Helping students to identify and achieve appropriate learning targets

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Abstract In order to support students with a wide range of attainment expectations, within a common first year of a range of engineering programmes, intending learning outcomes have been set out in detail at different levels and support mechanisms put in place to help them plan their own learning targets.

Keywords assessment criteria; attainment levels; mixed attainment; progression; SARTOR

Engineering departments face a number of conflicting pressures. A national need for qualified engineers and demand for widening participation in higher education has led to attempts to increase, or at least maintain, the number of students on engineering degree programmes. Unfortunately, a declining interest in studying engineering, at least in any traditional sense, among school leavers has forced engineering departments to be less selective and take in increasingly diverse ranges of students, in terms of ability, motivation, prior learning, aspiration, etc. Constant pressure to reduce the cost per student leads to reduced staffing levels, making it impossible to split students up into separate groups. Lecturers are faced with larger groups of students operating at increasingly wide ranges of attainment. The trend in this widening range is towards increasing numbers of students who, as well as being weak in prior subject knowledge and understanding, have a weak understanding of the learning process they are trying to engage in, have poor study skills, and need much more personal support than many lecturers are used to providing.

Alongside this, the Engineering Council and the professional institutions have responded to a perception of declining reputation and output standards for British engineering degrees by imposing different input and content standards for MEng and BEng programmes. For example, SARTOR states that: 'The MEng should not be derived by "adding on" bits to the BEng(Hons); the enhancement is pervasive throughout the programme. On the other hand, it must be possible to identify the additional learning required beyond a BEng(Hons) by a particular individual, in order to identify the appropriate Matching Section'.[1] This implies that if MEng and BEng students are being taught together, as permitted by SARTOR, they must be working to identifiably different expectations. By extension, if students who are on BSc programmes because they did not qualify at entry for BEng are also in the group, then they must be working to identifiably lower expectations than the BEng students. Some departments will wish to retain MEng and BEng programmes while being forced to admit many students who do not qualify, and are therefore placed on BSc programmes. Few departments, however, will enjoy the luxury of being able to teach these groups separately. For early years, lecturers must therefore not only teach very diverse ranges of students in single groups but must also be able to identify the different achievements of students who subsequently proceed on different programmes. There is a good argument for teaching students on different programmes together for the first year at least. Many academics are uneasy with the idea, implicit in SARTOR, of defining degree programme output so rigidly in terms of input. Experience tells us that 'A'-level performance is not a totally reliable predictor of progress on a degree programme. If we can keep students together in the first year at least, then we can select for progression on MEng or BEng more reliably and fairly at the end of the first or second years, on the basis of performance at that stage.

Defining clear intended learning outcomes (ILOs)

If we are to teach students with a wide range of expectations together, then we must ensure that the weaker students are given clear guidance to concentrate on the 'basics'. Otherwise, these weaker students, exposed to more difficult material, can waste time and effort on things they can't do, at the expense of more basic things they could do. These weaker students are not only weak in their understanding of the engineering subject material, but are also often weak in terms of study skills and can make some very unwise decisions unless they are given strong guidance. At the same time, it is essential to stretch the stronger students, who could start to coast alongside the weaker students unless they are given clear guidance as to what extra is expected of them. However, if we are to allow ambitious students with poor 'A'-level results to earn places on the MEng or BEng programmes, or students with good 'A'-levels who, for one reason or another, can't perform as expected, to drop back onto a less demanding programme without failing altogether, then this guidance cannot be rigidly linked to 'A'-level performance or initial registration. There has to be a large degree of informed student choice.

In order to provide the necessary information and guidance at Exeter, detailed ILOs/assessment criteria have been set out at two levels, in two lists, A and B. List A comprises the threshold assessment criteria, list B the criteria for good to excellent performance. These criteria are published in module descriptions and students are constantly reminded to refer to them. An example extract from one module description is shown in Table 1. In parallel with this, all examinations are split 50/50 into sections A and B, with section A typically comprising short straightforward questions intended to test list A detailed ILOs only, and section B comprising longer and much more demanding questions on list B outcomes. The declared expectation is that all students should be able to obtain at least 80% of the marks available in section A, thereby achieving the 40% overall required to pass the examination. Section B questions should offer no easy marks however, and accumulating marks should get progressively harder. Students who have not attempted to achieve list B ILOs should find it very difficult to score any marks at all in section B. Students are advised that they should ensure that they have achieved all list A ILOs before they attempt to achieve list B ILOs. If they are struggling they should concentrate exclusively on list A and should, by doing this, at least ensure that they pass and progress,

TABLE 1 *Example of detailed ILOs / assessment criteria – extract from a module description*

DETAILED LEARNING OUTCOMES / ASSESSMENT CRITERIA *Note:* *List A comprises core outcomes that will be covered fully in lectures and must be achieved by all students to meet the minimum university requirement for progression.* *List B comprises outcomes that are EITHER more difficult to achieve OR are to be achieved by private study (or both).* *All outcomes will be assessed, and coverage of list B outcomes is essential for both BEng and MEng students*	
A: THRESHOLD LEVEL	**B: GOOD TO EXCELLENT**
Electronics . . . Use earth as a reference value for defining potential. Given the potential at one point in a single loop, determine the potential at other points in that loop. Apply the potential divider principle to two resistors in series, and the current divider principle to two resistors in parallel. Describe the construction and use of a potentiometer. Connect voltmeters and ammeters correctly in a circuit. State the ideal impedance of voltmeters and ammeters. Measure resistance. State Kirchoff's 1st law and apply it to a single circuit junction. State Kirchoff's 2nd law and apply it to an isolated single loop. Sketch Thévenin and Norton equivalent circuits and describe the properties of the component parts. Deduce the Thévenin and Norton equivalent circuits for sources, given the open circuit p.d. and the short circuit current. State the principle of superposition and apply it to simple examples. Apply nodal analysis, with step by step prompting, to 2 loop circuits. . . .	. . . Explain, and determine quantitatively, the effects that voltmeters and ammeters have on the quantities they are being used to measure. Given the parameters of a basic analogue meter movement, determine, without guidance, the modifications required to convert it it to specified voltage and current ranges. Apply Kirchoff's 1st law reliably and without prompting to circuits containing many junctions. Apply, without guidance, Kirchoff's 2nd law to multi-loop circuits. Derive Thévenin and Norton equivalent circuits for circuits acting as sources and containing many components. Use Thévenin's and Norton's theorems to simplify multi-loop circuits. Use the principle of superposition, without prompting, to find (e.g.) single Thévenin and Norton equivalent circuits for combinations of parallel sources. Apply nodal analysis, without guidance or prompting, to 2 and 3 loop circuits. . . .

even if on a different programme from the one they originally intended to pursue. On the other hand, it is made clear to students that if they wish to achieve the marks necessary to proceed on BEng or MEng programmes (averages of 50% or 60% respectively) they need to make certain that they have not only achieved all list A outcomes but also a significant proportion of the list B outcomes.

This division of ILOs into levels is not totally original, of course. GCSEs in secondary education have been defined for different tiers, and detailed definition of ILOs has long been a feature of further education, but the use of ILOs in this way in HE does seem to be novel and the use here is different from that in secondary and further education. The important point here is that the ILOs are presented for use by students to make their own learning decisions during a module. Different tiers of GCSE syllabus are linked to different assessments with different ranges of possible outcomes and teachers will often try to avoid having pupils studying on different tiers in the same class. Here all students are presented with the same assessments, with all having access to the same range of possible outcomes. Rather than teacher-controlled pre-assessment to pre-determine what students attempt, ILOs are presented to provide guidance to allow the student to make their own choices as they progress through modules. There is also a strong element of guidance as to the *order* in which all students are advised to address material, not just what material. This is particularly appropriate to hierarchical subjects where a thorough rehearsal of the use of simple ideas is helpful before combining them to form more complex ones. For example, it is helpful to ensure the ability to at least apply Ohm's law reliably to a single resistor before attempting to comprehend Kirchoff's 2nd law, or to practice applying nodal analysis to a 2-loop network before attempting more complex networks. This guidance tells students what they should do first. Those that find this easy can then move on from list A to list B. Those that find this demanding can identify where to stop and consolidate.

While the use of ILOs is also being used to define assessment criteria, the use is not the same as used in hierarchies of learning, such as Bloom's, or the SOLO taxonomy due to Biggs and Collis (see Biggs,[2] p. 37), although some mapping is possible. A more helpful hierarchy for this purpose is that proposed by Sparkes,[3] who divides ILOs into knowledge (information that can be recalled), simple skills, complex skills and understanding. List A does largely comprise knowledge and simple skills, while list B involves more complex skills and understanding, but the lists are primarily drawn up with the *structure* of the material being studied in mind. List A comprises those ILOs essential for continued study in the subject, rather than simply lower order outcomes on any hierarchy of ILO levels. It is possible that list A could include understanding (synthesis, evaluation) if this is believed to be essential for progression, and list B could include simple knowledge (comprehension) where this involves material to be covered by private study for example. The prime motivation for this split of ILOs into levels is *not* to distinguish between end of module grades, but to give student guidance. Application to assessment criteria then follows on from this simply through the need to align assessment with ILOs. The implication for assessment is not simply that examinations may comprise a computer marked 'basic' section and a tutor marked advanced section, although this may be the way in which the exam is implemented. The important point here lies in understanding where the assessment design starts. It starts with the ILOs to be assessed. Assessment methods then follow on from that, and should take whatever form is appropriate.

Implicit in this division of ILOs, into threshold and good to excellent, is the fact that we are allowing students to proceed without having achieved all of the ILOs for every module. Indeed, lecturers asked to implement this are usually horrified at first by how limited the list of threshold outcomes has to be, and complain that this means that we are letting students through having only achieved half of the 'syllabus'. But this has always been the case. If we set an examination with a choice of 5 out of 8 questions, for example, and we allow a student to proceed having scored 40% on the chosen 5 questions then what proportion of the ILOs has the student achieved? (25%?) And which outcomes? How honest is it to present a syllabus of everything you would like your students to cover and then pretend that they all understand everything in that syllabus when many have scored less than 50%, even when they had a choice of questions? By demanding a score of 80%, on short questions which cover a wide range of list A material with little or no choice, we can ensure that students have grasped rather more of the ILOs, and we know very clearly which ones have been achieved. This provides a much more sure foundation to build on in following years.

It has been suggested that the explicit setting of 'straightforward' assessment related to the threshold list A of ILOs might encourage surface learning. The first answer to this suggestion is that the list A ILOs/assessment criteria may be easy to achieve, but they do (should) not comprise mere regurgitation of knowledge. Even the simplest of assessment questions requires the students to demonstrate that their knowledge is functional. For example: students are not asked to quote the laws of Ohm, Kirchoff etc. but to apply them, albeit in simple cases. This functionality is very important, as Laurillard[4] explains in considerable detail. Secondly, many recent texts on learning and teaching in HE discuss deep and surface learning (see e.g. Entwistle[5] (ch. 4), Ramsden[6] (p. 81), Biggs[2] (p. 15), Prosser and Trigwell,[7] Marton and Booth[8] (ch. 2)), and all list a number of ways in which these two opposing approaches to learning are encouraged. Straightforward factual-only assessments are indeed listed as encouraging a surface approach, but many other influences are also listed. 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. Thirdly, the discussion of deep and surface approaches to learning focuses on the learning *process*. This is made particularly clear by Marton and Booth,[8] whose discussion builds heavily on much of the original research in this area carried out by Marton and Säljö in Göteborg and explicitly rejects individual constructivism to concentrate on process. The evaluation of process is very valuable, 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 Kirchoff's 2nd law without first developing at least a working comprehension of potential, potential difference, e.m.f., 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 Kirchoff, 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.

Making these splits in detailed ILOs/assessment criteria and in examinations is difficult for lecturing staff without any formal training as teachers. The most difficult shift for many staff is that from thinking in terms of syllabus covered, by them, to learning outcomes achieved by the students. But this is in itself a valuable step: it is the transition from focusing on what the teacher does to focusing on what the student does. This shift in the level of thinking about teaching is, according to Biggs[2] (ch. 2), essential for quality learning in any group. At first, lecturers are tempted to simply divide up their syllabus or list of topics to be covered, simply restate syllabus topics using the language of aims and objectives, or go to the other extreme of writing blanket statements that are too vague and general to be of any help to students (see Ramsden,[6] ch. 8). These ILOs, or assessment criteria, need to be phrased very clearly in terms of what the student should be able to do at the end of the module. So rather than simply naming a theory or technique, a description must be given that describes what the student can do, with some detail as to difficulty of problem and guidance to be given. Hence, in Table 1 rather than simply listing nodal analysis as a syllabus topic we state that the threshold requirement is that a first year student must be able to apply nodal analysis, with prompting, to 2-loop circuits. A good to excellent performance would be shown by applying nodal analysis confidently and accurately, without any guidance, to 3-loop circuits. Students who have attended the course and understand the terms used can then work out for themselves whether they have achieved the objectives, and can therefore start to take responsibility for monitoring their own progress.

Aligning assessment strategies

If we opt for a lot of short questions with little or no choice, and expect students to achieve at least 80%, then even if the individual questions are very straightforward indeed (and the word 'trivial' might spring to mind) this actually becomes quite a demanding test. The level may be basic, but we are demanding near-perfect achievement of ALL the threshold criteria. This approach was proposed by Sparkes *et al.*[3] in 1992: 'It is suggested that essential knowledge and measurable skills might be assessed together in one examination and "criterion referenced" with a high pass mark; whilst understanding and complex skills are assessed separately and "norm referenced".'

Writing exam papers that are properly aligned (Biggs[2] p. 141) to these differentiated ILOs does seem to take a little practice. If the ILOs have been written clearly, writing examination questions is actually extremely straightforward. The questions are already defined. For example, referring to Table 1, a type A question might provide a diagram of a very simple single loop circuit, with a voltage source and two or three resistors, one point connected to earth and each node labelled, and ask the candidate to calculate and label the electrical potential at each node. A type B question might provide a diagram of a 3- or 4-loop network of voltage sources and resistors and, without offering any hints or guidance, ask the candidate to determine the current flowing through each component. Lecturing staff often find it difficult to write the totally straightforward type of questions required for section A however; they have to learn to resist the temptation to add twists. Writing section B questions so that they have no easy parts seems to be almost as difficult, but with practice both can be achieved. In the common first year at Exeter, electronic, mechanics and materials are grouped together for the purposes of assessment into one large module in semester 1. The examination part of this module's assessment comprises two papers, A and B, at the end of the year. The timing will be discussed below. At the second attempt, the desired result was approached, with an average mark on paper A of 80% and an average on paper B of 35%. There is still room for improving the clarity of information and quality of guidance given to students. The desired outcome of 80% on paper A being seen as the threshold requirement to proceed does therefore seem to be possible. At present a pass is dependent upon an aggregate mark of 40% across the two papers, but the eventual aim is for passing paper A at 80% to become a requirement to be even allowed to sit paper B. If paper A becomes computer marked, we could move to a system where students can retake paper A several times at the end of the year, only being allowed to take paper B if they pass paper A in time. If they fail to qualify to take paper B but eventually pass paper A, they can be allowed to proceed, with a bare pass, on an appropriate programme. What this system will ensure is that all proceeding students can be guaranteed to have achieved all of a defined set of 'essential' learning outcomes across a wide range of subject areas. Not all students will have demonstrated a great depth of understanding, but they will all at least have some known foundation upon which they can build further learning.

Moving the examination for this semester 1 module to the end of the year was done deliberately, with the intention of making it clear to students that they had to retain the semester 1 learning beyond the end of the semester. It has been suggested that students could forget and then relearn at the end of the year, but even if this does happen the result is still likely to be longer term retention, and in any case work in semester 2 builds on semester 1 work and so much does genuinely have to be retained. This may appear to be more demanding than the common approach of packaging learning up into relatively small modules assessed at the end of semester – the 'integrate and dump' approach to accumulating credits. Indeed, some students complained at this apparently unfamiliar requirement. Results do not indicate that this change in timing has caused lower examination performance however. On the contrary, results seem to have been improved by this move, although proving this is difficult since other factors were changed at the same time. There are several reasons why this approach might lead to better performance. With the main assessment not looming so imminently, students may feel less pressured and more able to take their time to try to understand the material. All the authors writing about deep and surface approaches to learning, referred to above, point to evidence that students are more likely to adopt a surface approach to learning if they feel under pressure. Also, if the degree programme has any logical structure to it, semester 2 material should build on and reinforce semester 1 material. It could be argued that if this effect is helping students then the exam is not testing the learning achieved during semester 1, and we are certainly losing some ability to identify exactly when the learning has taken place. It would certainly be helpful to know exactly what learning is occurring when, and this will be the subject of future research, but knowing what students can do after graduation is rather more important than what they can do at the end of semester 1. A test at the end of semester 1 did ensure that there was some pressure on students to learn the material before starting semester 2, but a scoring strategy was adopted to reward students for what they achieve, rather than penalise them permanently for mistakes. The semester 1 module assessment was nominally split 30% on coursework, 20% on the end of semester 1 test and 50% on the end of year exam. For students who did better in the end of year exam than in the end of semester 1 test however, the weighting was automatically changed to 30% coursework, 70% exam, effectively expunging the poor test score. Hence students have a motive for working for the test, to get marks ‘in the bank’, but even if they do very badly at that stage, they still have a strong reason for working hard since they know they can redeem their position at the end of the year. Results did indeed show a significant improvement from end of semester 1 test performance to end of year exam performance.

Issues of module delivery and student responsibility

Delivering modules to groups of students with diverse personal attainment targets also requires a shift in mode of delivery. If the students are to work towards achieving differing portions of the stated ILOs, modules must be delivered in a way that permits this by allowing and supporting students working at different paces. While lectures, tutorials, laboratories etc. are still relevant, teacher-centred activities that require whole classes to move at the same pace need to be minimised. For example: tutorial and laboratory classes can be broken up into smaller groups moving at different paces, or tutorials could involve more able students in teaching others, if the lecturing staff have the skills to manage this. Since much student learning takes place outside timetabled contact periods however, there is a general need for a shift towards a more ‘resource based’ approach to the learning. In this approach students have good resources provided: handout notes, textbooks, CAL resources if available, sets of questions with solutions, lectures that hopefully provide some inspiration, staff to ask questions of, other students to work with, and very clearly set out ILOs/assessment criteria. Students then know what they have to do to achieve their own targets and they have all the resources required to do this. If this situation has been genuinely and fully created then, and only then, does it seem fair to expect students to take responsibility for their own learning. The problem however, and it is a big one, is that pointed out in the introduction above. Even when they have all the necessary tools and information, many of the students entering our degree programmes are not able to make sensible decisions and use the resources provided appropriately without a great deal of support and guidance.

Helping students to manage their own learning

In order to help students to develop their understanding of the learning process in which they are engaged, and to develop their own study skills, the normal personal tutorial support given to first year students was considerably reinforced. Supported by a series of lectures about the learning process and study skills, a process was put into place to encourage students to reflect regularly on their own study and support them in thinking through ways to manage their own learning more effectively. This involved drawing students into a weekly learning cycle[9] of reflecting on and planning improvements to their own approaches to study. The process was originally developed by the author in an individual second year module,[10] and then extended to the first year, all students and covering the entire curriculum. All first year students were asked to complete a weekly review of their learning at the end of each week throughout semester 1 and part of semester 2. This review involved filling in a form that asked students detailed questions about their study of individual modules and more general questions about their approaches to learning. These forms were collected and passed to a study-skills counsellor who provided written feedback on every form. The forms were then returned to students, within a week of their completion and before the next review, via personal tutors in weekly group tutorials. These tutorials are in groups of four to six and are half an hour long. Many tutors used the reviews and the feedback as a starting point for group discussion. Where students filled these reviews in conscientiously, an ongoing written dialogue about study skills and personal development was established with each student as an individual. The process was voluntary in 2000–2001 but is to be made compulsory for students in 2001–2002, allocating a small percentage of marks from the semester 1 Professional Studies and Skills Development module. Although the process was voluntary last year, the return rate from students was about 70%. Providing the written feedback took the study-skills counsellor about a day of each week, and this was supported for the whole year by a grant from the University's Teaching and Learning Strategy Initiative fund.

The process included an initial attitudes and expectations questionnaire in freshers' week, learning plans and reviews before and after revision periods at Christmas, end of semester 1 and Easter. It also included a much more comprehensive student self-review of skills development over the whole year, completed at the end of the year. This was in a form designed to prepare the way for future implementation of the personal development planning (PDP) as described in the QAA guidance on the development of progress files.[11]

Student responses to the process, as shown in their end of year review, were mainly very positive. Students found this self-review process difficult in a number of ways and, while many were initially resistant to being pushed into such regular self-review, most accepted by the end of the year that it had been very helpful to them. To give two typical quotes:

> 'At first, it seemed really difficult as I had never come across this method of personal reviewing. Now, after practice, I still have to think about it and it can still be difficult, but it comes more freely and honestly.'

> 'As each review passes, I believe that I am improving in the way in which I manage my studies. The chance to see exactly what someone else believes you should be doing provides you with the external outlook you need.'

With some unsurprising exceptions, staff were also mainly positive, some extremely so. A common view was that the written feedback made a valuable contribution to their tutorial guidance, providing something that they lacked the time and skills to provide themselves. The collected weekly student learning self-reviews are producing a large amount of data – several thousand pages of student comment. Detailed analysis of this data is now in progress with support from the UK Engineering LTSN (Learning and Teaching Support Network) and it is hoped that this detailed analysis will lead to further useful development based on a deeper understanding of student perceptions.

Conclusions

A range of measures, introduced to address the progression problems faced in engineering programmes at Exeter, has been described. As a package, they have produced a significant improvement in academic performance or, viewed the other way, a radical reduction in the dropout rate. These measures also enabled the teaching of MEng, BEng and BSc students together in a common first year while convincing accrediting institutions, albeit only after considerable effort, that students progressing on different programmes have achieved qualitatively different outcomes and therefore had significantly different learning experiences. For example, in granting accreditation of the Department's MEng and BEng programmes, after much explanation, the IEE finally responded: 'The Committee notes also that the School has made great efforts to demonstrate that the difference between MEng students and BEng students pervades the programmes and that the MEng Year 4 is not merely bolted on to a BEng programme. The School's attempt to follow the spirit of SARTOR 3rd edition (1997) is commended, although the result is a rather complicated structure that has taken some time to understand.'

Rigorous quantitative analysis of the effect of each measure taken has not been presented. These measures were not introduced as a piece of pure research but to apply known principles to help students. Several measures have been introduced at once without control groups and so it may not be possible to disentangle the effects of individual measures. Looking at assessment results for evidence, for example, is problematical since the assessment has changed with the teaching strategy. It would have been wrong to do otherwise since one of the fundamental principles being applied here is that assessment must be aligned to teaching.

None of the theories applied here are totally new. There is an extensive research-based literature telling us how to teach more effectively. The many pressures facing engineering departments, with increasing student-staff ratios, student diversity and numbers of students who are ill-prepared for higher education, certainly present very difficult challenges, but these challenges are not insurmountable. They can be largely overcome by setting out ILOs very clearly for students, putting effort into ensuring that they have all the resources they need to attain these objectives, providing responsive support to help students to take responsibility for their own learning, and aligning the assessment strategy with this approach. In other words these difficulties can be overcome by following advice that is readily available. The strategies described in this paper represent one interpretation of some of this advice and an attempt to put it into practice.

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