Introduction to Learning and Teaching

an Engineering Subject Centre guide by Jane Pritchard

About the series:
This is one of a series of peer reviewed booklets looking at various aspects of teaching and learning aimed at all those involved in engineering education. The complete series is also available on our website.

About the centre:
The Engineering Subject Centre is one of the 24 subject centres that form the subject network of the Higher Education Academy. It provides subject based learning and teaching support for all engineering academics in the UK.

The Centre’s Mission is:
to work in partnership with the UK engineering community to provide the best possible higher education learning experience for all students and to contribute to the long term health of the engineering profession.

It achieves this through its strategic aims: sharing effective practice in teaching and learning amongst engineering academics; supporting curriculum change and innovation within their departments and informing and influencing policy in relation to engineering education.

The Higher Education Academy Engineering Subject Centre
Loughborough University
Leicestershire
LE11 3TU

tel: 01509 227170
email: enquiries@engsc.ac.uk
web: www.engsc.ac.uk

an engineering subject centre guide
Author’s biography

Jane Pritchard graduated from the University of Bath in 1995 with an honours degree in Materials Science and Engineering and subsequently a PhD in 1999 and has researched in a range of materials. Jane was a Lecturer in the Learning and Teaching Centre, University of Glasgow for four years with the final year on release to the Higher Education Academy Engineering Subject Centre. Here her work focused on new lecturers, part time teachers and working with educational development units across the UK HEI engineering sector. Jane has just been appointed as an Academic Staff Developer at the University of Bath and is the Director of Studies for the PG Certificate in Academic and Professional Practice. Her research interests include looking at the role of education in supporting social change and social justice and the influence of intensive courses on teachers and learners.

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Introduction to Learning and Teaching

Overview
This booklet is designed to be a brief introduction for those new to teaching and a refresher for experienced lecturers into the totality of parts that constitutes teaching in Higher Education. The reader can dip in and out as they feel appropriate. Each section provides an introduction to the topic and a description of terms and examples from engineering education. At the end of the booklet in ‘Where next?’ the reader is directed to additional Subject Centre resources, websites, journal papers and videos that explore the topic further. These resources give far greater depth to the topics introduced by this booklet. Topics covered in this guide are:

- Designing learning
- Student learning
- Assessment and feedback
- Evaluation of learning and teaching
- Large group teaching
- Enquiry based learning

We start by looking at designing learning in the context of a module, although the ‘rules’ can equally be applied to a single session such as a lecture or lab. We then move on to look at some of the language we encounter at this early stage, such as “aims” and “learning outcomes”. Links to level descriptors for modules and programmes with the UK Standard for Professional
Engineering Competence (www.engc.org.uk/ukspec) are made in *Where next*.

No introductory booklet would be complete without looking at some of the work on student learning and how this relates to our teaching. Moving on we come to assessment and feedback of the student’s learning and explore formative and summative approaches. We then look at evaluation, which brings us full circle back to design - the outcomes of evaluation influence our design as this is an iterative process of constant reflection and development based on responses to questions such as:

- how do we know what went well?
- what will we do differently next time and why?

We will finish with a look at two approaches to teaching: large group teaching (lectures) and enquiry based learning. (Note: small group teaching and learning technologies will be covered by other booklets in this series and so are not dealt with here.)

**Designing learning 1 – Introduction**

Design is as fundamental to teaching as it is to research and engineering practice. Let us consider the design of a module: whether you are designing a lecture, a module or a programme the elements that contribute to good learning and teaching are similar.

It is key at this stage for all involved in designing modules to be aware that in accredited engineering programmes the module must map to the overall programme specifications. (Note: there is a tool currently in development to support academics in
this mapping exercise, see www.engsc.ac.uk/er/pdp/easimap.asp for further details.) This paperwork should be in the department somewhere! We shall continue assuming you have located this and are aware of the way your module fits into the overall programme.

As with programme design, the pervasive trend in HE and particularly in engineering education (through the professional bodies adopting this approach to their accreditation procedures) is constructive alignment (Biggs, 1996).

Where the intended learning outcomes, assessment and teaching activities are aligned, i.e. what the student will be able to do by the end of the module (learning, the intended learning outcomes) with the how we know/they know they are able to do it, the evidence for the learning (assessment) with an appropriate learning and teaching activity to enable the learning to come about.

When setting out to design or re-design a module it is important to engage with your institutional policies for development/change to modules, such as module approval forms. These should be available through your institution’s website.

**Designing learning 2 – Where do I start?**

The starting point for any module design is with a question that is for both you the teacher and the student. The first question to ask is:

**What do I want my students to be able to do by the end of this module?**
This is termed the *Intended Learning Outcomes (ILOs)* for the module. The focus here is on the learner - traditionally modules were developed only as lists of what was going to be taught (objectives), so there has been a shift from teacher to learner. Consider writing five or six ILOs for a module.

Express ILOs using an active verb (what students will be able to do) + object + a qualifying phrase to provide a context.

For example: students should be able to write accurate laboratory reports that conform to the conventions of the subject.

The verb indicates the level of learning. Sometimes we just want learners to have some basic knowledge, so verbs such as recall and state suffice. However, when we want higher learning, we can use justify, evaluate or analyse as the verb. For a list of verbs relevant to levels of learning see www.senate.gla.ac.uk/academic/ilo/guide.html.

**Aims** are broad statements of what learning you hope to generate, e.g. this module will equip you with a fundamental understanding of fluid dynamics.

**Objectives** are statements of what you are going to teach.

**ILOs** are statements of what a student should know and be able to do at the end of the course. This is what you assess. Outcomes are expressed as active verb, e.g. by the end of this module you will be able to analyse experimental data and justify your chosen material for the design.
Student learning
There is a vast and highly engaging body of research literature related to student learning. The most common terms we hear used today are *surface* and *deep*, but there are many other conceptions around (see the suggestions for further reading given at the end of the booklet). However, we shall look at the surface/deep discussion that is prevalent in engineering education and is a good introduction to the topic.

**Surface approach:** Intention to complete task. Memorising information.

**Deep approach:** Intention to understand. Relate evidence to conclusions.

**Strategic approach:** Intention to obtain highest possible marks. Use previous exams to predict questions (Atherton, 2005)

**WARNING:** Students adopt an approach to learning, they are not surface or deep learners (i.e. these are not inherent attributes of the learner). Although they may have a preference, students can and do take different approaches in different contexts.

As a teacher, the context of your module (e.g. the ILOs and assessment strategies) will shape the student’s approach. For example, if the ILO verbs are to state and recall and the assessment based on memorisation tasks then the student needs only to take a surface approach. However, if you have used active verbs (i.e. ‘analyse’ and ‘justify’) the student needs to both memorise *and* apply the knowledge. Thus the student is encouraged to take a deep approach and, like students, teachers can also adopt different approaches to their teaching.
Student learning – examples

Two studies that highlight how context influences the student’s approach to learning in engineering are reported by Case and Marshall (2004). The work by Case looked at 11 second-year students on a chemical engineering course at a South African university, whilst Marshall focused on 13 students on a first-year engineering foundation course in the UK. The studies showed that students in both cases adopted an approach to their study in response to the course context but warn that in some cases students will not develop an understanding of a topic and only learn the processes. They finish by saying that “Given the strong focus in engineering and science courses on the ability to solve problems (often, as evidenced in assessment, explicitly valued more than understanding concepts), this might be a sensible strategy for helping students to succeed. However, the danger lies in that students might thereafter struggle to make the appropriate adjustment to a conceptual deep approach when required” (p.613).

Trigwell, Prosser and Waterhouse (1999) showed the relation between the teacher’s approach to their teaching and the student’s approach to their learning. When teachers describe their role as a transmitter of knowledge, the student adopts a more surface approach, whereas when the teachers describe teaching that focuses on the learner by engaging them in activities and dialogues then the student is more likely to adopt a deep approach to their learning. The impact of this work is to see that improving student learning requires focus, not only on developing the learner but on developing the teacher as well.
Assessment
We can start by asking,

What types of assessment do you currently use and why?

Are they appropriate to the module, i.e. what is it we would like students to be able to do with the ILOs? We often use assessments because of tradition and our familiarity with them, but they may not always assess the ILOs (i.e. they may not be valid). We must also ensure that the assessments are reliable (i.e. that two assessors would arrive at the same grade independently). Often reliability has been favoured over validity, although such compromise is unnecessary. Clear marking schemes for the assessment allow both the marker and the student to engage in the assessment in a meaningful way to enhance the student’s learning during the module.

In the section on designing learning, constructive alignment was introduced. You can draw up a grid of ILOs vs. assessments for your module which can also be given to the students to encourage them to engage with the module. This grid will allow you to see if you are over/under assessing an ILO and any gaps (note: this is an iterative process). A common gap is if a presentation is being used in the assessment regime but there is no ILO for the student to be able to communicate effectively both orally and in writing. Consider allowing opportunities for students to experience the assessment formatively prior to the summative stage. (Note: students are powerful agents in assessment. See self and peer assessment as a way of supporting their learning, especially at the formative stage www.brookes.ac.uk/services/ocsd/firstwords/fw25.html).
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Summative assessment provides overall evidence of the achievement of the student and of what they know, understand and can do, by assigning a value to what the student achieves.

Formative assessment provides feedback to learners in order to help them learn and feedback to teachers for deciding how a student’s learning should be taken forward.

(Sadler, 1989)

Assessment – examples

Baillie and Toohey (1997) report on the impact on learning of changing the traditional two-hour exam assessment of a second year materials module for engineers to an open-book exam. The open-book exam confers advantages of being more authentic of real life in that the exam is not a test of memory but rather an application of knowledge. There is evidence to suggest that this form of assessment encouraged the students to take a deeper approach to their learning, however, there was also some resistance that was linked to previous assessment experiences and expectations of the students. The authors go on to call for such assessments to be more integrated into the student’s experience as application of knowledge is more reflective of practice: ‘However the necessity of having assessment methods support the teaching and learning goals of the course cannot be over-emphasised when it comes to making a positive impact on student learning’ (p. 47).

Turns and Atman (2005) show how they have used concept maps as a way of assessing student learning at module and programme level for engineering students. They have applied this approach on a range of scales of assessment tasks, from gauging students’ current understanding of a topic to using them in final exams, as well as a reflective tool for learners during the programme. They discuss some drawbacks of the approach and go on to discuss the many benefits where both learner and teacher are able to see connections between areas of study both in a module and the programme and to explore conceptual understanding. The student can see what they are learning as well as the gaps both during the process of constructing the map as well as afterwards. The paper describes the range of uses of the concept maps as well as the impact on the students’ learning experiences. ‘Concept maps should be seen as a valuable component of an assessment toolbox’ (p. 172).
Feedback
Intrinsically linked to assessment is feedback/feedforward.

**Feedback** - comments on a completed work that the student cannot repeat. The comments are useful to inform the student about strengths of their work and areas for further development in *future* assessments.

**Feedforward** - mostly what has been called feedback, but where the student has an opportunity to respond to the 'comments', (e.g. a formative hand-in where the student can respond to the comments for that assignment).

(Knight, 2006)

Like assessment, feedback is a rich source of literature. A good starting point is the *Seven Principles of Good Feedback Practice* (Nicol and Macfarlane-Dick, 2004).

(Note: it is not necessary to engage in all seven simultaneously.)

1. Facilitates the development of self-assessment (reflection) in learning, e.g. get students to identify what they would like feedback on.
2. Encourages teacher and peer dialogue around learning (e.g. electronic voting systems, see p. 13 of this booklet for an example of this.)
3. Helps clarify what good performance is (goals, criteria, and expected standards), e.g. get students to mark work against the criteria or bring in past work and ask students to assess it against the criteria.
4. Provides opportunities to close the gap between current and desired performance, e.g. identify action points for them to respond to, to improve the work.
5. Delivers high quality information to students about their learning, e.g. consider only giving three pieces of feedback, positive, improvement and an example (PIE).
6. Encourages positive motivational beliefs and self-esteem (e.g. only give the marks to the student after the feedback has been responded to in the next piece of work).
7. Provides information to teachers that can be used to help shape the teaching (e.g. ‘minute papers’ to gain feedback from students at the end of a session).

Feedback – examples

Russell and Bullen (2005) describe an approach they have taken to assessing and providing feedback for students on weekly-assessed tutorial sheets (WATS) using computer assisted assessment for a Fluid Dynamics and Thermodynamics module for first year undergraduate students. They report the structure of the course and the assessment and feedback protocol. The weekly tests enable the student/teacher to identify areas to work on and to ensure new knowledge is being built on firm foundations compared with previous assessments. Each WATS contains four or five questions, plus linked supplementary questions. Each one is marked and the overall mark contributes to the final grade. Each sheet has unique data, thus deterring plagiarism amongst the students. Evidence is presented showing how regular short assessments with timely feedback have a beneficial impact on student learning. Examples of the sheets are shown along with how it worked in practice in the mini-project report (Engineering Subject Centre, 2005).

O’Moore and Baldock (2007) introduced Peer Assessment Learning Sessions (PALS) into a Civil Engineering numerical-based course on Reinforced Concrete Design and Hydraulics. They describe the benefits of this approach in terms of being efficient in providing feedback (formative and summative) for students and staff as well as supporting the development of key skills and graduate attributes. Most importantly, students obtain summative and individual formative feedback very rapidly. Both staff and students report a positive experience of this approach to supporting learning. The approach has been used across different years and modules. The assessment is carried out in a ‘traditional’ class setting against worked solutions following a template marking scheme. After class the lecturer reviews the marks and acts as a moderator. This enables the lecturer to see how the class learning is progressing and identify areas to work on in future.
Evaluation
Evaluation is fundamental to improving learning and teaching through a process of enquiry into our teaching (see principle seven on page 10). It is often handled at the end of a module through module evaluations (summative evaluations) but we shall look at some approaches to formative evaluations that we can all do anytime in our teaching that are suited to your needs at the end of a lecture. For example, after you have taught a session take a few minutes to ask yourself:

- What went well and how do you know that?
- What didn’t go well and how do you know that?
- What will you do differently next time and why?

**NOTE:** The answers to these questions is simply the data. It is the analysis of data and the decisions you make that is the evaluative process. You need to decide if you are looking for feedback on your teaching and/or on the students’ learning and then how you will respond to this.

Classroom Assessment Techniques or ‘minute papers’ (Angelo and Cross, 1993), are a quick way of gathering feedback on both the learning and teaching. Put the questions up on the board and ask students to write down their responses on paper, anonymously and hand them in as they leave. Remember your response to this is the evaluative part and students will engage in the process and see value in it as long as you respond.

**Example 1 – Evaluation for learning and teaching**

1. What was the most useful or meaningful thing you learned during this session? (FOCUS ON STUDENT – you can see if their learning matches your expectations of the session)
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2. What question(s) remain uppermost in your mind as we end this session? (FOCUS ON STUDENT)
3. What was the ‘muddiest’ point in this session? (In other words, what was least clear to you?) (FOCUS ON YOU – this is what you respond to either at the start of the next session or via email etc.)

Example 2 – Evaluation for teaching
1. What would you like me to stop doing?
2. What would you like me to start doing?
3. What do you want me to continue to do?

Evaluation – examples

Hall et al. (2002) show how using class evaluations in a lecture helped to support the lecturer and the student. Using an extension of the classroom assessment technique, staff asked students to identify the muddiest/most confusing point in the lecture on a card (anonymously) and hand them in at the end of the session. Some also asked students to list the most important aspect as well. Initially students did not see the benefits but as the lecturers started to respond to the muddy points for the whole class via the website, the students began to see the value and saw the cards as a way of getting instant feedback. The lecturers also reported their positive experiences of pursuing this approach as a way of gathering formative evaluation of the teaching to support the students’ learning during the module.

Ingerman, Baillie and Head (2004) describe an approach to evaluating a large first year professional skills module. The module underwent a significant change in format, moving from a lecture based course running over two semesters to a one week intensive course followed by group projects over one semester. As part of the module development an evaluation was conducted in collaboration with an external evaluator. The evaluation was undertaken on many levels in terms of student learning relating to the learning outcomes, the students’ experiences of the different learning environment compared with other modules and lessons learnt to enhance the module for the next academic year. A number of approaches were used for collecting data such as questionnaires, focus groups and interviews with students, the teaching assistants and faculty directly and indirectly involved in the module. A planning wheel for evaluation was developed that works alongside the teaching of the course and shows how evaluation is integral to module development rather than an afterthought.
Large group teaching
We often talk about lecturing when we think of large group teaching and it dominates much of engineering education. A lot of criticism is levelled at lecturing however, the reality is that, for some aspects of modules, it is a good, cost effective way of delivering information to a large number of students. However, there are things that we can do to improve the experience for both students and lecturers, to make the lectures more interactive, and to enable both parties to gauge the learning:

1. Ask them to work on a problem in pairs you have just worked through in your lecture so they get an opportunity to apply the lecture material and you get a rest.
2. Ask them to write down one or two precise questions on the lecture material so far and then share these questions with two to four people around them, then ask for questions from the whole group.
3. Use in-class voting systems to gauge students’ learning thus far and enable students to gauge the whole group’s learning – see page 14 for an example of this.

Effective lecturing is not just about delivering well-prepared coherent material, it is also about enabling students to engage with the material through some form of interaction in the lecture itself. A common pitfall of lecturing is giving too much information so students are just passively absorbing it. How do you think this form of lecturing would affect a student’s approach to learning in that session? A combination of content delivery and interaction can encourage students to take a deep approach to their learning in the lecture and is motivational for both you and the student.

An excellent short film on teaching large groups can be found at www.learningandteaching.dal.ca/vhtest/largeclasses.html.
**Large group teaching - examples**

Boyle and Nicol (2003) describe the use of in-class voting systems (or ‘classroom communication systems’) to support student learning and feedback in a large first year Engineering Mechanics class of around 120 students. The class is clustered into groups of four and the session is a mixture of mini-lecture, question and answer sessions using the voting system, videos and problem solving. The voting system allows students and teachers to identify their understanding as well as serving as a tool to promote discussion by comparing responses across the whole group. Students report that these interactive sessions enabled them to enhance their understanding of the concepts compared with a ‘traditional’ lecture. The approach described here also shows how peer learning in small groups as well as class-wide discussion was beneficial in supporting student learning.

Kolari and Savander-Ranne (2003) show how some variations in the lectures impacted positively on the students and lecturer in a masters level module on Phase Transformations and Heat Treatments. The aim was to change the lectures from information transmissions to sites of active learning, for example, a concept test in week one which informed both the lecturer and the students of their background knowledge of topics to be covered in the course. Pre-lecture assignments were used to enable students to recall the relevant principles for the upcoming lecture, to orientate the students towards the lecture topic and give the lecturer an insight into the group’s understanding of the topics. Each lecture started with a review of the pre-lecture assignment with whole class feedback, followed by the lecture materials and then in-lecture assignments. These were used to promote student interaction and enable the lecturer to gauge the student learning thus far in the lecture. The research showed that this approach to the lecture encouraged the students to become more actively engaged in their learning. The lecturers also reported greater satisfaction with this approach and describe how it changed their approach to teaching.
Enquiry Based Learning (EBL)
Enquiry Based Learning (EBL) covers a variety of teaching approaches (such as problem based learning and project based learning) that share the characteristic that they put the student’s enquiry into the discipline as the focus of the learning.

NOTE: We can introduce elements of enquiry at all levels of the programme as well as scales, from a five minute session within a lecture, to a final year honours project to a whole programme approach.

EBL engages the student in their learning and supports the development of critical thinking skills through the use of questions or open-ended problems. The form of the enquiry may be either provided by the teacher to the students (this is common in Problem Based Learning (PBL) where a problem is given to the students and they solve it) or the student(s) develop their own question(s) either individually, in groups or in consultation with you around a subject area and then research it themselves. Your role here is as a facilitator of learning in EBL, guiding the student through their enquiry.

Advantages of this approach include students engaging in open-ended scenarios that are student directed or developed by staff. It encourages students to take responsibility for their learning experience and work in a context more authentic of life beyond higher education (Kahn and O’Rourke, 2005). Students, in addition to developing the critical research skills of the discipline, also develop their team working skills and communication skills. EBL motivates students as they become more engaged with the topic as the enquiry is contextualised.
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**EBL – examples**

Morton (2008) describes the implementation of a problem-based approach for a robotics module in a second year Mechanical Engineering programme for 160 students. Following some introductory material (1 ½ weeks of the 11 week module) delivered by traditional lectures the class was divided into groups of five to eight students. For the next 9 ½ weeks the groups followed a pattern of investigating a given problem one week and reporting on an aspect of it the next, building a portfolio of problems and approaches to solving them over the module. Examples of problems the students engaged with include the potential for robotics, robot selection, power and actuation and reach and load. This part of the module was supported by ½ hour tutorials and students were given access to additional material. In week 11 the groups’ portfolios of work developed over the module were then presented to the whole class and industrialists as a poster which formed part of the module assessment.

Remenda (2008) describes what was done in a third year Hydrogeology course. In the classroom, enquiry based learning may be facilitated by the teacher posing a series of learning tasks (Vella, 2000) that invite students to immediately explore and enlarge on new information that has been offered. Three learning tasks were used to support Geoscience and Geoengineering students engaging in the literature. In the first assessed task, students were asked to read a review paper on the field measurements and their underlying theoretical bases and to report in a table. The second task, done in small groups, required students to read a paper, focusing on the clean-up of contaminated groundwater at four field sites, and present an oral report. As more than one group may work on a site, the presentations were determined by lottery. All groups had to hand in their slides for assessment. The final task asked students to choose a paper that interested them and to prepare a review of that paper. Themed, round-table discussions, where students had read and prepared questions on the reviews of all the group members, were the assessed product of enquiry. Students acquired the skills and confidence to read the scientific literature.
Where next?

General

Online video

Teaching at Nottingham - videos on teaching that include vignettes and academics sharing their experience and examples. www.nottingham.ac.uk/teaching/video/ [accessed 6 August 2008]

Websites

Excellent resource on all aspects of learning and teaching. www.brookes.ac.uk/services/ocsd/2_learntch/index.html [accessed 6 August 2008]

Books
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Designing learning

Website
Guidelines for writing ILOs senate.gla.ac.uk/academic/ilo/index.html [accessed 6 August 2008]

Easimap - an electronic tool to link the assessment of learning outcomes with students’ PDP records and e-portfolios www.engsc.ac.uk/er/pdp/easimap.asp [accessed 6 August 2008]

Journal papers


Engineering Subject Centre resource

Student Learning

Journal paper

Engineering Subject Centre resource
Assessment

Journal papers


Engineering Subject Centre resource

Feedback

Journal paper

Evaluation

Websites

Large group teaching

Conference paper

Website
Examples of approaches to large group teaching are at www.nottingham.ac.uk/teaching/resources/methods/largegroup/ [accessed 6 August 2008]

Books


Enquiry Based Learning

Websites
Aalborg University Unesco Chair (problem based learning in engineering) www.ucpbl.net/ [accessed 6 August 2008]

McMaster University Centre for Leadership in Learning www.mcmaster.ca/cll/inquiry/whats.unique.about.inquiry.htm#2 [accessed 6 August 2008]

University of Glasgow overview of EBL www.gla.ac.uk/services/learningteaching/goodpracticeresources/enquirybasedlearningebl [accessed 6 August 2008]
University of Manchester Centre for Excellence in Enquiry-Based Learning www.campus.manchester.ac.uk/ceebl/about/ [accessed 6 August 2008]

Book
References


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Author’s biography

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