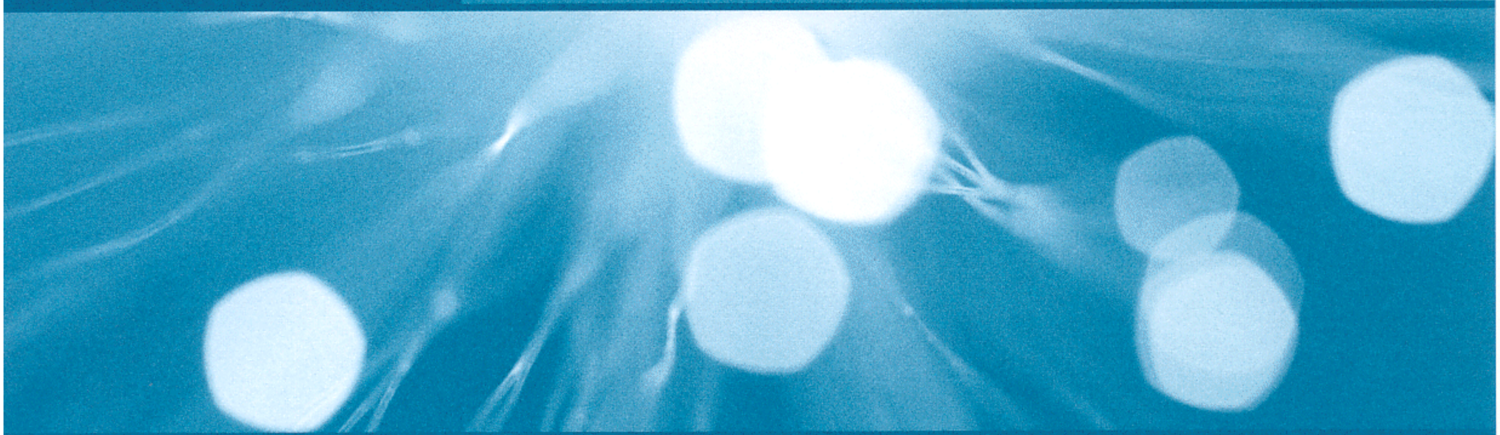
Learning and Teaching Theory



Engineering Subject Centre Guide:

Learning and Teaching Theory for Engineering Academics

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The Higher Education Academy
Engineering Subject Centre

Authorship

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How can Learning and Teaching Theory assist Engineering Academics?

Mention the words *Learning and Teaching Theory* to all but a few engineering academics and the reaction ranges from one of complete disinterest and non-engagement, to downright rejection as being totally irrelevant to their needs. So why should you as an engineering lecturer want to know about the theory of learning and teaching? In fact why should you NEED to know? Hopefully by reading the following few paragraphs you will at least see the benefit to read on, or ideally you will be convinced that acquisition of more knowledge will genuinely support your learning and teaching and ultimately benefit your students.

What is the relevance of learning and teaching theory to teaching engineering?

- There is a genuine scholarship behind learning and teaching. It's not all witchcraft, and while there may be a great deal said that is highly dubious, there is also a lot of genuine research into what works and what doesn't. Teaching isn't just a bag of tricks; it helps to know what to do when and why. Some knowledge of this research might help you to help your students learn more effectively, possibly with less effort from you in the long run.

- The world of higher education is changing and we all have to change with it. Gone are the days when the concept of "I've always taught this way" is acceptable. A wider diversity of students, budgetary constraints and obligatory demands from our administrators all lead to necessary changes. If we have to change our approaches, then let's ensure that we do so with the best interests of the discipline in mind. Without any knowledge of this theory yourself, the views of "experts" from other disciplines on teaching committees or advisors from educational development units etc. could inadvertently push you towards teaching approaches which are not appropriate for teaching engineering. For example academics from non science-based disciplines may argue that we can't talk about ideas being right or wrong - but try telling that to someone whose new bridge has fallen down! Some knowledge of educational theory can help in fighting the engineering corner and ensuring that adopted principles are relevant.

- Curriculum content is expanding to incorporate more than just core subject knowledge. Emphasis is being placed on life, key and transferable skills. Changes in demands from accreditation bodies to the students themselves mean that academic staff are constantly being required to do things they haven't been required to do in the past. For example we are requested to write intended learning outcomes and assessment criteria for the modules we teach. In order to do so it is useful and perhaps one could argue, essential, to understand the principles behind these initiatives.

These pages represent one practising (electrical) engineering academic's personal understanding of a range of theories and ideas associated with teaching and learning and his views on a number of issues he thinks are important. What is presented here is not necessarily "correct" and you are free, and even encouraged, to disagree. If you do disagree with anything you find here, or wish to challenge it, add to it, or feel that something important has been missed out, do please contact us at LTSN Engineering.

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Contents

The documents follow a logical order, dealing first with some concepts about learning and teaching, before discussing learning styles and how problem solving is so useful but is often misinterpreted. Thereafter the complex issue of intended learning outcomes and constructive alignment is explained in simple terms and finally there is a look at Personal Development Planning. Each section can be accessed and read separately however reading them in the order they appear may aid in interpretation.

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1 Learning styles

1.1 Introduction

A combination of political, social and economic drivers has effected major changes in higher education. Much of the change is centred on the ever-widening diversity of students entering the sector and academics are realising that a change to their teaching is required to accommodate this. We can no longer assume all students will achieve by being taught the same way, and consequently new teaching practices are required. Adopting new methods and techniques is aided greatly by the appreciation of the existence of different learning styles. The paragraphs that follow illustrate differing styles and offer suggestions as to how these may be embraced within the engineering curriculum.

1.2 Theory

The basic principle behind the theory of learning styles is that different people learn in different ways. There is much literature on learning styles and as with much educational theory, there are some differences of opinion particularly in classification of the different styles. It does not help us in the engineering community that much of the literature is from the business world where several inventory questionnaires have been developed to help people discover their learning styles or preferences, and part with significant amount of money in the process!

A common approach to viewing learning styles is linked to a learning cycle of experience, observation and reflection, formation and then testing of concepts. Although commonly referred to as the "Kolb Learning Cycle" this cycle was proposed by Kurt Lewin who got the idea from control engineering. David Kolb (1984) popularised Lewin's proposal (hence the common title).

The four stages of the Experiential Learning Cycle are:-

1. Concrete experience
2. Observation and Reflection
3. Abstract Conceptualisation
4. Testing concepts in new situations

The cycle is a continuous process with the current 'concrete experience' being the basis for observations and reflections, which allow the development of a 'theory'. The 'theory' is then tested in new situations to lead to more concrete experience.

Kolb developed from the Lewin model the idea that students have a dominant phase of the cycle during which they prefer to learn and therefore will have preferred modes of learning. In order to identify the preferred study and learning styles, Kolb developed a *Learning Style Inventory* that identified student's preference for the four modes corresponding to the stages in the learning cycle.

Subsequently Honey and Mumford (1986) developed a *Learning Style Questionnaire* building upon Kolb's work. They felt that the learning style inventory was not accessible to managers with whom they worked. They identified four styles of learning, which had much in common with Kolb's work and had strong correlations with the learning cycle, (See Figure 1).

Work in the United States has looked at learning styles and engineering and the impact of students' approaches to the effectiveness of learning. Richard Felder and colleagues developed The *Index of Learning Styles,* a self-scoring instrument that assesses preferences for learning in four dimensions.

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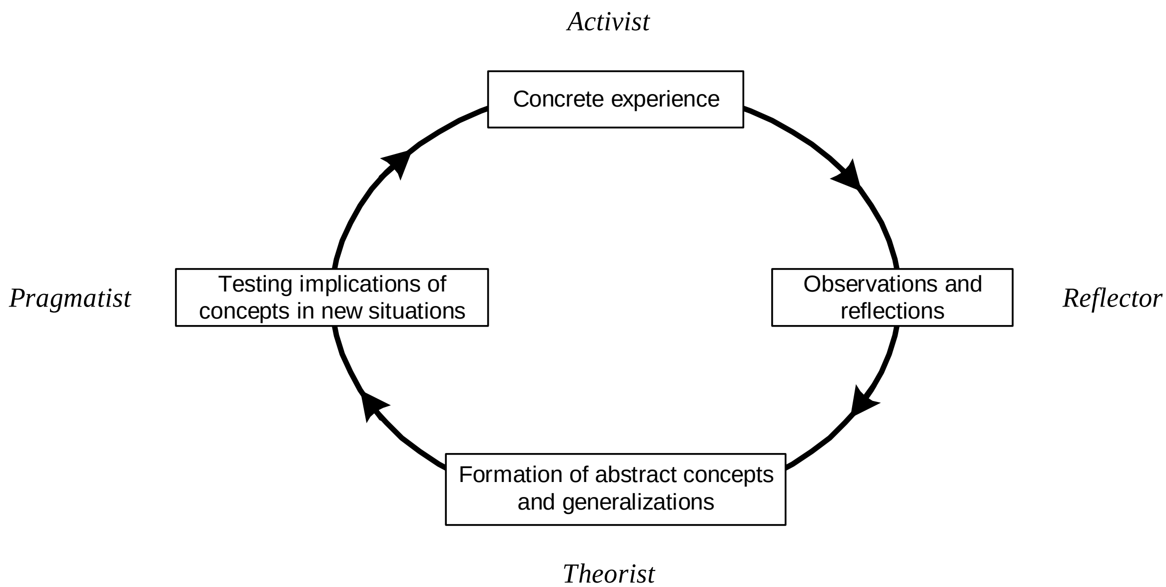

Figure 1 - The Lewinian Experiential Learning Model (after Kolb, 1984, p21)
with the linked *Honey and Mumford Learning Styles* (Honey and Mumford, 1986)

Felder and Silverman (1988) develop their models' dimensions through student preferences to the following aspects to learning:

- What type of information does the student preferentially perceive: *sensory* (external) - sights, sounds, physical sensations, or *intuitive* (internal) - possibilities, insights, hunches?
- Through which sensory channel is external information most effectively perceived: *visual* - pictures, diagrams, graphs, demonstrations, or *auditory* - words, sounds?
- How does the student prefer to process information: *actively* - through engagement in physical activity or discussion, or *reflectively* - through introspection?
- How does the student progress toward understanding: *sequentially* - in continual steps, or *glob*ally - in large jumps, holistically?"

From answers to these questions, they developed four dimensions of learning:

- Visual - Verbal Learners
- Sensing - Intuitive Learners
- Active - Reflective Learners
- Sequential - Global Learners

1.3 Learning Styles in Use:

For the student it may be important to recognise their own learning preferences, though it is impractical for us to pander to these preferences. Students should not be labelled as having one fixed learning style, instead we need to recognise that individuals will have particular modes of learning that are more dominant than others. We need to adopt approaches to teaching that enable students who have different learning styles to learn effectively. This means that we need to design our learning with different learning opportunities (and appropriate assessments – see section 6 - Constructive Alignment), to ensure that the learning is accessible to the largest number of students.

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Felder and Silverman found in their study, and it has been demonstrated in follow up studies, that certain approaches to managing the learning and teaching environment have a strong positive benefit on the learner, (see Table 1). Applying a mix of teaching approaches to the classroom and in planning the learning opportunities for students should benefit the maximum numbers of students.

Relate the material being presented to what has come before and what is still to come in the same course, to material in other courses, and to the students' experience *(global).*
Balance concrete information *(sensing)* with the abstract concepts such as theories and mathematical models *(intuitive).*
Balance practical problem-solving methods *(sensing/active)* with material that emphasizes fundamental understanding *(intuitive/reflective).*
Provide concrete examples of the phenomena the theory describes or predicts *(sensing);* then develop the theory *(intuitive / sequential);* show how the theory can be validated *(sequential);* and present applications *(sensing/sequential).*
Use pictures, diagrams and graphs liberally before, during, and after the presentation of verbal material *(sensing/visual).* Show films or use multimedia simulations *(sensing/visual.)* Provide demonstrations *(sensing/visual),* and hands-on experience *(active).*
Use multimedia, and computer-assisted assessment, sensors respond very well to it *(sensing/active).*
Provide intervals in teaching—however brief—for students to think about what they have been told *(reflective).*
Small-group brainstorming activities that take no more than five minutes are extremely effective for active learners *(active).*
Mix type of problems, so provide practice in the basic methods being taught through 'drill' exercises *(sensing/active/sequential)* but do not overdo them *(intuitive/reflective/ global)*; and use some open-ended problems and exercises that call for analysis and synthesis *(intuitive/reflective/global).*
Use group learning and team learning exercises to the greatest possible extent *(active).* Active learners generally learn best when they interact with others; if they are denied the opportunity to do so they are being deprived of their most effective learning tool.

Table 1 - Approaches to teaching that enable learning to a wide range of learning styles. Adapted from Felder and Silverman (1988)

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1.4 References

Kolb, D. A. (1984). Experiential Learning, Prentice Hall.

Honey, P. and Mumford A. (1986). A Manual of Learning Styles, Peter Honey, Maidenhead

Felder, R.M. and Silverman, L.K. (1988). Learning and Teaching Styles In Engineering Education Engr. Education, 78(7), 674–681 http://www.ncsu.edu/felder-public/Papers/LS-1988.pdf

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2 Levels of Thinking about Learning and Teaching

2.1 Introduction

Most academics will agree that education is not just about acquisition of knowledge, but the ability to apply that knowledge in the work place and ideally throughout all aspects of life. As engineering academics we strive to impart real-world situations into our teaching and learning (e.g. through problem solving exercises). We also strive to impart the ability upon our students of lifelong learning. Appropriate teaching will assist the student in this process, however to fully appreciate what is and what is not appropriate does involve an appreciation that there are different levels of thinking about learning and teaching. This section attempts, without embarking on too much theory, to outline this concept.

2.2 Theory

The model tabulated below, adapted from Biggs (1999, Chapter 4), should be read from the bottom up. It describes four levels of thinking about learning and teaching. The levels, range from the extremes of level 1, where the student is merely a "sponge" absorbing material without too much thought as to where the knowledge is taking them, to level 4 where the student is actively engaged in management of their own learning. In this model, levels of thinking about learning and teaching are defined in terms of what is focused upon. This gives us the teachers focus on what the student does as a response to teaching.

level	emphasis	description	value
4	How the student manages what the student does	**The ultimate aim of higher education – student takes control** The focus is on how the student can manage what they do, initially within frameworks created by the teacher, but ultimately negotiating or creating his/her own framework. This level links to PDP** and the idea of the independent learner. There is no shortcut from levels 1 or 2 straight to 4; a student cannot operate effectively at level 4 without having experienced level 3 teaching or constructive alignment.	Active learning models linked to "Constructive Alignment**"
3	What the student does	**Emphasis on learning through appropriate activity** The focus is on what the student does. "*Level 3 sees teaching as supporting learning."* It recognises that learning can only be effective if it is engaged in actively by the learner, and the teacher's task, which may involve the deployment of a great many level 2 skills, is to set up an environment of learning activities and assessment from which it is very difficult for the student to escape from without learning.	
2	What the teacher does	**2.2.1 Seeing teaching as a performance** This is the basis of much institutional assessment of teaching The focus is on what the teacher does: "*The teacher who operates at level 2 works at obtaining an armoury of teaching skills.*" However "*Level 2 is also a deficit model, the 'blame' this time being on the teacher*". Biggs argues "*The focus should not be on the skill itself, but whether its deployment has the desired effect on student learning.*" and goes on to describe a desirable third level.	Deficit models
1	What the student is	**Not the teacher's responsibility** The focus is on what the student is: "*A teacher's responsibility is to know the content well and to expound it clearly. Thereafter, it's up to the students... When students don't learn…it is due to something the students are lacking***"	

**The quotes are from Biggs (1999, chapter 4)*
*** See Section 7 on Constructive Alignment*

2.3 Application of theory to teaching practice

Most engineering academics appreciate the first three levels (not necessarily with any knowledge of Biggs or his theory!). However it is the author's contention that as teachers we should strive to be engaging students at level 4, which is the level where the focus is on how the student manages his/her own learning. It can be argued that Level 4 is the ultimate of higher education, producing graduates who are autonomous individuals capable of advancing their own learning. A student cannot operate effectively at level 4 without having experienced level 3 teaching or constructive alignment. Level 4 is a step above that which many of us practice and it is important for us to appreciate its significance.

What we need to do is turn this around so that when we think about teaching, rather than concentrate on what we do, is to think about how we engage the student. It is possible for a student to be engaged in extremely effective learning activities, with aligned assessment, without being consciously aware of the learning process. For a student to take responsibility for managing learning and for choosing how to learn requires a step beyond the teaching to which we usually subscribe. This can probably be seen most clearly in primary education, but it will still happen in higher education if the teacher designs the learning activities without explaining why the learning activities are designed as they are. Students can work very hard, actively and effectively, doing what they are told to do. This is not quite "spoon feeding". The students are doing the work, but they aren't taking responsibility for deciding what to do. They can learn a great deal, but not be able to learn independently when they leave university and do not have a teacher to tell them what to do. Managing one's own learning is therefore an important ability not necessarily covered by level 3.

Students operating at Level 4 are taking responsibility for their own learning and making good choices. However, they cannot be expected to make good choices unless they have experienced good and effective learning strategies and been encouraged to see their value through properly aligned assessment.

In order to move students so they are operating at level 4 needs us to make changes to the engineering curriculum and the students approach to learning. What we are trying to do is the ultimate aim of teaching in higher education in that we want the student to take control. We need to enable the student to manage what they do as part of their learning processes and this is best achieved by creating a learning framework within which the students can learn. The ideal type of framework is that provided by constructive alignment.

Paul Ramsden (1992) focused on improving teaching in higher education, and identified characteristics for improving the students' experience of higher education. The *Course Experience Questionnaire* developed a series of items to question particular factor associated with students' experience. Table 2 lists attributes of good teaching and good teachers.

Ramsden's Principles of Effective teaching • Interest and Explanation; • Concern and respect for students and their learning; • Appropriate assessment and feedback; • Clear goals and intellectual challenge; • Independence, Control and Active engagement; • Learning from students.

Table 2 - Attributes of good teachers (adapted from Ramsden 1992, p96)

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While this list is by no means exhaustive it is a useful focus for ourselves to reflect on our teaching practices. Although we will all recognise the characteristics of good teaching and look to attain them, often there are areas where we could look to enhance our performance in some areas. We can see also that these principles feed through to those we require for Constructive Alignment. Ramsden (1992, p175) also reports on the work of Peter Cawley (1989) who introduced problem based learning into a third year engineering programme. The course aimed to develop students' skills in vibration analysis, and improve the students' abilities in applying diagnostic and problem-solving skills into the course. The course adopted a problem based learning approach, using three pairs of problems typical to those engineers would meet in practice. Ramsden notes how the teaching strategy mirrors the goals. The design of the course was as follows:

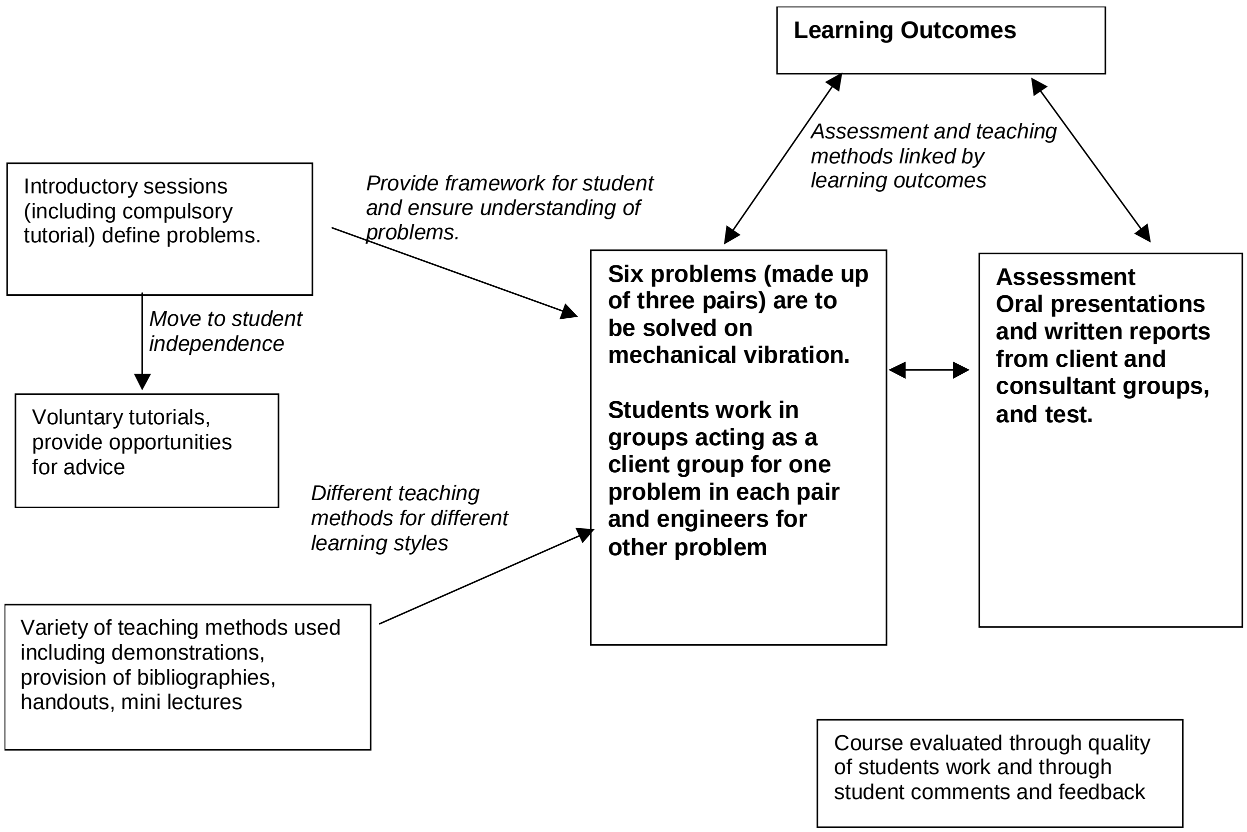

Figure 1. Good teaching design. Peter Cawley's Problem Based Learning Course (1989) (Figure derived from Ramsden's report of the course design (Ramsden 1992, p175)

The course highlights many principles of good teaching, constructive alignment and facilitates good learning by ensuring that the teaching methods correspond to the widest range of approaches to learning (see Section 3 Deep and Surface Approaches to Learning). It is approaches like these that will facilitate student learning at the highest level, and this indicates the type of behaviours and methods that we can adopt to encourage this level of learning.

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2.4 References

Biggs, J. (1999): Teaching for Quality Learning at University, (SRHE and Open University Press, Buckingham)

Ramsden, P (1992): Learning to Teach in Higher Education, (Routledge)

Cawley, P. (1989):Studies in Higher Education 14, 83-94

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3 Deep and Surface Approaches to Learning

3.1 Introduction

The concept of preferences to different individual learning styles was introduced in Section 1 Learning Styles. In this document we look at the associated concept of approaches to learning. The original work on approaches to learning was carried out by Marton and Saljo (1976). Their study explored students' approaches to learning a particular task. Students were given an academic text to read, and were told that they would subsequently be asked questions on that text. The students adopted two differing approaches to learning. The first group adopted an approach where they tried to understand the whole picture and tried to comprehend and understand the academic work. These students were identified with adopting a deep approach to learning. The second group tried to remember facts contained within the text, identifying and focusing on what they thought they would be asked later. They demonstrated an approach that we would recognise as rote learning, or a superficial, surface approach.

3.2 Deep and Surface Approaches

Deep and surface approaches to learning are words that most academics will have heard. In fact the idea that students can and do take a deep or surface approach to their learning is probably one of the most used bits of educational research in higher education. It is a very powerful and useful principle that we should apply most of the time to the way we teach. It is particularly applicable in engineering, and failure to apply it and apply it properly explains how an awful lot goes wrong with the learning processes.

Simply stated, deep learning involves the critical analysis of new ideas, linking them to already known concepts and principles, and leads to understanding and long-term retention of concepts so that they can be used for problem solving in unfamiliar contexts. Deep learning promotes understanding and application for life. In contrast, surface learning is the tacit acceptance of information and memorization as isolated and unlinked facts. It leads to superficial retention of material for examinations and does not promote understanding or long-term retention of knowledge and information.

Critical to our understanding of this principle is that we should not identify the student with a fixed approach to learning, but it is the design of learning opportunity that encourages students to adopt a particular approach.

3.3 Designing for Deep Learning

Very crudely: deep is good, surface is bad, and we should teach in a way that encourages students to adopt a deep approach; although achieving this is not so easy.

Perhaps the major influence on the students' approach to learning is the assessment methods. It is often argued that the explicit setting of "straightforward" assessments involving short questions testing separate ideas will encourage surface learning. However, again this is not necessarily the case as even the most apparently simple assessment questions can require students to demonstrate that their knowledge can be applied. For example, students can be asked to apply the laws of Ohm, Kirchhoff etc. albeit in simple cases rather than merely to quote them. (For further information on the importance of application see Laurillard (1993)).

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3.4 Basic Principles and the Approaches to Learning

The evaluation of process is very valuable in determining the depth of learning, but if we concentrate on process alone we risk losing sight of the structure of the material being learnt. Engineering, like mathematics and science, is a hierarchical subject. As argued above, there is little point in trying to comprehend Kirchhoff's 2nd Law without first developing at least a working comprehension of potential, potential difference, emf., current, etc. and the ability to apply Ohm's Law reliably. This is not to say that understanding of the subject proceeds in a simple linear fashion (the naive bricks in the wall model of learning). Working with the laws of Kirchhoff, Thévenin, Norton etc. will undoubtedly lead to a deeper understanding of earlier principles, but learning cannot start there. Attempting to work with more complex principles without a good grasp of the more basic principles from which they are built can only lead to frustration and a surface learning approach in which students attempt to memorise solutions to complex problems they cannot understand. Encouraging students to practice the application of basic principles will not force them adopt a deep approach to learning, but it at least makes it possible.

3.5 Putting theory into practice

The following table (Table 3) compiled from the work of Biggs (1999), Entwistle (1988) and Ramsden (1992) provides some very valuable characteristics of the approaches and illustrates the importance of how we manage the curriculum impacts on the learning process. For example, clearly stated academic aims, opportunities to exercise some choice and well aligned assessment strategies that help students to build confidence can be found among the factors identified as encouraging a deep approach.

The last row of the table provides us with some simple guidelines as the "do's" and "don'ts" in teaching.

A particular example is to use problem based learning. Rather than producing assessments that require rote application of Kirchhoff's 2nd Law, such as working out the current in an abstract network, we need to provide assessments where students need to link multiple ideas and concepts together, such as using Kirchhoff's Laws, Ohm's Law and their understanding of electrical principals, to design an amplifier for a particular purpose.

Therefore, in order to encourage active learning we need to be positive about the study of engineering. We need to concentrate on the key concepts, not just in isolation, but also by demonstrating the way that the components link together. We can also see that over reliance on traditional lectures, where students are passively taking notes and not being required to engage actively with material, will not encourage a deep approach. Similarly, over assessment, through repeated testing, while seen to regularly focus the learners on the material, is likely to have the opposite effect to that desired by just encouraging memorising of facts. Fewer assessments in general, and assessments that encourage and require students to engage with problems, will also encourage the students to use and apply their learning, facilitating the deep approaches that we require.

We need to think carefully about the assessment and assessment processes, as it is this part of the curriculum that affects the students' approaches to learning most. We need to construct assessment that gives students opportunity to receive feedback, but also must make the assessment relevant to the real world of engineering.

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	Deep Learning	Surface Learning
Definition:	Examining new facts and ideas critically, and tying them into existing cognitive structures and making numerous links between ideas.	Accepting new facts and ideas uncritically and attempting to store them as isolated, unconnected, items.
Characteristics	Looking for meaning. Focussing on the central argument or **concepts** needed to solve a problem. Interacting actively. Distinguishing between argument and evidence. Making connections between different modules. Relating new and previous knowledge. Linking course content to real life.	Relying on rote learning. Focussing on outwards signs and the **formulae** needed to solve a problem. Receiving information passively. Failing to distinguish principles from examples. Treating parts of modules and programmes as separate. Not recognising new material as building on previous work. Seeing course content simply as material to be learnt for the exam.
Encouraged by Students'	Having an intrinsic curiosity in the subject. Being determined to do well and mentally engaging when doing academic work. Having the appropriate background knowledge for a sound foundation. Having time to pursue interests, through good time management. Positive experience of education leading to confidence in ability to understand and succeed.	Studying a degree for the qualification and not being interested in the subject. Not focussing on academic areas, but emphasising others (e.g. social, sport). Lacking background knowledge and understanding necessary to understand material. Not enough time / too high a workload. Cynical view of education, believing that factual recall is what is required. High anxiety.
Encouraged by Teachers'	Showing personal interest in the subject. Bringing out the structure of the subject. Concentrating on and ensuring plenty of time for key concepts. Confronting students' misconceptions. Engaging students in active learning. Using assessments that require thought, and requires ideas to be used together. Relating new material to what students already know and understand. Allowing students to make mistakes without penalty and rewarding effort. Being consistent and fair in assessing declared intended learning outcomes, and hence establishing trust (see Section 6 **Constructive Alignment**).	Conveying disinterest or even a negative attitude to the material. Presenting material so that it can be perceived as a series of unrelated facts and ideas. Allowing students to be passive. Assessing for independent facts (short answer questions). Rushing to cover too much material. Emphasizing coverage at the expense of depth. Creating undue anxiety or low expectations of success by discouraging statements or excessive workload. Having a short assessment cycle.

Table 3 - Compares the characteristics and factors that encourage Deep and Surface Approaches to learning. (Compiled from Biggs (1999), Entwistle (1988) and Ramsden (1992))

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3.6 References

Biggs, J. (1999). Teaching for Quality Learning at University, SHRE and Open University Press.

Entwistle, N. (1988). Styles of Learning and Teaching, David Fulton.

Laurillard, D. (1993). Rethinking University Teaching, a framework for the effective use of educational technology, Routledge.

Marton, F. and Booth, S. (1997). Learning and Awareness, Lawrence Erblaum Associates, chapter 2

Prosser, M. and Trigwell, K. (1999). Understanding Learning and Teaching, on Deep and Surface Learning, Society for Research into Higher Education & Open University Press, chapter 4.

Ramsden, P. (1992). Learning to Teach in Higher Education, Routledge.

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4 Problems and Problem Solving

4.1 Introduction

Problem solving is what engineers do. It is what they are, or should be, good at. At one time the basic problem solving skills engineering students needed were developed in school, with university engineering programmes being able to build on them. Unfortunately that is no longer the case. A look at today's GCSE and A-level papers show us why many students coming in to university have had very little training in the process of problem solving: the "problems" set tend to be largely single step tests of knowledge of individual principles. The current A-level students are not asked to tackle multi-step problems, and if faced with a large set of information where the required objective cannot be reached in one single familiar step many will not know what to do. Very few new undergraduates will have the confidence and mental processes available to say "I don't know how to solve this problem yet, but if I set about it systematically and think about it I expect I'll work it out".

It is common in engineering education to talk about the "mathematics problem" i.e. the weakness in mathematics of students entering university engineering programmes. Certainly the lack of fluency in specific mathematical techniques is an obvious aspect of this "problem", but the more serious aspect may be the lack of understanding of problem solving processes.

It is this author's contention that problem-solving skills may be the most important thing we can teach our students and, if students don't come to university with the necessary skills, we do have to teach them. To progress onto other engineering course content without ensuring that students can apply a systematic problem-solving process is pointless. Consequently problem solving should be systematically and explicitly taught in the first year of all engineering degree programmes.

4.2 How do we teach problem solving?

We can divide what needs to be taught into two areas: the process of problem solving, which is generic, and the tools for executing steps of solutions, which are subject specific.

To teach problem solving requires the cooperation of all staff teaching first year students. Students should be given an agreed general problem solving process and then set multi-step problems in all their individual subject modules with all staff insisting that the students follow the same process at all times. Periodically the general process should be reviewed with the students, helping them to abstract the generic process from its specific applications, and to appreciate the need to practice specific skills.

4.3 The problem solving process

What follows here is a generic description of problem solving that can apply within any academic discipline or context provided that there is a familiarity and fluency with the tools applicable to that context.

A problem comprises a situation and an objective. The situation can be real or described, and where described, can exist in the real world or in an abstract, intellectual, world. The situation includes resources, which may be physical objects or information, and constraints or rules. The objective can be a) either to achieve a specific result, (for example a physical change in the situation or a piece of information) or b) may involve producing a proof or explanation.

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Both types involve going through a process, but in the first type that process is a means to an end whereas in the second type it is the process itself that is important.

The problem solving process, for simple problems, involves:

1. **Assemble and evaluate information and resources.**
First obtain a clear description of the situation and ensure that it is fully comprehended. This may involve writing down lists and diagrams, re-describing the situation, trying to get a clear mental picture of all the relationships which exist within the situation, of what the resources are and what they can be used for, and of the constraints and their implications. The objective must also be clarified.

2. **Brainstorm and plan solution process**
The brainstorming process involves first looking at the situation and asking what immediate changes can be made, what will be the consequences of these changes, and looking at the objective and asking what would enable the objective to be reached. It also involves considering any similar problems previously solved. The aim is to identify a set of steps that lead from the original situation to the desired objective.

3. **Implement solution**
Once a set of steps has been identified, the solution process proceeds from one step to the next, regularly reviewing progress and checking back to make sure that the steps taken so far are valid and have produced the required result, until the required objective is reached.

4. **Check results**
A final check is then made to verify that the result produced is the required objective. If, at intermediate stages, checks on progress reveal an error, then it is necessary to go back one or more steps and rethink the problem, again looking for a set of steps that leads from the original situation, or from the results of previously verified steps, to the objective.

The mistake many students make is in trying to go straight to stage 3 without first going through stages 1 and 2, and then all too often stage 4 is forgotten altogether! Part of the reason for this is that many A-level questions provide stages 1 and 2 and only ask the student to go straight to stage 3.

4.4 What makes a problem simple or difficult and why do we need to know?

Understanding what makes a problem simple or difficult allows us to set suitable problems for the level of student and to determine assessment criteria. The difficulty of a problem depends on many factors.

- Situation - how simple or complex.
- Situation - clear and fully and unambiguously defined, or unclear with many components ill-defined or unknown.
- Objective - may be well or ill-defined.
- Solution – required number of steps.
- Solution – availability and ease of use of tools required

For a simple problem, it should be possible to plan the whole series of steps needed to solve it before starting. This may not be possible for difficult problems, where a number of partial solutions may have to be tried out in a trial and error process, looking to see if any of these produce a problem that is easier to solve.

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Table 4 illustrates properties, either alone or in combination that can make a problem simple or difficult to solve. The table is followed by a set of examples. It may help to glance through this table, then read the examples and then come back to this table.

4.5 Analytical skills and creativity

Problem solving involves both analytical and creative skills: analytical in comprehending the problem and the relationships within the original situation, and in checking the results of results of each step, and creative in devising the solution. Imagination plays a large part in both of these skills: problem solving requires the ability to imagine a chain of intermediate steps and their consequences. For example to solve the problem of crossing a river by chopping down a tree and laying it across the river appears to be quite simple. However it would be very difficult to arrive at for someone who has not previously walked along a fallen tree, seen a tree laying across a chasm, knows that they can chop a tree down and knows how to manhandle a felled tree.

In reality, problem solving rarely involves any really novel steps; it usually involves putting together a set of previously experienced processes. It is the building upon of generic processes allied to subject expertise.

The ability to imagine the individual steps in a solution and their results can only be gained through experience, acquisition of subject specific knowledge and understanding, and practice in using the necessary tools. True creativity in problem solving lies in lateral thinking, that is in the ability to imagine the results of processes in different contexts to those previously experienced. This requires the ability to abstract, at least sub-consciously, generalisations, and while such transfer may be possible between different contexts within one academic discipline it is not as easy to achieve between contexts in different disciplines.

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	Simple	Difficult
Description	Simple to describe, requiring only a few brief statements	Complex to describe
Situation and objectives	Simple to understand	Difficult to understand perhaps requiring several years of learning
	Defined clearly, completely and unambiguously, and all information known to be accurate and consistent.	Ill defined – experts may differ on what the problem is, and information may be inaccurate and/or inconsistent.
	Totally clear what information is relevant to achieving the objective	Very difficult to be sure what information is relevant, out of a vast amount available
	Situation and objective concrete.	Situation and objective abstract
Tools/techniques required	Obvious as to which tools are needed to solve the problem	May not be immediately obvious what techniques will help to solve the problem
	All tools and knowledge how to use them immediately available	Tools and techniques not immediately available. New techniques may have to be acquired, learnt or even invented
	Tools simple to use. e.g. a hammer (physical) or addition (intellectual)	Tools difficult to use, requiring years of training. e.g. finite element analysis software (physical), or general theory of relativity (intellectual).
Familiarity	Situation and objective familiar: the solver has seen both before	Situation and objective totally unfamiliar: relationships within the situation and the objective both require abstract imagination to comprehend.
	Solution process is standard and well known	Solution process completely new, requiring considerable use of intuition and creativity.
	Steps in the solution and their results are all familiar	Steps required for the solution are unfamiliar and require imagination of and results that have not been seen before.
Complexity of solution	Single step required	Several steps required, with many alternative routes possible or required
	Whole solution process can be planned out before starting on first step.	Not possible to plan whole solution process immediately and partial solutions have to be investigated to find most promising routes to final solution.
	Defined clearly, completely and unambiguously	Solution involves intuitive steps that are difficult or impossible to describe.
	Solution involves one process	Problem comprises parallel problems which need to be solved separately, possibly by different people or teams who then need to combine their solutions.

Table 4 - Properties of simple or difficult problems.

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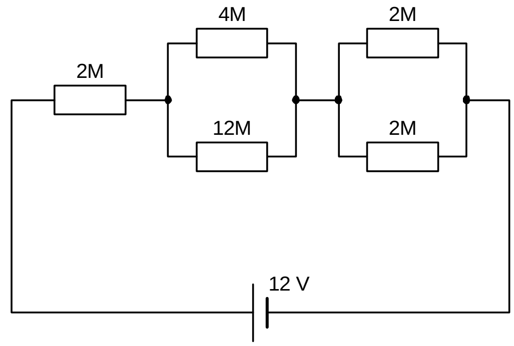
4.6 Examples

4.6.1 Example 1. NOT a "problem"

For the circuit shown:

- *(a) redraw the circuit replacing each of the 2 parallel combinations with a single resistor,*
- *(b) calculate the total circuit resistance,*
- *(c) calculate and label the current drawn from the battery,*
- *(d) calculate and label the p.d. across every resistor, and*
- *(e) calculate and label the current flowing through every resistor in the original circuit.*



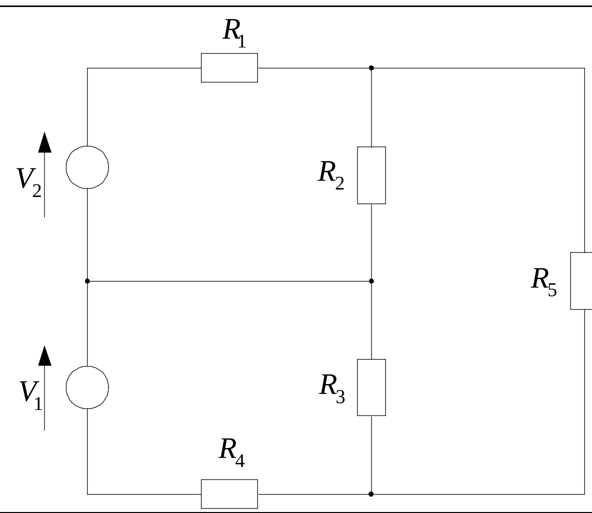
This does not count as an exercise in problem solving since stages 1 and 2 of the generic process described above have been done for the student who is simply guided step by step through stage 3. This is simply an exercise of specific skills that will be useful in solving circuit problems. There is nothing wrong with setting this kind of exercise; indeed it is a necessary precursor to setting real problems, but it does **not** exercise the problem solving process.

4.6.2 Example 2. A simple practical problem

If, rather than set out steps (a) to (e) in the example above, the same circuit diagram had been presented with the objective being to determine the current flowing through the 4 MΩ resistor, this would count as **a simple problem**. The starting point and objective are very clear and simple, the techniques required (ability to add resistors in series and parallel and apply Ohm's law) are simple and should be very well rehearsed, and the solution process, though involving a few steps should also be very familiar.

4.6.3 Example 3. A Slightly more difficult problem

Obtain an expression, in terms of the component values shown, for the current flowing through resistor R_5 in the circuit shown below. (Hint: this can be done by nodal analysis, but this is not the most efficient method.)



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Here the starting point and the objectives are clear enough but the solution is not instantly obvious. It will involve several steps and there are several different ways of solving the problem. The able student will redraw the diagram and may experiment with a number of different ways of simplifying the circuit before deciding which method to use. Nodal analysis, mesh analysis or superpositions are all possible but simplification using Thévenin's and Norton's theorem could provide the quickest solution. Students may have some difficulty or at least lack of fluency in using the techniques required and will therefore have difficulty in imagining the process before starting. The fact that variables are used rather than numbers for component values makes the problem seem more abstract to students who are not totally confident with algebra and this also makes imagining the solution (stage 2) more difficult as well executing it (stage 3).

4.6.4 Example 4: Another slightly more difficult problem

Starting from the Fourier transform pairs given in the formula sheet, or otherwise, sketch and derive an expression for the Fourier transforms of the finite energy signal
$x(t) = \left(1 + \cos(2\pi t)\right) \operatorname{rect}(t)$

Here, the starting point should be clear enough, but only if the student can interpret the equation and sketch the function (stage 1). Unless the student is to get bogged down in integration by parts, spotting the solution (stage 2) involves seeing the function as the product of two functions $\left(1 + \cos(2\pi t)\right)$ and $\operatorname{rect}(t)$, the first of which is itself a sum. The solution then involves sketching and writing down the Fourier transforms of both functions and then seeing that they can easily be convolved to provide the required Fourier transform. All of the stages should be reasonably familiar, but they have to be very familiar if the whole process is to be imagined before execution (stage 3). There are several steps to the solution and many students have difficulty with the basic concepts (tools) involved, never mind putting them together to solve a previously unseen problem. If a similar, but not identical, problem has been seen modifying the previously seen solution still requires imagination and understanding, and systematic implementation of stages 1 and 2. Of course, if this exact problem has been seen before, and its solution recalled, this problem is much less of a challenge: the student does not have to think through stages 1 and 2.

4.6.5 Example 5: A difficult problem

Determine the specifications of an earth station transmitter to be used in a satellite communication link between two earth stations, given the specifications of the satellite and the data channel required.

Here the starting points and objectives can be clearly and unambiguously defined but, while most required information should be available and accurate, the problem solver may have difficulty in extracting the relevant information from the wealth available. The problem requires abstract thinking and several years of study are required just to comprehend the problem and the techniques required solving it. The solution process will be familiar if it has been rehearsed, but many steps are involved, a lot has to be held in the mind at once, and rigorous checking is required at every step. The author has set this type of problem, as an open note examination exercise, to 3rd year students. A scenario is described giving system and channel specifications and students are expected to draw up a power budget to complete the specifications. Although difficult mathematics has been avoided by treating subsystems as "black boxes" and providing design formulae, students have always found this exercise to be extremely challenging, because of the amount of information which has to

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be sorted and the number of steps involved. Data, often more than is actually required, has usually been tabulated at the end of the paper, helping students with stage 1. When this was not done, although drawing up their own table of data from the scenario should have been straightforward enough, many students found this made the problem much harder for them (they did not automatically go through stage 1). It is clear that faced with the requirement to sort out the required data from original sources would make this problem far more challenging still. In recent years this satellite communications design exercise has been set to both MEng and BEng students. Both sets of students have been given essentially the same problem so that both sets have to carry out exactly the same calculations and checks at stages 3 and 4 of the problem solving process, but BEng students have been given extra hints to help with stage 2.

4.6.6 Example 6: Extremely difficult

Put a man on the moon. (Seen from before the construction of the Apollo spacecraft.)
Here the objective is fairly clear, but what is the starting point? What resources and existing techniques are relevant? Enormous expertise will be required in many areas, and many new tools and techniques will certainly need to be invented, and it is by no means certain that a solution is possible with the resources available. It is far from clear what resources are available and they will certainly change with public opinion etc. The final objective may be reasonably easy to imagine, but the very many intermediate steps have never been seen before and require great imagination to visualise in advance. This is far from a familiar problem and many stages of exploring many partial solutions will be necessary before a route to a final solution can be found. Many people and teams will be involved; often working in parallel on different parts of the problem or different partial solutions, and a lot of interpersonal issues will confuse and add difficulty to the problem.

4.7 Conclusion

From the above the complexity of problem solving exercise to both the teacher and the student may be seen. Both must appreciate the process and the tools required. It is important to appreciate that without the process the solution, even if correct, is unlikely to be beneficial as a learning activity for the acquisition of life skills. The reader should be able to use the information provided above to evaluate whether their current problem solving setting meets the criteria to engage the student through all the required steps to make the exercise truly worthwhile.

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5 Levels in module descriptions

5.1 Dealing with different programmes/grades and the multidimensional nature of degree programmes

In writing programme specifications we have to distinguish between a range of different types of programme. One common distinction engineering departments have to make is between MEng, BEng and BSc programmes. There is an equal need to develop clear criteria to distinguish between different levels of performance within one programme, to distinguish between the different classifications (3rd / 2.2 /2.1 / 1), and in particular to define threshold standards. Threshold standards, with implications of certification, raise specific issues that need to be addressed separately. First I want to address the differences between programmes and classifications, and some important issues highlighted by trying to define these differences.

Table 2 of the QAA Engineering Benchmark Statement sets out the full range of "attainment targets" in detail and recognises three attainment levels - threshold, good and excellent. We are cautioned very clearly against aligning these attainment levels collectively with programme classification. It is extremely tempting though to look at the three columns, threshold, good and excellent and mentally substitute third, second and first. But many engineering departments are faced equally strongly with the need to distinguish between the three main types of engineering degree programmes: BSc, BEng and MEng. If we do start trying to decide between applying these columns to degree classification or to degree type we can see why such a simple transfer is not possible. One set of columns offers only a one-dimensional hierarchy of assessment criteria. A set of assessment criteria for different degree classifications within different degree programmes must involve a two-dimensional table for each assessment criteria heading, as shown in Figure 2.

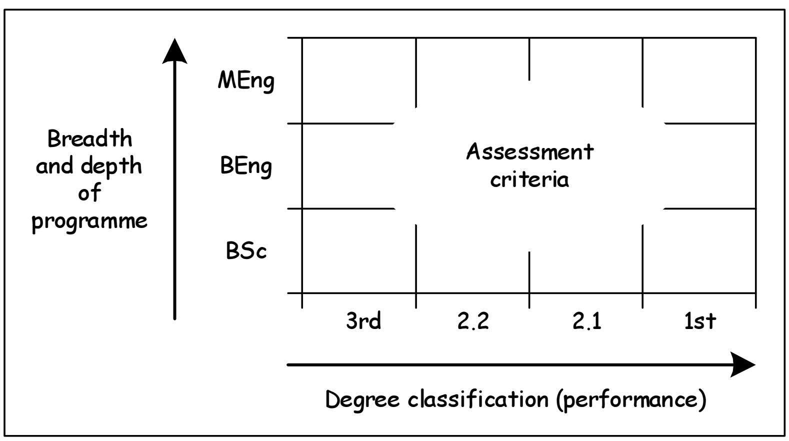

Figure 2 - A two-dimensional table for each assessment criteria heading

At this stage, trying to establish such a two-dimensional table for each assessment criteria heading might seem to be a step too far. Many university teaching staff find a one-dimensional hierarchy of assessment criteria difficult enough to adjust to. But it is clearly difficult to agree on appropriate output standards for engineering degree programmes, as shown by the differences between the many attempts in the QAA benchmark statements, the UK Engineering Council's "Standards And Routes TO Registration (SARTOR) (Engineering Council 1997), the UK Engineering Professor's Conference statement on output standards (EPC 2000), the US Accreditation Board for Engineering and Technology (ABET 2000) etc. It may be that part of the problem lies in trying to describe in a one-dimensional way

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something which is multidimensional. This multidimensionality can be seen simply from the SARTOR requirement that the MEng must differ from the BEng in breadth, depth and the degree of autonomy demonstrated by the student. BEng and MEng programmes can therefore be seen as occupying different volumes in a three-dimensional space, as shown in Figure 3. A BSc programme might occupy a volume in this space that is smaller, equal, or even larger than the BEng, but the volume occupied would be a different shape.

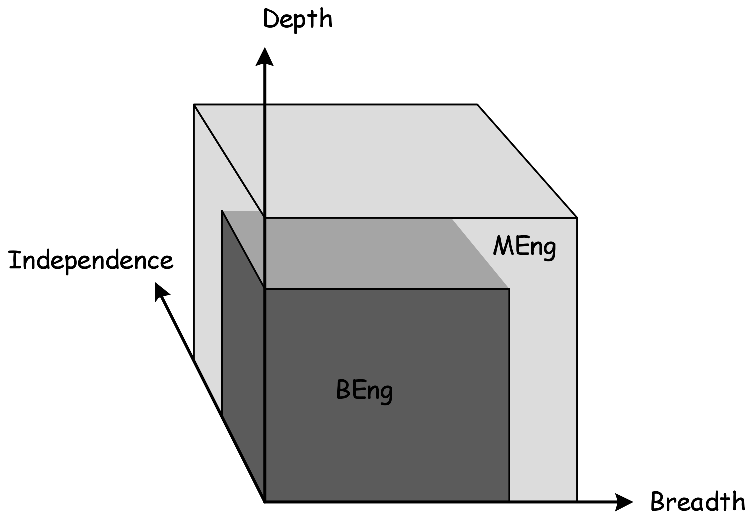

Figure 3 - MEng and BEng programmes occupy volumes in a space that is at least three-dimensional.

These three dimensions are not all that there are. Depth, for example, is not really one dimension; it breaks down into the complexity of concepts and the way in which the student is able to use concepts. There are many dimensions and the different attempts to write hierarchies of assessment criteria can be seen as different lines drawn through something that is multidimensional. Recognising the multidimensional nature of the problem may be an essential prerequisite to any chance of eventually arriving at a truly consistent way of comparing assessment criteria. We may not be ready to address this fully yet, but if we do not even recognise the multidimensional nature of degree programmes, we can fall into the trap of imposing damaging oversimplifications. One such oversimplification is to describe degree programmes as progressing through levels up, such as those described by Bloom's Taxonomy (Table 5).

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Level		Typical learning outcome
Knowledge	This is the recall of information and facts	define; describe; enumerate; examine; identify; label; list; name; quote; reproduce; select; show; state; tabulate.
Comprehension	This is the grasping of meaning	contrast; convert; describe; differentiate; discuss; distinguish; estimate; extend; generalizes; give examples; interpret; paraphrase; predict; summarize.
Application	This is being able to use information in new situations.	apply; assess; calculate; compute; construct; control; demonstrate; determine; develop; establish; examine; illustrate; modify; relate; show; solve.
Analysis	This is being able to break down information and knowledge into parts to understand the structure and then make inferences and conclusions.	analyse; classify; compare; connect; divide; explain; infer; order; separate.
Synthesis	This is more than analysis it is being able to create and combine enabling deductions to be made	adapt; anticipate; compare; compose; contrast; create; design; devise; formulate; generalize; generate; integrate; model; modify; plan; reconstructs; revise; structure; synthesize; validate.
Evaluation	This is being able to judge the value of theory, make choices on reasoned argument. Being able to discriminate between ideas	assess; compare; conclude; criticize; critique; decide; discriminate; evaluate; interpret; judge; justify; recommend; reframes; select; summarise; support; test.

Table 5 - Bloom's hierarchy of learning, and the associated learning outcomes. As one progresses from Knowledge through the other levels to Evaluation, you advance through higher levels of learning, which require more complex cognitive processes. (based on *Taxonomy of Educational Objectives, Cognitive Domain Bloom et al* ***1956)***

In the worst examples, academics are told that level 1 should be characterised by words relating to lower order thinking, such as knowing, while level 3 (and M) modules should be characterised only by words associated with higher order thinking, such as synthesis and evaluation. This is a picture of a degree programme involving acquiring a lot of knowledge in the first year and then engaging in progressively higher order thinking with respect to this material, without acquiring new information. This model is depicted in Figure 3.

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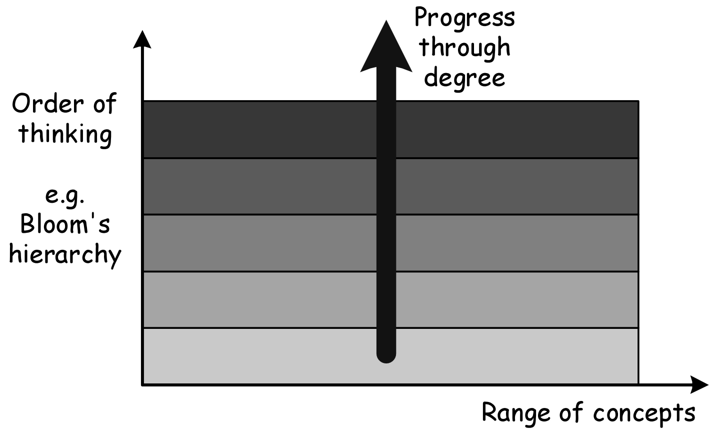

Figure 4 - Over-simplistic view of degree programme as working up from basic knowledge at the start to higher order thinking, where, e.g., “stage 3” must be entirely at “level 3”.

This model is untenable on two counts. First, the idea that level 3, for example, can only concern dealing with concepts at high levels in Bloom’s taxonomy, e.g. synthesis and evaluation, is invalid, in mathematical sciences and engineering at least. There are many concepts that are inherently extremely difficult to grasp. It would be totally unrealistic to expect most undergraduate students to even comprehend some concepts associated with modern cosmology or particle physics for example. How we operate with concepts is one dimension; the complexity or difficulty of concepts is another. We may not yet have some systematic measure of the “difficulty” of concepts, and “difficulty” itself is probably not a single dimension itself; there are many different aspects of a concept that can make it difficult to comprehend. The second reason why the model shown in Figure 4 is untenable is that it completely ignores prior learning.

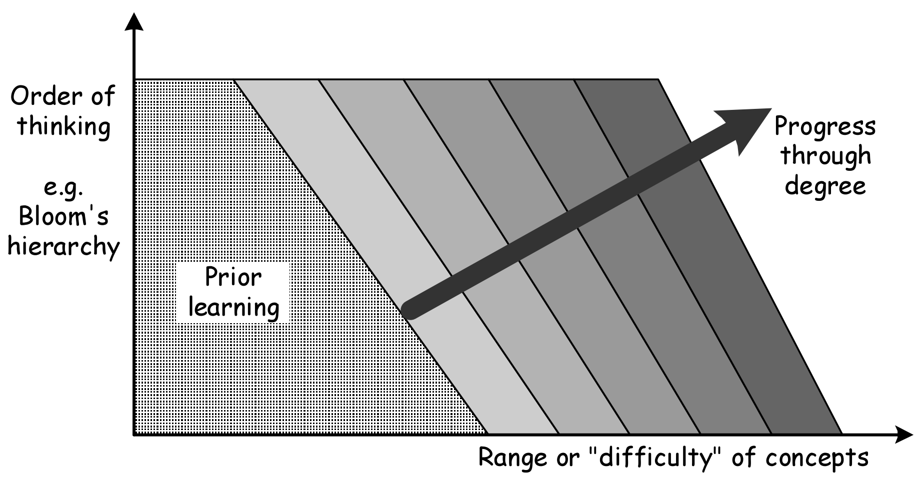

Figure 5 -A degree programme involves acquiring new knowledge throughout as well as applying increasingly higher order thinking skills to existing knowledge, and students arrive able to analyse, synthesise and evaluate, for example, with some concepts. (This is still greatly simplified.)

Much of the literature on learning in higher education seems to regard learning as only starting on the day of entry into university. To be sure, it is often emphasised that deep learning involves relating new information to prior learning, but little further attention to the

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fact that prior learning has occurred. The reality is that the 3 years of a typical undergraduate programme are but one stage between at least 18 years of constant learning at home, and in primary and secondary education, and many decades of further learning. Bloom's taxonomy applies equally well to concepts addressed in primary and secondary education. Students already come to university with an enormous range of previously acquired conceptions. Some concepts are only grasped at the knowledge/comprehension stages, but some are already used at the synthesis and evaluation stages. A degree programme should build on this, acknowledging where concepts can already be used creatively, developing the use of concepts grasped at the knowledge/comprehension stages, and introducing new concepts. A more realistic description of the progression that a degree programme should involve is shown in Figure 5, but it should be remembered that this is still very simplistic and does not show the many other dimensions, such as autonomy. If we fail to recognise this prior learning, we cannot **align** first year study to the abilities and expectations of the students. The result can only be a profound dislocation, involving confusion and lack of appropriate challenge. Visualising a degree programme as developing as in Figure 4 can result in very content heavy but intellectually unchallenging first years that encourage surface learning.

If we accept the multidimensional nature of degree programmes, then we cannot expect any descriptions, such as the benchmark statements, which do not explicitly address all these dimensions, to provide an adequate description even of the space in which a degree programme sits, never mind the shape it might occupy in that space. In engineering at present we have the QAA benchmark statement, SARTOR, ABET, EPC output standards etc., but these are just lines drawn through that multidimensional space, with no really systematic way of even determining how the different lines relate to each other, and with a strong feeling that there may be important, though difficult to describe, dimensions that they do not address at all. They do, however, represent a start on a process of thinking more analytically about curricula.

5.2 References

There are a number of consortia that deal specifically on developing policy on levels and credit accumulation:

SEEC: Southern England Consortium for Credit Accumulation and Transfer, http://www.seec-office.org.uk/

NICATS: Northern Ireland Credit Accumulation & Transfer System Scheme, http://www.nicats.ac.uk/

NUCCAT: The Northern Universities Consortium for Credit Accumulation and Transfer, http://www.nuccat.ac.uk/

Bloom BS et al. (1956) Taxonomy of educational objectives: The classification of educational goals: Handbook I, Cognitive Domain. New York.

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6 Constructive Alignment – and why it is important to the learning process

6.1 What is Constructive Alignment?

Constructive Alignment, a term coined by John Biggs (Biggs, 1999) is one of the most influential ideas in higher education. It is the underpinning concept behind the current requirements for programme specification, declarations of intended learning outcomes (ILOs) and assessment criteria, and the use of criterion based assessment.

There are two parts to constructive alignment:

- Students construct meaning from what they do to learn.
- The teacher aligns the planned learning activities with the learning outcomes.

The basic premise of the whole system is that the curriculum is designed so that the learning activities and assessment tasks are aligned with the learning outcomes that are intended in the course. This means that the system is consistent.

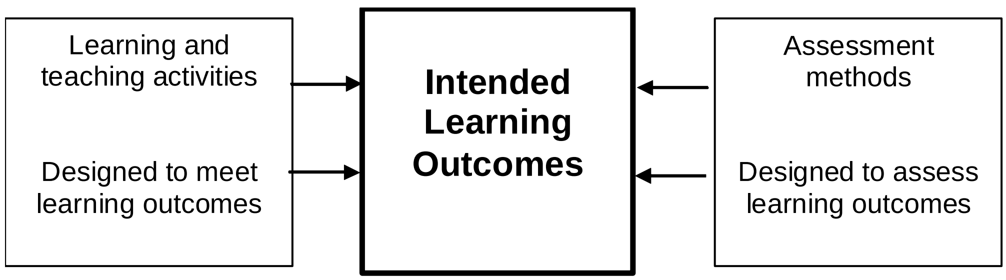

Figure 6 - Aligning learning outcomes, learning and teaching activities and the assessment. Adapted from Biggs(1999) p 27

Alignment is about getting students to take responsibility for their own learning, and establishing trust between student and teacher. If students construct their own learning and this takes place inside the students' brains, where teachers cannot reach, then the real learning can only be managed by the students. All teachers can do is to create an environment which is encouraging and supportive of students engaging in the appropriate and necessary mental activity. We can do this by providing the pieces and specifications of what the students must become able to do as a result of modifying their cognitive structures, and set up or suggest activities that students can use to achieve these changes or intended learning outcomes.

We must have a clear idea of what we want students to be able to do at the end of a unit of study, and communicate these intended learning outcomes to students so they can at least share in the responsibility of achieving them. However, we know that students will inevitably tend to look at the assessment and structure their learning activities, as far as they are able, to optimise their assessment performance. We must therefore make sure that the assessment very obviously does test the learning outcomes we want students to achieve, that, by being strategic optimisers of their assessment performance, students will actually be working to achieve the intended learning outcomes. In other words, the ILOs, the learning activities and the assessment must all be aligned. The assessment criteria should differ from the ILOs only in so far as that they might give more detail of performance levels required for specific rewards. If we tell students that we want them to achieve something (ILOs) and then assess them against assessment criteria that do not match, they will feel cheated and will

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become cynical strategic surface learners. Alignment is really simply a matter of honesty and fairness that establishes the trust required for students to be confident that they can manage their own learning.

6.2 Achieving Constructive Alignment

Constructive alignment is actually extremely difficult to achieve: it is virtually impossible to get it right first time, through so-called rational top-down course design. That is why the ILTHE, for example, emphasises the importance of the reflective practitioner; the teacher who constantly modifies course design and delivery, constantly trying to work closer to the unattainable perfect constructive alignment. Moreover, this is not simply a matter of modifying learning activities and assessment. Sometimes, in the delivery of a module, assessment outcomes, or our work with students, reveal learning outcomes we had not anticipated but that we nevertheless recognise as valuable. These emergent learning outcomes need to be identified and incorporated into the intended learning outcomes. Constructive alignment cannot be achieved or maintained in an institutional system that does not allow frequent modification of module descriptions (Figure 7).

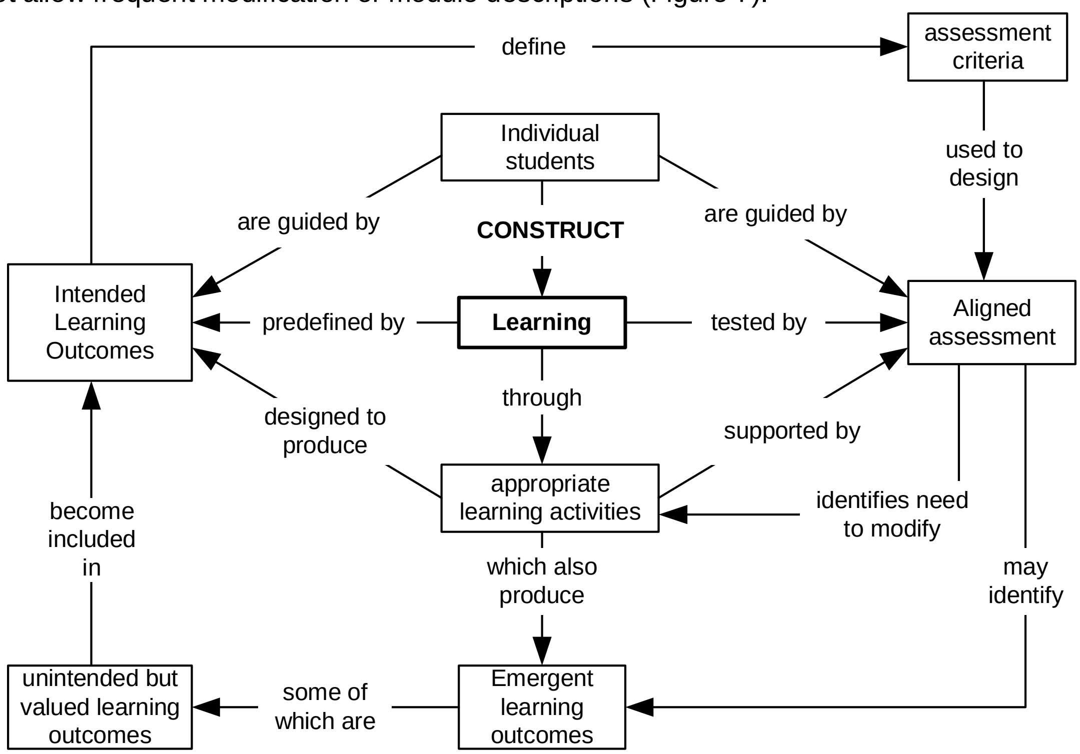

Figure 7 - Concept map illustrating the main ideas put forward by Biggs and the relationships between them in the Curriculum Design Process.

If we are taking a single component of a programme, we can 'Constructively Align' that course by tackling the following steps:

- Define the learning outcomes.
- Select learning and teaching activities likely to enable the students to attain the outcomes.
- Assess the students' outcomes and grade the students learning.

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6.3 Setting the Learning Outcomes

This is how we are intending to define the course for our students, (though the students maybe influenced by the assessment). We need to think about the learning as what we want the student to do. We want the students to 'behave' like engineers making competent decisions in their future careers; the outcomes should mirror this. As we want the students to do things, then it makes sense for the outcomes to be specified in terms of verbs, this will also have the added benefit of leading us to design assessments that measure the objectives.

In considering the verbs to describe learning outcomes, we can return to the work on levels and the different levels of learning. We will probably want to mix the levels of learning required having some lower level outcomes that deal with the basic facts, as well as having higher levels that require the students to deal with new situations. This will provide us with the basis of the learning outcomes for our unit.

For example if we are aligning a course on networks, then our low level outcomes would be to state Kirchhoff's Law and Thevenin's Law. However, we also would want extended understanding where we would expect students to apply these laws to new contexts, perhaps designing their own circuits.

6.4 Selecting Learning and Teaching Activities

We need to consider activities that will cause the students to engage with the learning. Course documentation usually defines the amount of study, in many institutions this is defined in terms of contact time in lectures and tutorials. However, we have seen (See Section 1 –Learning Styles) that these are not the most effective way for the majority of students to learn as they can adopt passive learning approaches. Consequently, we need to consider approaches that require participation that is more active and encourage more high-level learning. Therefore, if we want students to consider that we expect them to synthesize concepts and link them together then we should consider assessment activities that encourage that behaviour, such as a mini-lab project, or a case study such as designing and costing a new power plant in a location with particular requirements.

6.5 Assessing and Grading the Student

We need to ensure that we assess the learning outcomes. If we are seeing how the students apply knowledge of the environment and environmental legislation to new situations then that is what we should assess. However, we should also consider how we assess the student and arrive at the final grade. We can take two approaches to assessment. The first, the traditional norm assessment model, is where we break down the students 'learning' into their responses to individual questions and sub units, assigning marks to their 'correct' responses. The problem with this is that it encourages students to play the assessment game, and go for a mark 'trawl' in exams, trying to pick-up bits of marks here and there. The alternative is criteria-based assessment where grades are awarded according to how well students meet the desired learning outcomes (see Table 6 for an example).

Objectives	Grading Criteria
Grading will be based on you attaining the following criteria: • Demonstrate appreciation and understanding of the delicate balance in the environment. • Demonstrate understanding of sustainability and related issues in the environment.	Grades will depend on how well you can demonstrate that you have met all objectives: *A: Awarded if you have clearly met all the objectives, displaying deep knowledge of the content, creative thinking, applying the concepts effectively to new situations* *B: Awarded when all objectives have been met well and effectively*

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• Have knowledge of relevant UK and EU environmental legislations. • Relate specific pollution control technologies to industries. • Appreciate the range of engineering related environmental problems.	*C: Awarded when the objectives have been addressed satisfactorily, or where evidence is strong for some objectives, but weaker in others.* *F: Less than C, or work not submitted*

Table 6 - A constructively aligned assessment scheme (adapted from Biggs 2003)

Nearly all degree programmes will require the criteria grades to be converted to a grade, this is fairly straightforward; a good 'A' gets 78%, a bare 'A' gets 70%, and so on. For a more in-depth discussion of assessment, see Biggs(1999) Chapters 8 and 9.

6.6 Advantages of Constructive Alignment

Constructive alignment encourages clarity in the design of the curriculum, and transparency in the links between learning and assessment. In a truly Constructively Aligned curriculum it facilitates deep learning as the activities are designed for that purpose. This should improve the quality of learning and graduates in our profession.

6.7 Further Reading

Biggs, J. (1999): Teaching for Quality Learning at University, (SRHE and Open University Press, Buckingham)

Jackson, N. (2002) QAA: Champion for Constructive Alignment! (Imaginative Curriculum Symposium, November 2002)

Biggs, J. (2003): Aligning Teaching and Assessment to Curriculum Objectives, (Imaginative Curriculum Project, LTSN Generic Centre)

7 Useful links and recommended reading

James Atherton's web site covering learning and teaching theory (www.dmu.ac.uk/~jamesa/learning/) is a more comprehensive site than this one. It contains much not commented on here, but is generic in its coverage, whereas this site has a bias towards an engineer's view.

"Teaching for Quality Learning at University" by **John Biggs** is very readable, combining a solid research base with a very practical approach, and is an excellent place to start.

"On becoming an innovative university teacher" by **John Cowan** is let down by its title: it should be called "how to make your students think". It is a truly excellent book written by an engineer, with clearly explained principles illustrated by numerous practical examples throughout. If you have heard of reflection but aren't sure how it works or how to get your students to do it, this is the book to read.

"Rethinking university teaching" by **Diana Laurillard** is the book everyone should read before using computer aided learning in any form. Too much use that is made of computers in teaching is lead by the technology or simply what looks impressive. Coming from a mathematical science background, Laurillard starts with a very systematic analysis of the learning process leading to a specification of what any system, including computer aided, needs to do to help a student learn.

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