# AC 2007-1468: TEACHING 101: INITIAL CONVERSATIONS

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# Teaching 101: Initial conversations


## Abstract

The engineering education literature contains many examples illustrating the design of course learning objectives and appropriate assessment items to attain desired learning outcomes. Anecdotal evidence suggests this literature is accessed by only a small proportion of engineering academics. What is lacking in the literature is the investigation of strategies to lead and encourage research-focussed academics to gain expertise in these matters. The overarching aim of this research project is to find the most effective strategies for encouraging such research-focussed (and occasionally reluctant) academic staff to adopt theoretically based pedagogical approaches in their teaching practice, to ensure verifiable graduate outcomes.


## Introduction

How can academics in a research university be led to acquire, use and value theoretically based pedagogical practices, to ensure verifiable graduate outcomes?

This question is especially relevant in engineering education where teaching has largely, and usually most effectively, long been perceived as a combination of logic and "seat of the pants" good practice with little acquaintance and often a mistrust, with the underpinnings of education theory or even terminology.

In New Zealand the tension between teaching and research in research-led universities has been exacerbated recently by the introduction of institutional funding linked to a quantitative measure and ranking of individual staff research performance - the Performance Based Research Fund (PBRF). There is a perception that the PBRF has focussed attention, even further than previously, on the improvement of the research section of one's CV for career progression, de-emphasising time spent on teaching improvement.

Added to this potentially divisive teaching-research tension, professional disciplines such as engineering are subject to regular professional accreditation, which is currently requiring demonstrable achievement of graduate capabilities[1]. To do this effectively, teaching must take place with clearly defined learning outcomes and assessment targeted to evaluate the attainment of those outcomes at both course and programme levels.

For academic managers, charged with responsibility for the maintenance of teaching and learning quality, this is a challenging environment.

Internationally, it has been recognised[2] that the recent changes of accreditation systems to outcomes based assessment, are beginning to lead to more scholarly approaches. The discourse and literature around engineering education, seeking to position the Scholarship of Teaching and Learning at the level of the Scholarship of Discovery (Research), has grown rapidly, as universities recognise that they have a responsibility to examine internal practices and processes with the same research rigour used with pride on external investigations[3].

Much of that discourse and literature is, however, not mainstream for many engineering academics. For several years conferences on engineering education have highlighted the need to stimulate "sustained conversations about teaching and learning" [4] and develop communities of practice in engineering education research [5,6].

Amidst these competing stressors it is timely to remember that the prime objective of a Faculty of Engineering is to teach the next generation of engineers and teach them well.

## Context

For the authors, three issues in particular around the delivery of the curriculum and assessment processes stimulated a recognition that, to quote Newton, "Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it." For change to occur, some external force was clearly necessary. The three issues were:

- A recent IPENZ accreditation review, whilst acknowledging a high level of teaching and graduate outcomes, highlighted a lack of rigor in the preparation of learning objectives and the evaluation of learning outcomes / graduate attributes with reference to these objectives.

- Statistical evidence had recently been presented to the Faculty that conclusively demonstrated that, when incoming Grade Point Equivalent scores were used as a measure of the relative strength of a degree cohort, engineering students were not achieving an appropriate proportion of A and B grades relative to those given to students from other degrees. Very capable incoming engineering students were not receiving the grades they might have achieved in another degree path. This was of particular disadvantage when engineering students applied for cross disciplinary scholarship and post graduate research awards.

- The result of a departmental initiative requiring staff to write Learning Objectives for each course highlighted the unfamiliarity and reluctance felt by many staff in engaging with the process of reframing their teaching in this way.

It is suggested that a major contributing factor to each of these issues, is the lack of understanding and acknowledgement by engineering academic staff of the usefulness of educational "tools" and theory linking, for example, Learning Objectives and Assessment.

## Nature of the problem

It is suggested that the over-arching problem that needs addressing is how to lead academics in a research-led university to reflect on their teaching practice with the aid of acquiring, using and valuing education theory. However, in the context of the issues specified above, the first and most urgent step was identified as working with staff to make links between the definition of learning objectives and appropriate assessment.

A variety of resource material in a discipline based context is, and has been for some years, available for engineering academic staff wishing to incorporate theoretical knowledge of teaching and learning into their practice. In addition to the book "Teaching Engineering" by Wankat and Oreovicz[7], a particularly accessible guide, several websites are readily located. Although the institution has had a tradition for many years of valuing good teaching, manifested by honouring its best teachers, few staff other than those who may have attended the university based Certificate of University Learning and Teaching, appear to have accessed this material.

Felder and Brent [8] recognised that current accreditation processes require all teaching staff to be involved in defining and assessing learning outcomes. They perceived that a difficulty was likely to arise with unfamiliar and imprecisely defined jargon. Although their paper addresses the designing and teaching of courses to satisfy ABET criteria, their reflections and the processes they recommend are directly applicable to teaching staff in Australia and New Zealand. On a positive note, Felder and Brent suggested that, in an environment where courses were often defined in terms of course content with only loose connections to other courses in the programme, the opportunity provided by accreditation requirements to specify programme outcomes, and then outcome-related course learning objectives could be seen as a very "unifying framework for course and curriculum development" ( p.8). In particular, Felder and Brent argue that course learning objectives as explicit, observable expectations of what students completing the course should be able to do, are crucial to the process of demonstrating how specific program outcomes are addressed.

Recognising that different tasks call for dramatically different knowledge and skill levels, with some tasks requiring only rote memorization to complete and others calling for sophisticated analytical skills and creativity, Bloom's Taxonomy[9] has been used by many authors and curriculum developers [10, 11, 6]. Bloom's six cognitive levels as illustrated in Table 1 have been found to be accessible and relevant for engineering educators formulating course learning objectives.

Wankat and Oreovicz[7] and later Felder and Brent[11] recognised a tendency for assessment, particularly summative assessment, to focus on the lower levels. Both emphasised that all assessment items should include examples and problems at each level of Bloom's Taxonomy so that students would gain the desired proficiencies, otherwise students would master only those skills on which they had been tested.

The literature quoted, combined with a reasonably short search of the internet provides exemplars from engineering education illustrating the design of course learning objectives and appropriate assessment items to attain desired learning outcomes. The problem, rarely discussed in the literature, was finding the most effective strategies to lead and encourage individual, research-focussed academic staff to make these connections. In particular, the literature lacks reports of strategies to motivate and provide pathways for reluctant staff to gain some expertise in writing and identifying appropriately targeted learning objectives, and devising assessment tasks which would grade the learning outcomes to match pre-defined grade descriptors.

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|---|---|---|
| Knowledge | Observation and recall of information; knowledge of major ideas, mastery of subject matter | *Question Cues*: list, define, identify, show, name, examine, |
| Comprehension | Understanding information, interpret facts, compare, contrast, translate knowledge into new context, order, group, infer consequences | *Question cues*: describe, predict, summarize, interpret, contrast, estimate, discuss |
| Application | Use information, use methods, concepts, theories in new situation, solve problems using required skills or knowledge | *Question cues*: apply, demonstrate, calculate, show, solve, examine, modify |
| Analysis | Seeing patterns, organisation of parts, identification of components | *Question cues*: analyse, explain, compare, order |
| Synthesis | Use old ideas to create new ones, relate knowledge from several areas, predict, draw conclusions, generalise from given facts | *Question cues:* modify, design, formulate, rearrange, plan, create / combine |
| Evaluation | Assess value of theories, make choices based on reasoned argument, verify value of evidence, recognise subjectivity | *Question cues*: assess, decide, rank, recommend, compare, select, measure |

Table 1. Bloom's Taxonomy adapted from Bloom and Krathwohl[9], naming thought processes from lower to higher levels of cognitive skill.

This project has focussed on technical courses in one department within a large research led university. This department has a long history of issuing lower grades than the ability of its entering cohort, relative to the wider university, would imply, even when scaling of final grades has occurred. For traditional taught courses, class sizes are uniformly over 100 students, and the majority of assessment is summative done under time constraints via tests, and examinations. Grade boundaries have traditionally been drawn to reinforce a norm based distribution. The traditional taught courses are in direct contrast to the popular and effective Project and Design courses organised in the department, which tend to use very well defined learning objectives, and have a high degree of accountability in marking for which assessment could more easily be deemed to be criterion based.

The department recently required staff to write learning objectives for all courses. The reasons for this exercise were given as:

- A new BE structure was about to be introduced. A coordinated approach to the planning of the new courses was desired.
- There was concern that students were being overloaded with too much content in specific courses. It was difficult for academic managers to get a straight answer from some staff as to how much content was really in their courses. Defining learning objectives was seen as one way to make explicit the requirements of courses and thereby to identify what was really being required of the students.
- To ensure that duplication of topics was identifiable and thereby done only when strategically desirable, and also to identify any gaps in the curriculum.
- To enable tracing of the development of graduate attributes for accreditation purposes.
- To improve design of assessment by requiring assessment to be developed directly from the course learning objectives.
- To make course learning objectives more explicit and thereby make it easier for new lecturers to grasp what it is they should be teaching in particular courses.

Notably no training or guidance was given on style, depth, and in particular how to differentiate between goals, learning objectives, and learning outcomes. In our roles as academic managers, the resultant documents were made available to us for review and analysis.

**Analysis of Learning Objectives – the starting point.**

The process followed for the writing of learning objectives, had been to group all courses in the new degree into various subject areas and to assign all staff to one or more subject working groups. The principal purpose in grouping courses and assigning working groups was to adopt a coordinated approach to the planning of the new courses and involve all staff. The intent was for these working groups to decide the learning objectives for each course. It was further intended that at a later stage these same working groups would consider appropriate ways to assess the learning outcomes and then identify the particulars of content which would enable students to meet the desired objectives at each level of the degree. Working groups were established for the following subject areas: Fundamentals; Electromagnetics and Radio; Communications; Signal Processing, Networks and Data Communications; Power Systems and Power Electronics; Systems, Control and Electronics; Digital Hardware; Computer Systems and Software; Design, Projects and Professional practice.

Once all groups had met and begun drafting the learning objectives, a meeting of the convenors was held to check progress and refine the process where needed. The most common request was for a template to follow in developing the learning objectives. A second oft-repeated request was for clarification on the level of detail required. Many staff favoured short non-specific learning objectives which were really learning goals rather than learning objectives. There was perceptible resistance amongst some working group convenors (and by inference amongst the working parties) to the notion that assessment should be linked to learning objectives and that assessment decisions should be made before the lectures had been delivered. Those managing the first phase of the process deliberately didn't provide a template, or guidance on style or depth. The intention was to engage all staff later in defining such a template, once they had all developed a better appreciation of the issues by grappling "blindly" with these very issues.

An analysis was undertaken by the authors of the learning objectives written for the two Bachelors degrees in Electrical and Electronic Engineering and Computer Systems Engineering. This analysis identified that the various subject working groups had made very different interpretations of learning objectives.

The "spectrum" of responses ranged from **too brief** (and not able to be linked clearly with assessment), e.g. "understand the basics of speech signals and speech acoustics", through **too high level** (lacking in specificity), e.g. "have a foundation for understanding AC power systems", and **too general** with no obvious identification of the expected development of student capabilities from year to year, e.g. in Design courses at Part 2 "to gain an understanding of the importance of workplace and electrical safety" and at Part 3 "Students will be aware of electrical safety requirements". We considered good exemplars to be those for which assessment modules could be written directly from the learning objectives. With this definition of "good", there were a few good exemplars of disciplinary learning objectives, including an ideal (two-level) set of learning objectives which covered both discipline specific learning objectives and provided linkages to the desired graduate profile. Relatively few responses fell in the "good exemplar" category. The majority of the learning objectives were too brief and, in general, it would not have been possible to write assessment modules from the bulk of the learning objectives. Nor was it always possible to identify the different cognitive levels being targeted.

Not unexpectedly, it became apparent that the writing of learning objectives had not addressed all of the issues mentioned above as the motivation for the exercise. This no doubt stemmed from a lack of knowledge of fundamental educational theory and terminology, and the fact that the "objectives" of learning objectives had not been well understood or defined. The intent had been to engage everyone, albeit imperfectly, in the act of writing learning objectives and capture as "untainted" a vision of what was in the courses as possible. What was also exposed was the lack of shared understandings around good pedagogical practice in linking learning objectives, course delivery and assessment.

In seeking to answer our overarching question "How can academics in a research university be led to acquire, use and value theoretically based pedagogical practices, to ensure verifiable graduate outcomes?", it was recognised that an iterative process incrementally raising awareness would be needed.

This first round of learning objectives was taken as a starting point for a project for which this paper is the first full reporting. The following research questions were formulated

- What information does analysis of the first round of learning objectives provide?
- Have assessment outcomes reflected these learning objectives?
- To what extent have staff used the concept of learning objectives in setting their assessment items?
- Does analysis of assessment results highlight mismatch between learning objectives and learning outcomes?
- Could an introduction to levels of cognitive skills via Blooms taxonomy assist staff in reflecting on learning objectives and their methods of assessment ?

## Methodology

An action research methodology seemed appropriate, for an iterative, reflective process that would allow for inquiry and discussion as components of the "research". Commonly those who apply an action research approach are practitioners who wish to improve understanding of their own practice. Although the naming and number of the steps involved can vary, action research always involves a series of cycles, sometimes envisioned as a spiral[12]. Initially, a problem is identified, action is planned and implemented, then the results are evaluated and reflection occurs. The insights gained from the initial cycle feed into planning of the second cycle, for which the action plan is modified and the research process repeated, as illustrated in Figure 1.

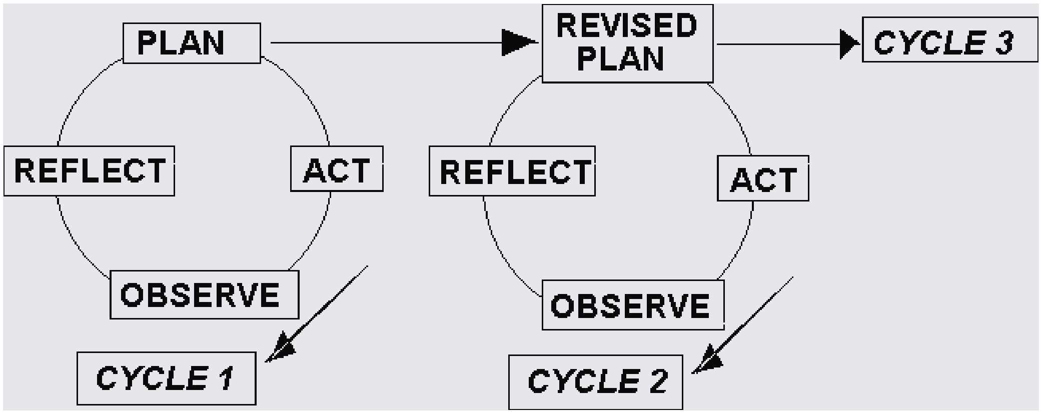


Figure 1. The Action Research process from Riding, Fowell and Levy [12]

**The first action cycle**

After analysing the learning objectives a group of "early adapters" was identified that included four subject working group convenors A,B,C and D and one other staff member E. The aim of using this potentially co-operative group as a pilot, was to identify appropriate strategies and pathways for influencing colleagues less willing to engage in pedagogical discussions.

For reasons given earlier in the paper, Bloom's Taxonomy appeared an appropriate discussion starter. Only one of these early adapters, A, had heard of Bloom's Taxonomy and his knowledge was superficial. The first action was to bring these early adapters together for an introduction to Bloom's Taxonomy and discussion of its use in writing learning objectives.

After time to consider this material, and following submission of the first semester results, three of this group were individually interviewed by the investigators. One researcher was experienced in qualitative investigative methodologies, and the conduct of the interviews followed best practice[13]. Each interviewee was asked to reflect on

- their original approach to development of learning objectives for a representative course
- their understanding of how Bloom's Taxonomy could inform their learning objectives and assessment
- their thinking behind the assessment items used in recent examinations
- the extent to which the question type and subsequent grade distribution illustrated assessment across all levels of Bloom's Taxonomy
- whether they planned changes to the learning objectives and assessment strategy based on their interpretation of the exam grade distributions

Discussion of exam questions and results as a vehicle to linking learning objectives and assessment with Bloom's Taxonomy was seen as a very grounded means of focussing attention on the application of education theory, recognising the need engineering educators felt to view theory and knowledge in their own specific contexts.

## Interview results

The three staff interviewed were: A, a working group convenor and course co-ordinator of a fourth year elective course, with long experience in the subject area and in the institution and with a willingness to engage in pedagogical theory, although having no in-depth knowledge; B also a teacher of long standing, a working group convenor and course co-coordinator of a fourth year elective course with no prior exposure to educational theory; and C a teacher in a second year compulsory course with a background in high school teaching and interest in educational research.

Lecturer A was motivated to use good pedagogical practice, set questions with an awareness of different learning styles, consciously tried to ensure a spread of "difficulty" and was overall pleased with the grade distribution. The most significant part of the interview with A centred on the exam question analysis. Although this lecturer had made a deliberate attempt to link learning objectives to exam assessment, post-exam analysis (during the interview) on a question by question basis revealed that, in practice, as had been noted earlier as a common practice [7, 11] the majority of the assessment had focussed on the lower levels of knowledge, comprehension and application. Having initially been pleased at the average marks gained by the students on his questions (17.0, 12.7 and 15.4 ex 20 respectively), lecturer A was unaware prior to the discussion and sighting of the mark distribution displayed by the histogram that he had not stretched the more able students by examining the higher cognitive levels. The question histograms for lecturer A's part of this course, displayed in Figure 2 below, show that in a class of 65 students, 19 gained full marks for Q1 and 14 gained full marks for Q3. This most likely indicates that the top end of the class had not been stretched academically. Interestingly, Q2 (which was entirely descriptive, using verbs such as "sketch", describe", "indicate", "explain") shows a markedly different distribution from that of Q1 and Q3 which were both entirely calculation based, using the restricted range of verbs "determine" and "find".

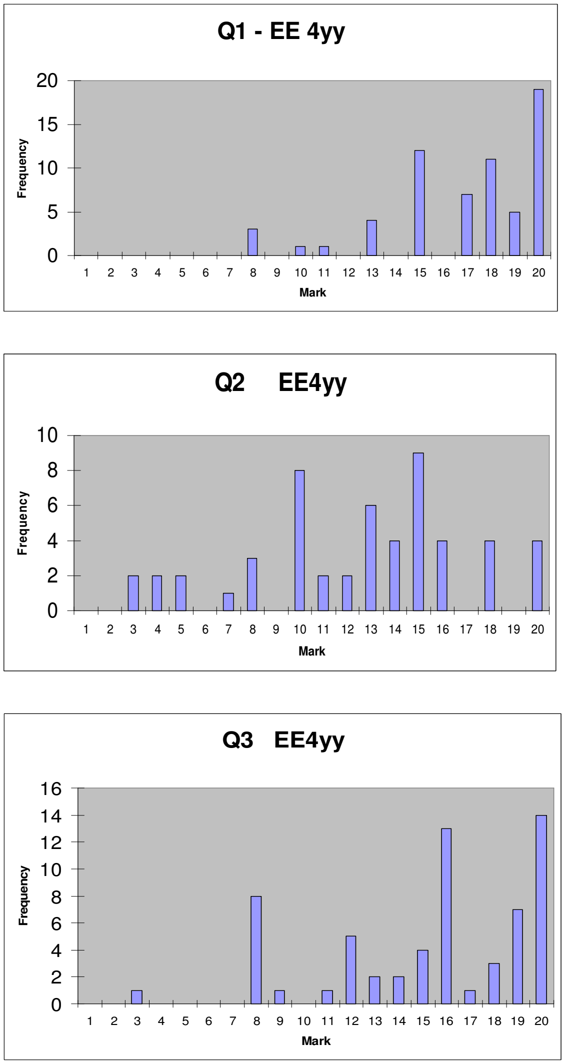


Figure 2. Mark distribution for Q1-Q3 on the course EE4yy taught by lecturer A.

Lecturer B had been heavily involved in writing the learning objectives for his subject area, and for the particular course being discussed (EE 4xx) and was very familiar with the depth and breadth deemed appropriate for the course. The goal of his elective was to introduce final year students to the concepts and terminology of a large technical field that relied on a wide range of earlier background knowledge such as mathematics and linear systems theory. He recognised, in fact “agonised over”, the level of the course being mostly at the very lowest levels of the Taxonomy, knowledge and comprehension, with some venturing into application, due to the difficult and new nature of the material being considered. His approach to assessment was based on experience, with a deliberate attempt to cover the breadth of the course. He suggested that students would identify the likely level of assessment from tutorial problems rather than specified learning objectives. Further discussion with B revolved around linking assessment results from tests and the examination to the achievement of learning objectives.

Of note was that examination results showed mean scores on his questions ranged from 9 to 13 out of 20, which was, as highlighted earlier in this paper, disappointing from a group of students perceived as “able”. His explanations for this relatively poor performance were that lack of synchronisation in use of terminology between the two lecturers had been confusing for the students, timing of course material, a difficult exam timetable….were all factors. By contrast he rejected the suggestion there was too much content in the course. “Students did not complain (for the first time) about too much content”.

It had not been common practice for lecturers in this department to reflect in detail on student performance on a question by question basis, and histograms showing mark distribution for each question were neither quickly available nor considered on a regular basis. Figure 3, which shows the mark distribution for two of the questions set by lecturer B, provided a useful tool for discussion.

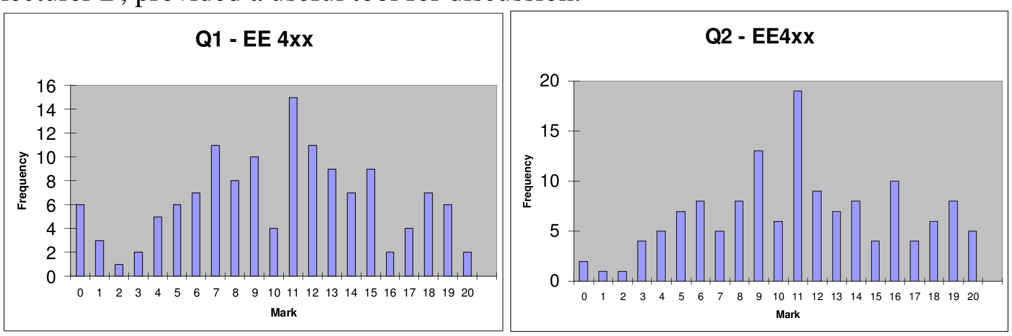


Figure 3. Mark distribution for Q1 and Q2 on the course EE 4xx taught by lecturer B.

The verbs used in each part of Questions 1 and 2, “show that”, “determine’ “explain” “draw diagram”, “discuss”, “sketch” …., matched Lecturer B’s description that they were at the level of Knowledge, Comprehension and Application. Although considerable care had gone into this assessment and several of the question parts had been similar to homework problems, the low question averages of 9/20 and 11/20 demonstrated that for these two questions a considerable portion of the students had not demonstrated that they had achieved the desired learning outcomes.

This sincere, experienced lecturer, committed to doing a fair and equitable assessment found it difficult to envisage that question type, allocation of marks during grading, or any fault could lie in the assessment itself. He was happy to assist with the research, but comfortable that his experience in the area did not require linkages to be made to educational tools such as Blooms Taxonomy or better definition of learning objectives and matching these with assessment items. It was unclear whether he would alter procedures in the forthcoming semester.

The interview with Lecturer C was very revealing about the process followed by one working group convenor in writing the learning objectives. Although Lecturer C was a long-standing lecturer in a core year 2 course, he had not been consulted about the learning objectives and did not agree with what had been developed. Following his interview he re-drafted the learning objectives for the portion of this course he taught. The difference between his approach and that developed by the working group was to produce far more detailed objectives, from which it was much easier to write assessment modules. His interview also revealed that the colleagues with whom he shared the year 2 core course were making no attempt to analyse exam performance on a question-by-question basis. Even a cursory examination of the question mark histograms for the course would have revealed that some had a far from desirable distribution. Examples of such non-desirable distributions (for Q5 and Q6 taught by Lecturer F who was not part of the early adapters group) appear in Figure 4 below. Both questions have a much larger spread of marks than is desirable. Q5 has an unexpectedly high number of full marks while Q6 has a very large number of students obtaining almost zero marks. It is perhaps significant that Q6 was entirely mathematically based with no real-life connection.

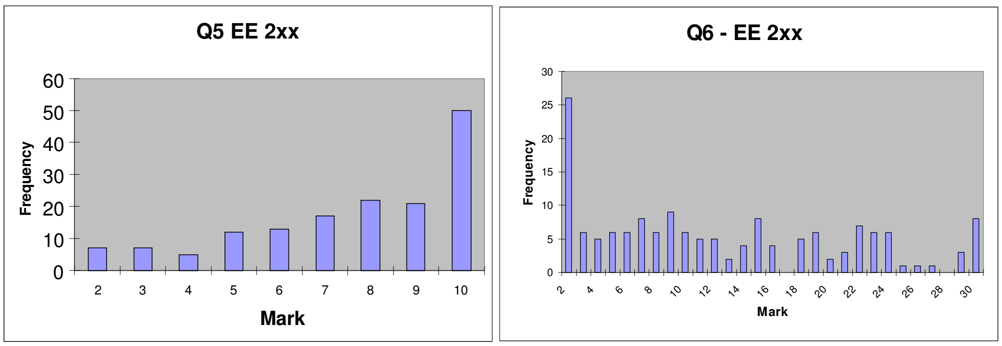


Figure 4. Mark distribution for Q5 and Q6 on the course EE2xx taught by lecturer F

Lecturer C (a former secondary school teacher) used his knowledge of secondary school Physics (Year 13) and the first year prerequisite course (which he also teaches) to set the level and breadth of the topics covered in EE2xx. He felt he worked more from implicit, tacit knowledge than from the learning objectives. He was particularly conscious of the amount of material that students could reasonably cover and tried to avoid covering too much material. Histograms of his two questions are provided in Figure 5. He was happiest with question 1. In his view the distribution and mean (12.1 ex 20) seemed appropriate. By contrast, he felt the mean of Q2 (15.1 ex 20) was too high and the distribution skewed too much to the higher end. That question was entirely numerical, and concentrated on Levels 3 and 4 of the Taxonomy, with some implicit testing of Levels 1 and 2.

It is the opinion of these authors that a mean of 15 ex 20 i.e. 75% is the desired result. The concern Lecturer C felt may well arise from a previous institutional practice of aiming for about 20% First Class Honours with a mean mark of approximately 65% being normal. Now that the institutional practice has changed, so too must lecturers grading practices. Interestingly, the overall mark histogram for this course was quite appropriate. The three lecturers (each setting two questions) had very different mark histograms. Two were of the desired bell-shape, two were skewed to the low end and two were skewed to the high end. Overall, their means were low, for the reason indicated earlier. If previous practice was followed, and only the final mark histogram was analysed, then the course would appear to have been successful, if perhaps a little hard. However, from the point of view of an accreditation exercise, looking only at the final histogram masks achievement of individual learning outcomes. It is far more desirable to look at the individual question histograms to identify whether the specific learning outcomes have been met.

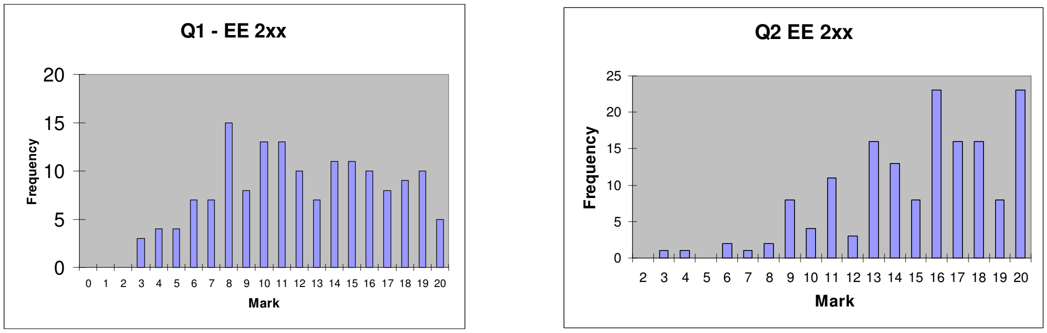


Figure 5. Mark distribution for Q1 and Q2 on the course EE2xx taught by lecturer C.

**Reflection on the first action cycle**

We identified at the first interview stage variances in the extent to which these early adapters "bought into" the use of Bloom's Taxonomy (despite their undoubted commitment to improving student learning). We further identified that even those who strongly embraced this tool struggled to devise summative assessment which tested across all cognitive levels. Although it has been recommended [7, 11] that the aim was for all assessment items to include examples and problems at each level of Bloom's Taxonomy, the time constrained test or exam situation may not be the best vehicle for testing higher level skills.

In the early part of this paper, it was mentioned there was a concern that the current grade distribution for traditionally taught courses in engineering did not match the perceived ability of the cohort on a scale relative to the whole university. The histograms from Figure 3 clearly illustrated this. It is noted that the type of histogram obtained from a Design course, in this case at third year level (Figure 6), was more likely to reflect the desired spread of marks, with discrimination and differentiation in the ranking, but an overall mean of around 75%. Learning objectives for Design courses are characteristically very precisely outlined and assessment is explicitly criteria based, often resulting in high pass rates.

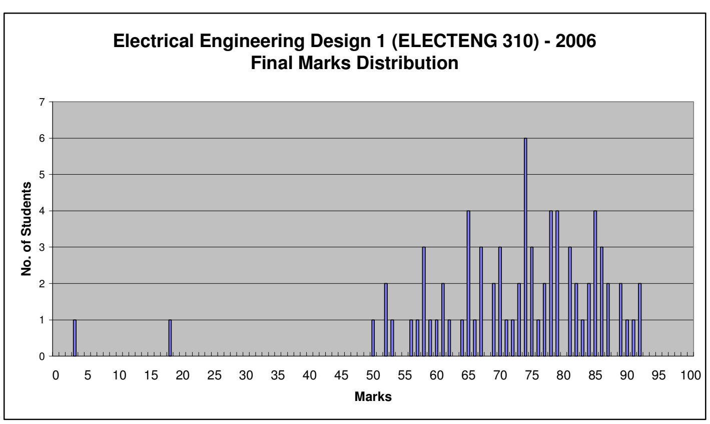


Figure 6. Mark distribution for 3rd year Design Course

Clearly the practices in traditionally taught courses were not giving such a spread. It is the contention of the authors that rather than “scaling” or grade inflation to achieve a desired grade distribution, staff must look more closely at teaching and learning practices for a solution. Well defined learning objectives, communicated to the students and explicitly linked to assessment practices, could achieve the desired result and more truly reflect student learning outcomes.

**The second action cycle**

At the completion of the second semester exam cycle, all members of the early adapters group (who were now equipped with a knowledge of some elementary educational theory) were re-interviewed. The purpose of the interview was to probe whether the pathway we were following (i.e. a facilitated course retrospective, using Bloom’s taxonomy to structure discussion of learning objectives and assessment of the learning outcomes) was an appropriate pathway for influencing colleagues less willing to engage in pedagogical discussions and make appropriate changes in their practice. Specifically the second interview probed

- the extent to which they had reflected on the first interview
- whether they had introduced any changes to the second semester courses on the basis of the first interview
- whether any issues arose when they attempted to implement these changes
- whether question-by-question analysis of exam results highlighted any issues
- whether any changes were planned for the following year’s courses
- whether they had found Bloom’s Taxonomy to be useful.

**Interview results**

Lecturer A had reflected extensively on the first interview and had planned consequential changes for his semester 2 course – a compulsory Part 2 course with an enrolment of approximately 150 students. Specifically, he communicated the learning objectives more clearly to his students and attempted to write examination items to properly assess all levels of Bloom’s taxonomy. (When writing the semester 2 examination questions, he sat with a copy of the learning objectives and Bloom’s Taxonomy open on his desk).

Despite careful reflection, this lecturer still found it difficult to write exam questions which tested all levels of Bloom’s Taxonomy within a single question. Lecturer A is now reflecting on whether it would be better to try to assess all levels of Bloom’s Taxonomy within the exam as a whole rather than within each separate question. His question histograms are provided in Figure 7. He reported improved, but still disappointing results for assessment items measuring Levels 1, 2 and 3 of Bloom’s Taxonomy. Specifically, in comparison with the first semester results, a higher percentage of the class had mastered the material relating to the lower levels of Bloom’s Taxonomy. However, there were still too many students who were struggling with material assessing these levels. He hypothesised that the students hadn’t done enough preparatory work, although why this happened was unclear. He further reported bi-modal results for assessment items measuring Levels 5 and 6 of Bloom’s Taxonomy. (Specifically, on those parts of the question designed to measure the highest level cognitive skills, students tended to score either full marks or zero.) For two of his questions (Q3 and Q5), rather too many students appeared to be getting full marks, which he attributed to these questions tending to stretch students by seeking application of knowledge in new and unfamiliar situations rather than truly measuring synthesis and evaluation ability.

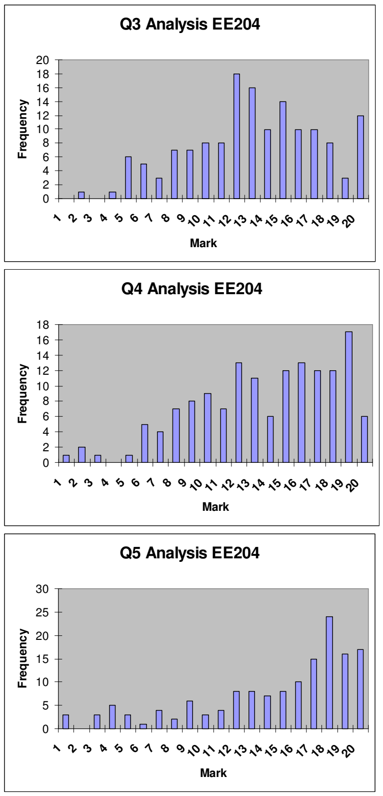


Figure 7. Mark distribution for Q3-Q5 on the course EE2yy taught by lecturer A.

Following reflection on this second set of exam results he planned to make changes to coursework weighting, test structure and delivery style to better engage the less academically able students. Furthermore he planned changes to his assessment items to better stretch the able students and measure the attainment of high level skills.

He reported that he had found the concepts and language of Bloom’s Taxonomy to be useful and wished he had known about this earlier in his academic career.

> “…just having access to the taxonomy alone isn’t enough. Previously, as I have analysed exam results, I have felt I was stabbing in the dark without any structure to guide my analysis. In analysing exam results, there are a number of confounding issues, specifically: unclear learning objectives, poorly written exam questions – either not truly testing the learning objectives or testing only a narrow range of cognitive levels, lack of effort by students, student misconceptions arising from prior learning.  It is difficult to be objective about something you have been closely involved in – i.e. writing exam questions. I found discussing these with an independent party, explaining how I constructed the questions to test different cognitive levels and showing how they related to the learning objectives was a very valuable exercise.”

In contrast, lecturer B reported that he had not reflected on the first interview, and hadn’t planned any changes to his second semester courses on the basis of that first interview. “I am a  bad student”. He appeared confident that his teaching style, course structure and exam questions were appropriate. His perception of his teaching style (for a compulsory Part 3 course with an enrolment of approximately 140 students) was to stress evaluation and synthesis. He consciously tried to set questions with graded levels of difficulty from knowledge through application to understanding. The questions used a range of operational verbs – derive, draw, prove, determine, sketch. However, the results were quite disappointing, with mark distributions even more extreme than in the first semester, and the lecturer showed no signs of being ready to grapple with the issues. When asked to comment on these mark distributions, he blamed the students and his colleagues. In particular, he felt the students were not properly mastering material in earlier pre-requisite courses. He was apparently not intending to make any further changes. He commented that the grades achieved by the students on his questions were a true indication of their ability, and that many of the weaker students had poor mathematical ability. Surely the question should be asked, that if this was a true indication of what was learned, then how effective actually was the teaching?

Lecturer C had reflected on the first interview and commented that some aspects of that first interview had caused a change in practice. Specifically, for semester 2 he was trying  to test a greater variety of skills using a range of questions types. In semester 2, lecturer C taught a large first year course with approximately 550 enrolments. He had taught this course for a number of years and had played a significant role in setting the learning objectives for the course. In common with Lecturers A and B he reported that a large number of students weren’t able to master even knowledge and comprehension questions. He was interested in seeing “an analysis made of what physics they are coming in with”.

Lecturer D shared the large Part 1 course with lecturer C. Lecturer D had participated in the training course on Bloom’s Taxonomy but had not been available for interview at the end of Semester 1. His interview thus covered aspects of both interviews 1 and 2. This lecturer found Bloom’s Taxonomy to be easily understandable and useful.

> “For years and years, I have never spent much time actually analysing what it is I do, and this gave me a way of breaking down in my mind what it was I was trying to do. So as an analysis tool for my own personal benefit it was useful. I did find it a bit too detailed – possibly a little finely hued, so I would personally work with a smaller number of areas.”

He plans to use Bloom’s Taxonomy to inform revisions of the learning objectives for his Part 1 course.

> “I found I wasn’t really writing questions that explicitly teased out these levels, they were a bit mixed up together. I will rewrite the learning objectives using more operational descriptions chosen to describe measurable outcomes. I am interested, and we all should be, in where the students are falling down.”

Lecturer D is a very experienced academic, well regarded by both students and colleagues,  with extensive large class teaching experience. He was quite disappointed with the students’ performance in the two questions he set for the Year 1 course. Q1 (mean 8.1 ex 20) covers material (on transistors) which is always in the examination, year after year. This multi-part question covered basic knowledge, application to a familiar situation and application to an unfamiliar situation i.e. Levels 1 to 4 on Bloom’s Taxonomy. The question made extensive use of circuit diagrams and electrical symbols, and it would be interesting to pursue whether the abstract and very symbolic nature of the question made it difficult for some of the students, especially those who are not visual learners.

By contrast the results for Q2 were better, with a mean of 11.3 ex 20. This question was a mathematical logic question. There were fewer circuit diagrams than Q1 and the questions involved rather more interaction. The results clearly show the students found this easier, although in the view of the interviewers, a mean of 11.3 ex 20 is still too low.

One is left with the overall impression that the level of Q1 and to a lesser extent Q2 was simply too high for a Year 1 course.

Lecturer E had also participated in the training course on Bloom's Taxonomy but had not been available for interview at the end of Semester 1. His interview also covered aspects of both interviews 1 and 2. When asked to comment on the usefulness of learning objectives and Bloom's Taxonomy he reported he

> "obtained a sense of thinking about how you could express course goals in terms of words that students could pick up on. That one should express the Learning Objectives in terms of observable things so that students will do certain things during the courses. In particular, one should use "operational" type words – mainly verbs. By making descriptions operational, you can measure it, and it is concrete so people can actually understand it and do it".

Lecturer E taught half of a final year elective course (CS4xx) with 60 enrolments. He displayed a very positive approach and his exam results were good and did not show the bi-modal split seen in other lecturers' results. Analysis of his question statistics showed higher means than for other lecturers (Q1 - 69%, Q2 - 78.6% and Q3 - 66.1%) and bell-shaped histograms for Q1 and Q3, while Q2 was skewed toward the high end. The questions tended to be wordy and required descriptive answers, with the first part of the question testing knowledge and the second part using that knowledge. When asked to explain his philosophy in setting exams, he commented

> "what I really think about is just creating an assessment process that is going to give a good standard deviation – think about both ends – have they met the minimum and then at the top end, what kind of thing is going to challenge the top of the class".

While he acknowledged Bloom's Taxonomy was a natural categorization, he saw 3 rather than 6 categories, specifically knowledge, application and deep understanding. He felt that the pilot programme with the early adapters had helped –

> "without you guys coming along, I wouldn't have looked for it myself. I am reluctant to put any extra work into any of this stuff - not rewarding. I wouldn't do all this stuff if it took extra time."

A negative feature common both to the original development of the learning objectives and to the pilot programme was the issue of staff reluctance to invest the time in reflection on teaching issues. Lecturer E was not at all alone in his perception that "extra work put into this stuff is not rewarded". Sentiments such as his no doubt have their genesis in the perception that research has a much higher priority than teaching in academic promotion exercises. Nevertheless, any tool which improves learning is likely to lead to more efficient teaching, and for that reason alone, should be attractive to even the most research-focussed academic.

**Reflection on the second action cycle**

It was suggested earlier that the over-arching problem that needs addressing is how to lead academics in a research-led university to reflect on their teaching practice with the aid of acquiring, using and valuing education theory. However, the first and most urgent step was identified as working with staff to make links between defining learning objectives and appropriate assessment. A small cohort such as investigated by this work-in-progress does not really allow generalisations. However, we have classified our early adapters into 3 categories, known collectively by the title EARs. Here, E represents eager learners, as typified by Lecturers A and C. In their case the facilitated retrospective approach further motivated them to inquire into educational methodology. The letter A represents affirmed learners, as typified by Lecturers D and E. The facilitated retrospective approach gave them confidence in their existing teaching and assessment style (by exemplifying the pedagogy underpinning its success) and/or suggested minor modifications. They wouldn't have investigated Bloom's Taxonomy without the facilitated retrospective as they were not prepared to invest the time. The letter R represents reluctant learners, as typified by Lecturer B. For these lecturers, the optional facilitated retrospective approach has no effect, and compulsion is required.

A key part of our work with this group, as a pilot group, was to identify appropriate strategies for influencing colleagues even less willing to engage in pedagogical discussions. As noted earlier, the literature lacks reports of strategies to motivate and provide pathways for reluctant staff to gain some expertise in writing and identifying appropriately targeted learning objectives, and devising assessment tasks which would grade the learning outcomes to match pre-defined grade descriptors. Even lecturer B appeared to fall in this category. Although he was willing enough to join the pilot programme, he appears to have made little effort to incorporate or examine Bloom's Taxonomy or learning objectives. He appeared very confident in his own ability to judge the level – anything less would be lowering the (his) standards. While he is a motivated and well meaning individual who sincerely believes in what he is doing, in his case our efforts to increase his engagement with pedagogical tools were not successful. While he might now know the words he is still lacking in drive or motivation to shift from his own level of complacency.

The behaviour of Lecturer B raises some important issues. If the class exam results are bimodal, year after year, in certain areas – what action should we and can we take? Further, what is the most effective way to reach a shared consensus on the level at which particular exams should be pitched? We are led inexorably to the view that a measure of compulsion is the only way to ensure academic staff such as lecturer B begin to apply even the most elementary aspects of good teaching practice. There is a narrow window of opportunity when even the most research focussed staff member is eager to discuss their exam results. This is essentially the three or so weeks following exams, concluding with the examiners meeting. Within a week of that meeting it becomes almost impossible to get research-focussed staff to address teaching issues. We favour a compulsory facilitated course retrospective within this period, conducted as a part of the existing Course Audit undertaken within the institution.

The issue of students not attaining their initially perceived potential is a troubling one. In examining why it is that (for a range of courses and levels) so many students fail to master the lowest levels of knowledge and comprehension, several of the early adapters have questioned the level of student engagement, implying a lack of effort on the part of the students. However, other possible explanations exist, including:

- questions set too hard
- delivery style mismatched to learning style

- insufficient or poorly designed engagement strategies
- misconceptions from earlier courses hindering learning
- too much content in the course

At least one of the early adapters felt the use of a facilitated retrospective gave a more analytical approach to identifying the causes of such problems. Specifically, Lecturer A commented “Perhaps the most valuable part of the process was that it gave me more confidence in my analysis of the issues and possible solutions.” If the facilitated course retrospective process could be shown to identify these issues correctly, then buy-in may well improve.

**Conclusions**

This paper reports on the steps trialled at one institution to empower and encourage staff to make better links between their defining of learning objectives and appropriate assessment. After an introduction to levels of cognitive skills via Bloom’s Taxonomy, staff were led through two rounds of reflection on the match between learning objectives and assessment results, for specific technical courses taught in sequential semesters.

The results of cycles one and two in this action research based project have provided information on the research questions. The extent of the lack of linkage between learning objectives and assessment items identified in cycle one was somewhat depressing. However, the cycle two interviews identified that most of the early adapter group had made significant improvement in linking learning objectives and assessment in their courses following the first interview. We concluded that an approach no more complicated than creating a forum for reflection on individual exam questions, in the context of the cognitive scale underpinning Bloom’s Taxonomy and incorporating statistical tools such as histograms, could be a useful first step in introducing academic staff to pedagogical tools. Indeed the relevance of a facilitated exam question retrospective may be key in encouraging academic staff to embrace such tools.

If all staff are to embrace these ideas, and leadership is to demonstrate the value of “buy-in” to pedagogical good practice, a culture change is needed, which initially may require a level of compliance, and the use of performance indicators. Busy research-focussed staff need attention-grabbing, relevant strategies for professional development. We recommend therefore, that a facilitated course retrospective be included as part of the compulsory Course Audit already in existence in our School. Our preliminary results show that guidance, using relevant, discipline based resources and exemplars, has the potential to engage “early adapters” particularly younger staff and those preparing new courses.

Is the outcome of our work so far these early results or is it the conversation? At this point, we believe it is the conversation that is the first step and this paper is that first step.

“*A journey of a thousand miles, starts with a single step*”

*Mao Tse Tung*
*(1893 – 1976)*

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