort				**.60**			
Approaches to studying during the unit							
Deep approach to learning	.30	**.44**		.26			
Surface approach to learning	- .21		**.52**				
Organised effort				**1.06**			
Lack of difficulty in the demands made by unit							
Prior knowledge required *					**.47**		
Pace at which new material introduced *					**.65**		
Academic difficulty of the material					**.70**		
Workload experienced *					**.55**		
Generic skills required					.34		**.50**
Experiences of teaching and learning in the unit							
Aims and congruence of unit	**.60**						
Choice allowed	**.44**						
Teaching for understanding	**.58**	.21					
Set work and feedback	**.68**						
Assessing understanding	.36				- .28		
Staff enthusiasm and support	**.56**						
Student mutual support for learning							.29
Interest and enjoyment from the unit	.28					**.72**	
Learning outcomes							
Self-rating of academic progress prior *			-.34				
Self-rating of academic progress during *					.35		
Knowledge and skills acquired during	.33						.23
Generic skills acquired during the unit							**.68**

7 factors explained 57.9% of variance. Loadings below /.20/ omitted. Loadings of .40 and above in bold university. This factor also loads on one particular aspect of the students' experiences – teaching for understanding - the meaning of which can be deduced from the items listed below in Table 3.

Factor I suggests that descriptions of good experiences of teaching, generally, are linked with high scores on the deep approach adopted in the unit. An earlier ETL analysis, which focused specifically on changes in deep and surface approaches, showed deep approaches increasing and surface approaches decreasing, in association with high ratings of constructivist teaching, perceptions of easy pace and knowledge demands, and higher levels of self-rated learning outcomes (Entwistle, Nisbet & Bromage, in press). The loadings on Factor II indicates that a consistent deep approach (before and during the unit) is related specifically to 'teaching for understanding'. In much earlier research, it had already been established that deep or surface approaches are, not surprisingly, linked to preferences for teaching designed to encourage that particular approach (Entwistle & Tait, 1990).

Table 3 Items making up three of the scales describing experiences of teaching

Aims and congruence

- It was clear to me what I was supposed to learn in this course
- The topics seemed to follow each other in a way that made sense to me.
- What we were taught seemed to match what we were supposed to learn
- The handouts and other materials we were given helped me to understand the unit.
- I could see how the set work fitted in with what we were supposed to learn

Teaching for understanding

- On this unit I was prompted to think about how well I was learning and how I might improve.
- The teaching encouraged me to rethink my understanding of some aspects of the subject.

* This unit has given me a sense of what goes on 'behind the scenes' in this subject area.

- The teaching in this unit helped me to think about the evidence underpinning different views.
- This unit encouraged me to relate what I learned to issues in the wider world.

Set work and feedback

- It was clear to me what was expected in the assessed work for this course unit.
- I was encouraged to think about how best to tackle the set work.
- 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 course unit.
- The feedback given on my set work helped to clarify things I hadn't fully understood

Factor III describes the surface approach and also lack of purpose - "When I look back, I sometimes wonder why I ever decided to come here". Factor IV focuses almost exclusively on *organised effort,* made up of items combining study organisation, time management, effort and concentration, with an additional indication of deep approach. Factor V is defined by the set of items that describe the perceived easiness of the demands made by the unit, and is linked with expectations that the unit would be easy and self-ratings of high levels of actual performance (based on the grades awarded up to that point). This factor seems to indicate self-confidence rooted in prior performance and ability. The last two factors are quite specific to particular aspects - Factor VI to interest in the subject matter and enjoyment of the unit and Factor VII to feeling confident about generic skills and comfortable with working collaboratively with other students.

Although the loadings on the factors gives some indication of the relationships between the scales and items included in the analysis, the search for simple structure involves reducing the influence of scales not strongly involved in the definition of the factor, and as factors are themselves are related, we need also to look at the correlations between the factors (Table 4). The pattern of correlations indicates that Factor I (Experiences of [constructivist] teaching) has substantial associations with interest and generic skills. Deep approach has similarly strong relationships with organised effort and interest, while surface approach is negatively correlated with organised effort and generic skills (which includes collaborative working). Organised effort is also linked with this combination of generic skills and collaborative working.

Table 4 Inter-correlations between the factors for the total sample

Factors		*Deep*	*Surface*	*Org Eff*	*Self-conf*	*Interest*	*Gen skills*
I	***Experiences of teaching***	.21	-. 16	.28	.16	.40	.41
II	***Deep approach***	. —	- .25	.38	.02	.33	.24
III	***Surface approach***		. —	-. 33	.08	- .30	- .12
IV	***Organised effort***			. —	.13	.28	.38
V	***Academic self-confidence***				. —	.17	.11
VI	***Interest and enjoyment***					. —	.25
VII	***Generic skills & collaboration***						. —

Table 5 (below) shows that the patterns of loadings for the first three factors are closely similar across all four subject areas, and that is also true for the remaining factors. The only notable variations show the loadings on self-rating of knowledge and skills, for both engineering and economics, to be much higher on experiences of teaching than in the overall sample, while being negligible for history. Engineering and economics do not include deep approach in the first factor, although engineering brings in a negative loading on the surface approach. It should be borne in mind, however, that any differences in loadings on the factors across the subject areas also affects the relationships between them, and thus makes it difficult to be sure about the size of underlying relationships, although the patterns remain clear.

Analyses within subject areas illustrated from analogue electronics in engineering

In electronic engineering, we decided to concentrate on one part of the subject area – analogue electronics – that was described by our Subject Adviser as being both important and difficult. All but one of our seven settings involved analogue, and five of these were taught in quite similar ways. Two of these units were final-year units that, for various reasons, were not continued into the collaborative phase of the project, but the remaining three 2nd and 3rd year classes were similar in content, but sufficiently different in the settings, to provide valuable comparisons.

Table 5 Comparison of two factors across subject areas

Subject Area (Sample size)	**Engineering** (N =365)			**Biology (**564)			**Economics** (453)			**History** (514)		
Factors	*Teach*	*Deep*	*Surf*	*Teach*	*Deep*	*Surf*	*Teach*	*Deep*	*Surf*	*Teach*	*Deep*	*Sur*
Scales and items												
Reasons for attending university												
Intrinsic reasons related to content					**.51**			.22			.38	
Lack of purpose now experienced			**.62**			.36			.32			.28
Approaches to studying prior to unit												
Deep approach to learning		**.54**			**.80**			**.43**			**.92**	
Surface approach to learning		- .22	**.76**			**.84**			**.63**			**.76**
Organised effort					.22						.23	
Approaches to studying during the unit												
Deep approach to learning		**.75**		.26	**.53**			**.96**		.22	.33	
Surface approach to learning	- .36	**- .42**	**.40**			**.46**		- .24	**.67**			**.58**
Organised effort								.21				
Experiences of teaching and learning in the unit												
Aims and congruence of unit	**.75**			**.53**			**.59**			**.59**		
Teaching for understanding	**.58**	.27		**.63**	.23		**.63**	.25		**.55**		
Set work and feedback	**.55**			**.55**			**.61**			**.69**		
Staff enthusiasm and support	**.64**			**.51**			**.73**			**.53**		
Learning outcomes												
Self-rating of academic progress prior			- .32						- .33			- .25
Self-rating of academic progress during	.29	.26					.30		- .24			- .33
Knowledge and skills acquired during	**.60**	.21		.33			.59					
Percentage of variance explained from 7 factors		*59.6%*			*58.4%*			*59.8%*			*58.3%*	

The first step in the analyses was to use the interviews with staff, and with MEng students taking the MEng, just after completing the undergraduate degree, to decide what were the main ways of thinking and practising that were required of students in this part of the subject area. Subsequent analyses of both interviews and questionnaires showed that students had concerns about some of their experiences, but were equally clear that there were particular aspects of the teaching that they found essential in helping them to learn. We thus concentrated on trying to decide what it was that proved difficult and what teaching-learning activities would best help students to learn analogue more effectively.

Ways of thinking and practising in analogue electronics

The main focus of the three course units was on explaining the nature and functions of a range of analogue circuits and how the outputs of such circuits could be determined through circuit analysis, which generally involved finding ways of simplifying the circuits through 'transforms' and then using appropriate laws (such as Ohm's law) to set up simultaneous equations which could then be solved algebraically. One of the obvious difficulties for students lies in the fact that they have to deal with a series of different representations and intellectual processes – of the functions of the circuit within electronic devices, of the physical set up of components within a circuit, seeing the functions of various parts of the overall circuits in terms of the physics, recognising what transforms are appropriate for that type of circuit, applying the transforms, using the laws appropriately to set up the equations, and then solving the equations to determine the output values. Analogue also involves using a variety of concepts drawn from other course units and integrating them as they try to understand this part of the subject area.

Staff and the more experienced students were clear that there were distinctive ways of thinking about analogue circuits that differed in some important ways from thinking about digital circuits.

> *Analogue just doesn't come naturally to most people… Many of the concepts are mind-boggling. 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 - 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 you are talking plus or minus 50%. 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 <u>huge</u> variation behind them. So, instead, it's more important to have … a conceptual, intuitive understanding of what's going on. [Final year lecturer]*

> *I think first of all you've got to understand what devices do… First look at the circuit and understand what it does - just roughly and then do the maths and work it out… I think it was not doing it mathematically, but trying to intuitively understand it first of all [that was difficult]. Say, if you increase voltage here, what will happen?… [In the second year] you didn't really understand it intuitively… 'cause you do need the experience, [and it only] comes with time…. A lot of this stuff doesn't fall into place until … even now, you know, you're slowly, like working on it. (MEng student)*

Table 6 summarises what came to be seen as the main WTPs for analogue electronics within our electronic engineering course units, representing the target skills and understanding that staff were expecting of students, with some difference in balance between the early part of the degree programme and later on,

Table 6 Ways of thinking and practising in analogue

- Appreciating the overall function of a circuit
- Recognising the crucial groups of components
- Seeing how to set about analysing different circuits
- Having the necessary analytic tools for solutions
- Developing a memory bank of contrasting examples
- Thinking intuitively about designing new circuits

when intuitive thinking became more feasible with experience and as the tasks involved designing circuits as well as analysing them.

Effects of differing teaching–learning environments on approaches to learning

Having established in general terms what WTPs were involved in the analogue courses, we then explored through both questionnaires and interviews how students reacted to their experiences in the three contrasting units mentioned above. Table 7 provides indicative evidence of changes in approaches to learning from before the unit to during the unit (for clarity's sake, shown in terms of percentage agreement with defining items, although patterns for the scale means were similar).

In all three units, the responses to the defining item of deep approach (as well as the scale means) suggested that students were less likely to adopt a deep approach during the analogue work than in their previous studies, and that the tendency was particularly marked in Unit A. Students also indicated that they were putting less effort into their work. In Units A and B, students showed evidence of an increased surface approach along with less well organised studying; but in Unit C the surface approach decreased while study organisation remained much the same. In the interviews, students explained their changed

Table 7 Changes in approaches to studying from before the unit to during it

	Percentage agreement with items before and during units			
	Course unit	A (94)	B (68)	C (54)
I usually set out to understand	*Before*	95.6	87.5	81.2
	During	**72.1**	**82.5**	**75.0**
Trouble making sense of things	*Before*	25.0	40.0	43.7
	During	**61.8**	**55.0**	**34.4**
Generally put a lot of effort in	*Before*	60.3	77.5	53.1
	During	**51.5**	**60.0**	**40.6**
Systematic and organised study	*Before*	65.9	62.5	46.9
	During	**44.1**	**47.5**	**50.0**

approaches in terms of having failed to understand the early material and getting problems wrong, leading them to transfer their effort to units that were proving more rewarding.

> *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 again. [In analogue], it's all built on what you've done before, so hardly ever will the topics that we do in analogue be totally distinct. One just builds on the other, so you really need to understand every topic really well if you are to understand the next one at all. Which means if you don't understand any in the middle, it can be quite difficult because there is a lot of gaps if you don't understand everything… Because of the understanding that you have got to have to get it, if you don't understand it then you're completely stuck.* (3rd year student)

> *Everything was priority for me except [analogue]. I felt, you know, especially the way the marks worked, and as long as you passed all the courses overall, then you passed the year. And so it came to the point where I just had to say right analogue's going on the backburner and when I've got time to revise it I will, but it's more important for me to do well in the other courses so I get into [the next] year.* (2nd year student)

So, from the students' perspective, what differences were there between the three course units? Table 8 makes it clear that students in Unit C (where the surface approach decreased markedly) rated this unit much more favourably in terms of pace, workload, congruence of teaching with learning and interest, than did students in the other two units. The pace was particularly problematic for students in Unit A, although the feedback in this unit was rated more highly than in the other units. Unit A was perceived as more interesting than Unit B and there was more satisfaction with the number of worked examples provided.

> *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… If you hadn't taken the first couple of steps, it was harder to grasp the more difficult ones. Plenty of examples were given along with patient explanations. The pace with which new material was presented was seen as problematic particularly in Unit A, although the feedback was appreciated much more. Interest was not generated all that strongly in either Unit A or B, with B showing the lower level. (2nd year)*

Table 8 Experiences of the teaching-learning environments

Percentage agreement with items for the same three units

Course unit	A (94)	B (68)	C (54)
Easy pace in lectures	25.3	46.9	72.5
Amount of work required was easy	33.3	34.7	52.5
Teaching fitted in with learning	72.0	67.3	97.5
Most of material was interesting	45.3	34.7	82.5
Plenty of examples were provided	66.7	51.0	95.0
Staff were patient in explaining	81.3	81.6	92.5
Feedback given made things clearer	63.7	30.6	47.5

Comments from several of the students indicated that they felt that understanding came only some time after the ideas had been introduced in lectures. While that is, no doubt, a fairly common experience in studying at university, the extent of the delay in electronic engineering seemed to be unusual. Scheja (2001) introduced the term *delayed understanding* to describe what he had found in an interview study of the same subject area in Sweden, and as a student in our study commented:

> *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]… When you're being taught something, you're just desperately trying to learn it, and there's not necessarily a whole lot of interest. You're scrambling back to notes [in preparing for the exams], trying to understand the course. [Later on], you do get interested and [then] things start to fall into place. (3rd year student)*

A collaborative initiative designed to support a deep approach to problem-solving

In considering the possibilities for collaborative initiatives, it was realised that only relative minor changes could be implemented within the timescale and the formal procedures involved in making any substantial changes in the syllabus or teaching arrangements. The analyses had suggested that a general problem in analogue electronics was that too many students were relying on surface approaches to learning in tackling the set problems although these were seen by staff and students alike to be central to understanding analogue electronics. It was thus decided to seek ways of encouraging a deep approach more directly, in particular by encouraging students to become more reflective about the process of problem-solving in analogue by making comments in a 'logbook' in which the workings on the problems were to be systematically shown. Staff were also asked to stress in lectures the need to think about the process and, where arrangements made it possible, to encourage discussions of problem-solving strategies in student groups.

This collaborative initiative was agreed for all three of the units described above but, in the event, illness led to its implementation being delayed in Unit A, while changed teaching arrangements caused it to be discontinued in Unit B and taught by a different and more inexperienced lecturer in the other unit. The idea of the 'logbook' was introduced in Unit C, although with differential emphasis being given to its use by the four tutorial assistants employed. For the collaborative initiative, an additional set of items was included in ETLQ that asked specifically about the aspects of teaching and learning in analogue that students had identified as important in the previous year of the project; it also included elements directly relevant to the collaborative initiative. Students' reponses to these items are shown in Table 9.

The use of log-books was the main innovation introduced and it was hardly surprising that students rated that activity highly only where it had been fully implemented. In the interviews, reactions to the log-books varied. Initial reservations about an additional task were expected, and found, but there were also positive comments. Students appreciated having all their workings together and found their own comments (when they had used the) helpful when reviewing their workings later in the course.

> *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 Adrian 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.*

Table 9 Mean scores of ratings of relative helpfulness of teaching-learning activities

Setting ***Teaching-learning activity***	*Mean scores on a 1 – 7 scale* **Course A** *Mean (SD)* N = 59	 **Course B** *Mean (SD)* N = 73	 **Course C** *Mean (SD)* N = 27
The way diagrams presented	5.0 (1.3)	5.3 (1.2)	5.9 (0.6)
The way ideas explained in lectures	4.3 (1.6)	5.6 (1.2)	5.2 (0.8)
Lecture explanations of problems	4.2 (1.8)	5.8 (1.3)	4.9 (1.1)
Worked examples provided	5.0 (1.4)	3.6 (2.1)	5.7 (1.1)
Working on problems on own	5.2 (1.3)	4.6 (1.5)	5.3 (0.9)
Using the log-book	4.2 (1.7)	4.3 (1.5)	5.1 (0.9)
Staff help in tutorials	5.0 (1.7)	4.0 (2.3)	5.9 (1.1)
Discussions with other students	4.8 (2.1)	4.7 (2.0)	5.0 (2.0)
Feedback on work submitted	3.5 (2.1)	3.6 (2.2)	not given
Class tests and the results	4.3 (1.8)	4.2 (1.9)	not given

Some students also found that they had become more aware of the need to keep up with their work in preparing for the tutorials. A typical comment was:

> *I got used to writing down all the problems in the log-book 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 log-book now is really important to my understanding*.

It was clear, however, that students did not appreciate being told precisely how they should use the log-books, as they need to develop a way of using them that is coherent with their established ways of studying. And some students had found it difficult to know what type of comments to make: reflection on learning processes does not come naturally and so requires a thorough introduction and substantial help until the idea has been fully grasped. Clearly. More preparation for the use of logbooks would be necessary in future, if the activity is to be used more widely.

Aspects identified as supporting student learning of analogue electronics

What students felt about the three units, as shown in Table 8, began the process of identifying the aspects of a teaching-learning environment in electronic engineering are most likely to support student learning and understanding. To these can be added other items covered by the ETLQ scales which had been chosen to represent 'constructivist teaching' and which were associated with increases in the deep approach in electronics, as in the overall sample. The interviews added to this list and made it even more specific to the subject area. Bringing these together, we began to see that there are certain aspects of a teaching-learning environment for analogue that seem to be logically essential for developing the required knowledge and skills in that subject area. That connection between specific WTPs and teaching provision came to be described as the *inner logic of the subject and its pedagogy.*

Table 10 identifies these logically essential elements, which will need to be present in the most supportive way possible. These are necessary, but not sufficient, elements within a fully effective teaching-learning environment which can be expected to include additional elements, some of which were mentioned by students, while others can be drawn from the more general literature on teaching and learning in higher education.

Table 10 Teaching-learning activities supporting the learning of analogue electronics

Elements believed from the analyses to be essential

- Circuits linked to real-life illustrations from industry
- Main circuit components highlighted in diagrams
- Ways of thinking about circuits exemplified
- Ways of solving tutorial problems discussed in class
- Students work through sets of carefully varied examples
- Worked examples provided at the appropriate time
- Progress monitored through tutorial work and tests

Additional aspects supporting learning suggested in the project

- WTPs made clear to students alongside intended learning outcomes
- Links with prior work and other units made clear
- Enthusiasm for the subject shared with students
- Recognition of problem areas without implied threat
- Patient and thorough explanations provided in tutorials
- Sufficient tutors available to provide prompt advice
- Explanations given alongside worked examples
- Students record solutions and comments systematically
- Students encouraged to discuss solution strategies together

General design features of a supportive teaching-learning environment

- Aims related to general prior knowledge and aspirations of class
- Purposes of the unit mentioned regularly as *throughlines*
- Different forms of teaching relate to each other and to aims
- Purpose of assignments carefully explained
- Authentic problems used, where possible, to highlight relevance
- Students given appropriate incentives to work hard
- Student attendance and progress monitored
- Students made aware of how well or badly they are doing
- Individual support available to students when required

The idea of an 'inner logic' relating the teaching and learning to the WTPs emerged from hearing how staff described what was needed to develop an understanding of analogue circuits. The students were required to understand the functions of the circuits and also how to derive solutions that indicated the outputs produced by the circuits from characteristics of the input signals. Students made it clear to us that they needed to have the function of a new type of circuit explained initially through concrete examples of its use in practice. Given the strong vocational reasons that most students initially have for taking engineering courses, such a starting point would seem to be essential.

More detailed understanding of the circuits begins in lectures in which the links between circuit diagrams and explanations are crucial. The links can be made clearer by drawing attention to groups of components, for example, moving an overlay on an overhead or using a series of PowerPoint slides. General principles and strategies in considering the outputs of circuits then have to be explained, thinking aloud about the stages in carrying out circuit analysis. Students recognised from their own experience how important it was to work on large numbers of examples, both on their own and in tutorial classes, but another crucial element in the learning process was often missing or incomplete in the settings we investigated. Students need feedback on how well they are doing. In understanding circuit analysis, students felt it was essential to be proved with a sufficient number of worked examples to check against their own prior workings, and they were particularly appreciative they were provided with explanations for the key steps in the solution. Other feedback comes from periodic (and perhaps unexpected) tests which students in our sample felt could have been more frequent.

These seven elements seemed to match directly the required WTPs for this subject area, but a fully effective teaching-learning environment would also need to incorporate at least some of the other aspects mentioned in Table 10. Of course, the practicality of including all those additional aspects, and the resource implications, weighs against inclusion, and their relative importance will depend on the particular degree course, the characteristics of the students and the year of study, but our analysis of the teaching and learning of analogue engineering suggests that using these teaching-learning activities as a check-list could be valuable. Many of these will already be included, but others might well be worth considering, to take account of what students reported had helped them to understand this difficult area of study.

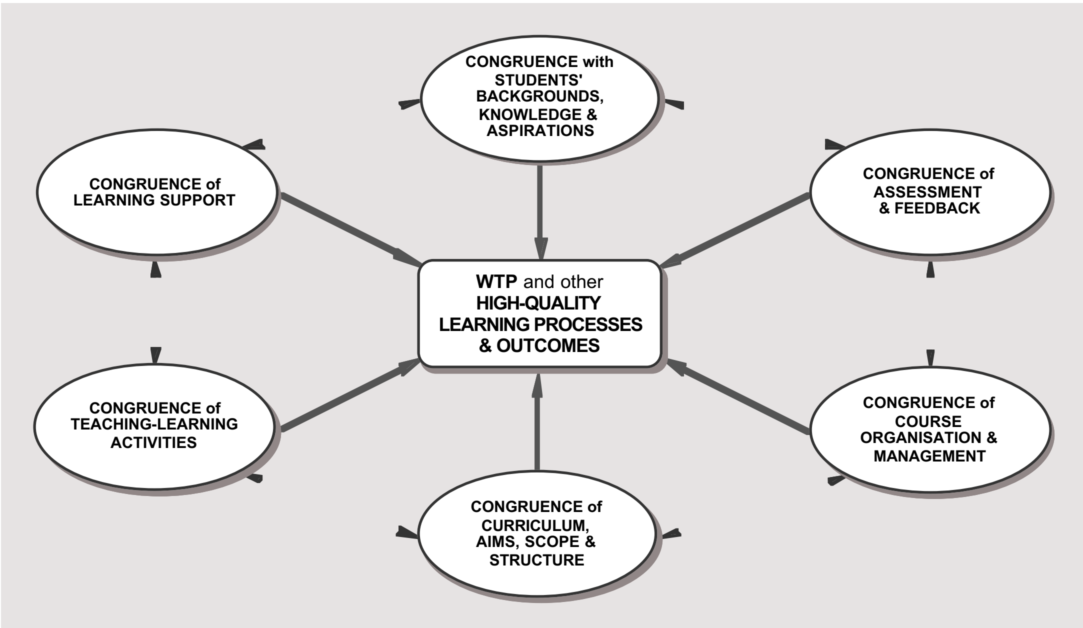
Conclusion

The purpose of the ETL project has been to explore ways of enhancing teaching-learning environments in four contrasting subject areas and to consider the implications for educational development work more generally. From our questionnaire analyses we have confirmed and strengthened earlier conclusions about the relationships between students perceptions of the teaching-learning environments they have experienced, their approaches to learning and studying, and their levels of academic performance (Prosser & Trigwell, 1999; Biggs, 2003; Ramsden, 2003; Vermunt, 2005). The analyses coming from the ETL project provide persuasive evidence that the nature of the relationship is bi-directional, with previous deep approaches being linked with appreciation of 'teaching for understanding', and with increases in deep and decreases in surface approaches being associated with the whole set of experiences which had been used to define a constructivist teaching-learning environment.

There were more similarities than differences among the subject areas in the factor analyses of the questionnaires but, using the whole set of data, important differences have been emerging that show the importance of treating each subject area as having distinctive teaching methods that reflect the nature of the subject itself. This is hardly a surprising finding, given earlier research into differing academic cultures (Becher & Trowler, 2001), but the strength of the link shown in the ETL project warns against looking for 'one size fits all' developments in university teaching and learning, and suggests how both the language of educational innovation, the concepts used to analysis teaching and learning, as well as the particular form of those innovations, have all to be compatible with the everyday discourse about teaching in the discipline and the ways of thinking and practising that are most salient for a particular course or course unit.

In electronic engineering, we had found it particularly valuable to use the notions of *inner logic* and *delayed understanding* (Scheja, in press; Entwistle *et al., 2005*) to explain the experiences students reported to us, while in economics *threshold concepts* (Meyer & Land, 2005) and *troublesome knowledge* (Perkins, 1999) were identified as valuable tools for staff in planning their courses. In history, the development of historical understanding was linked with the provision of a 'safe' *shared space* which allowed staff and students to feel comfortable in discussing interpretations of historical events together (Anderson & Day, 2005).

Figure 2 Differing Forms of Congruence within Teaching-Learning Environments



In biology, the analyses suggested the notion of *congruence* among the component parts of the teaching-learning environment, as a development of the idea of *constructive alignment* (ETL Subject Area Research Briefing for Biological Sciences, on the project website*).* 'Alignment' can be seen as impling a single 'line of sight' between a WTP and **a** particular teaching-learning strategy and method of assessment, whereas Biggs himself, and the student learning literature more generally, has been stressing the importance of seeing the teaching-learning environment as an integrated whole – a web of interconnections in which any one element out of place can affect how students approach and carry out their learning. The term *congruence* is thought to convey this broader conception more clearly by referring to the whole range of interacting contributions that a well-designed teaching-learning environment could make to students' engagement in learning and the high quality learning processes that contribute to it. The various dimensions of congruence that emerged in our analyses of the biological sciences data are shown in Figure 2.

Overall, the project has shown the importance of providing teaching staff with more detailed evidence about the ways in which students are reacting to the teaching-learning environments and going about their learning and studying. The approaches they use are partly habitual but importantly variable, depending on their experiences of the particular degree course and individual units. A revised and shortened version of the ETLQ is currently being produced and will be made available through our website. Although a 4-page questionnaire could not be used routinely, and data analysis support is needed, it might well be used at times for a particular unit, or when course revision is being planned. Our study depended, however, on the interplay between questionnaire and interview data, and the value of having discussions with groups of students in considering areas of difficult and possible improvement cannot be over-emphasised.

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