Self-Directed Project Based Learning – A Case Study

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***Abstract**: This paper describes a self-directed project-based learning approach implemented in an introductory Signal Processing course at the School of Electrical Engineering and Telecommunications in the University of New South Wales. The course was structured around a major laboratory project where the learning was much more student-centred than in traditional lecture-based courses and the students learnt the material naturally and progressively to arrive at their solution to the project. The entire course was delivered using DVD-based lecture presentations and the live lectures acted more as discussion classes to address detailed questions on the lecture material. Tutorial classes were run in a traditional manner to help the students develop the required level of analytical skills. The proposed project-based learning approach also utilised continuous assessment throughout the session, differing from the single final exam used in traditional approaches. Evaluation of the course structure by the lecturer and the lab instructors indicated that students gained a better conceptual understanding of signal processing theory than in previous years. Students were generally positive towards the process, even though they found it difficult to adjust to it. Initial indicators show an improvement in student study behaviour.*

***Keywords**: Signal processing, education, engineering education, self-directed learning, problem-based learning (PBL), teaching modes.*

1. Introduction

1.1. Motivation

Digital Signal Processing is an introductory signal processing subject in the UNSW Electrical Engineering program. As a third year subject, it provides a basis for applying transform theory to analogue and digital filter design. In recent years this course has been the focus of a long trial in educational methodology, in which new modes of teaching have been developed and implemented (Ambikairajah *et al*., 2006). Objectives of this broader trial include: (a) Gaining a deeper understanding of the context in which student learning occurs, (b) Proposing new teaching methods to allow students to exercise greater control over their learning experience, and which address specific problems discovered from student feedback, (c) Implementing new technologies designed to convey the richness of the classroom experience to students engaged in self-directed study, (d) Experimenting with the novel technologies in a variety of different teaching modes during the regular teaching semester, and (e) Evaluating both the new educational technology and the delivery modes they facilitate, over a series of courses.

Given the difficulty students have with processing complex mathematical concepts at the time of live lecture delivery, revisiting material in students' own time is desirable. Previous attempts to address this problem have included videotaping of lectures, or overhead slides accompanied by a recorded voice-over. These were unsuccessful, as significant equipment set-up was required for the former, and the latter lacked interaction with the teacher. The school therefore developed technology to pre-record lectures using an electronic whiteboard and tablet PC, with accompanying audio and video (Ambikairajah *et al*., 2007, Ambikairajah *et al.*, 2005). In this way, a lecturer's annotated slides could be provided in digital format with the relevant notes and explanations, allowing students to go over and revisit lecture material effectively in their own time.

1.2. Related work

Problem Based Learning (PBL) replaces older-style teaching methods with self-directed learning, and does not centre around a series of lectures on theoretical information, but rather the implementation of a laboratory project. The students must research relevant technologies or procedures, design a strategy and implement a system to solve the problem. Problem-based learning of this kind, as shown in Figure 1, is designed to integrate a wide variety of learning experiences to contribute to the learning process.

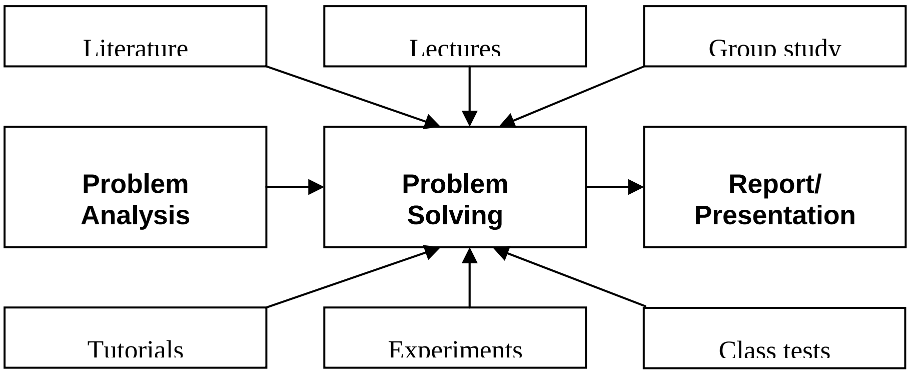


Figure 1. Problem Based Learning as implemented herein (Fink et al., 2002)

Problem-based Learning (PBL) is such a methodology that has been employed in a diverse range of fields, aiming to provide a student-centred, active, problem-centred approach to learning (Greenberg *et al.*, 2003 and Nelson, 2006). It encourages creativity and independent thinking as learners seek to solve a specific problem, acquainting themselves with necessary theory and grasping its application. It tends to focus on group-work, and seeks to integrate knowledge from a variety of different sources, including lecture material, experiments, research, peers, tutorials, and literature (Fink *et al.*, 2002). In such a teaching framework, the responsibility for learning is shifted significantly from the teacher to the student. Instructors play more of a facilitator's role, guiding and assisting students towards their goals. The proposed project-based learning is similar to problem-based learning where the course is structured principally around the laboratory work, with all other elements subordinate to it. The structure of the course is intended to imitate the real-life experience of engineering design, moving from problem analysis to design to the final communication of that solution. These skills will be invaluable both in the remainder of the students' university career and their professional workplace.

2. Teaching Methodology

2.1. Self-directed learning

It has long been recognised that adults learn best when they can appreciate the goal of their study, and have some control over the learning process (Ellis, 2007). The introduction of lectures on DVD in previous years (Ambikairajah *et al.*, 2007) gave students some control over their learning process, in that they could choose their learning environment and pace of study, yet there are many other factors in self-directed learning which can be of great benefit to students. Allowing learners to set goals and identify expected outcomes, select learning experiences and materials, and even to determine assessment methods all contribute to help motivate adults to learn effectively (Hiemstra, 1994).

2.2. Graduate Attributes

The University of New South Wales has recognised a number of key areas that are of great benefit for graduates, whether they go on to the workplace or into further education or research (*UNSW,* 2003). Graduates need skills that equip them for a lifetime of learning, skills that are above and beyond the particular disciplinary skill set that is developed over the degree program. Such skills include the ability to work in groups, to think critically, to communicate, to locate and utilize information, and to analyse and solve a variety of problems they will come across in the course of their profession. The educational policy adopted by the university is therefore to seek to develop course programs that enable students to not only develop knowledge and abilities related to their subject area, in our case the analytical tools required for signal processing, but to continue to develop their professional attributes that will be useful in a wide set of circumstances. In this context, employing a form of PBL methodology in engineering education is very attractive, as by its very nature it encourages independent thought, communication skills, information literacy, and a host of other benefits to students that are perhaps less tangible than their analytical mathematical ability.

2.3. Evaluation Methods

Although this was not the first time the course had been taught by this lecturer, it was the first time that a project-based approach had been taken. In order to make a comparison with the previous year, two main evaluation methods were identified:

(i) Final pass rate: While this is broadly indicative of student performance, this measure is complicated not only by the differences in student cohort and exam questions, but the major structural differences in assessment between the two approaches.

(ii) Tutor comments: Although these provide some deeper insights than marks or questionnaire preference rankings, these are subjective and also depend on tutors' memory of previous years.

Bearing the limitations of these evaluation methods in mind, the more enlightening of the evaluations conducted was the progressive survey of student attitudes, conducted at four points during the semester. Details of this survey are given in section 4.2. Combined with tutor comments, the survey findings gave an indication of the independent thought, communication skills, information literacy, and other benefits developed during the course.

3. Course Design

Having implemented a flexible content-delivery system for Signal Processing education, we sought to implement a form of project based learning in the rest of the course which creates an environment where students are challenged to take responsibility for their own learning. The following section explains the project based learning approach utilised in this course, along with the other aspects of the course designed to support this approach.

3.1. Project-Based Learning in the Course Design

Traditionally, as in most other engineering courses at UNSW, subject material has been taught through lectures, problem sets were dealt with in rather large tutorial groups, and laboratory sessions have worked through a number of concepts with short, practical examples. For pragmatic reasons of setup time and to mitigate steep learning curves, many of the laboratory experiments were MATLAB simulations. Rarely, however, did the laboratory sessions connect with the preceding or following experiments, creating rather a number of isolated examples of the analytical theory learnt in lectures.

The laboratory program became the primary drive of the course, centring around a single large problem that required students to master a variety of course-work elements in order to arrive at a solution. The assessment structure reflected this primacy of experimental work, with 60% of the final result deriving directly from lab work. The remaining marks came from 2 in-class analytical examinations, coming half-way through and at the end of the session. Structuring the course this way allowed us to entirely remove the final exam, which served to place greater emphasis on the laboratory work as the principal element of learning.

At the start of the semester, students were provided with all the lecture material relevant to the course syllabus. Detailed printed lecture notes were available in bound form, along with all pre-recorded lectures on DVD and recommendations of good reference text books. In this way, students were given a large amount of resources upfront, which they could draw upon whenever they needed. The challenge for the students was to appropriately use these data.

3.2. Other Aspects of the Course Design

The course design adopted aspects of previous initiatives in teaching methodology and educational technology that were found to be successful from previous years. A free-form discussion class was introduced (Ambikairajah *et al*., 2007) in place of two hour lectures where students can raise questions they had concerning the concepts they had encountered in the laboratory or from watching the DVD. This discussion class was complemented by a one-hour tutorial each week, where set problems were discussed. Combined with the laboratory session each week, students were thus exposed to a variety of avenues for guidance and assistance in their studies, albeit without the traditional lecture/tutorial/laboratory format. Note that this aspect of the course had already been extensively trialled (without use of PBL) in previous courses. Students had ready access to the pre-recorded lectures on DVD and all the available lecture notes.

3.3. Course Objectives

The course was designed such that students progressing through it should gain the ability to work through a number of design stages, including (but not limited to) :

- determining whether a problem exists;
- creating an exact statement of the problem;
- identifying information needed to understand the problem;
- identifying resources to be used to gather information;
- generating possible solutions;
- analysing the solutions; and
- presenting the solution, orally and/or in writing.

These skills are invaluable to students, both in the remainder of their university career and in the professional workplace.

3.4. Problem Description

The aim of the laboratory project was to enable the students to develop a system with real-world application, in a way that was sufficiently broad as to cover as many syllabus topics as possible, whilst giving some flexibility in its design and implementation. The laboratory project we assigned the students in semester 1 2007 was to design a spectrum analyser. Students were required to develop and implement in MATLAB a 16-band filterbank. It was based on analysing an 8 kHz audio signal, with the ability to perform multi-rate processing and to develop the ability to track the signal power in each band over time. In order to satisfactorily complete each stage of the project, students needed to identify and locate the appropriate theory in the learning materials provided, understand it and then apply what they learnt to a practical project.

The laboratory project was set out in distinct stages, to introduce concepts in a logical order. Freedom was given to students to approach each stage in the best way they saw fit, but enough structure was provided that they would not get lost in a sea of information and equations. The students were allowed to work together during the lab sessions, although assessments took place on an individual basis. Each stage had an assessable checkpoint, which had to be attempted before work could start on the following stage. In this way, students' work on the project resembled somewhat the experience of a professional engineer working in a team environment. The project specification and deliverables were provided, significant milestones and their required due dates were set, but the technical method used and the theoretical underpinnings were left up to the students themselves. In many ways this represents the reality of project work for an engineer: often we do not have complete control over the way the project is structured, but as those with technical expertise we must implement a system that meets the specifications regardless.

3.4. Course Assessment

Instructor roles for this format of the laboratory were significantly different to the usual role of a lab instructor. Given the shift in responsibility from instructor to student inherent in Project Based Learning, tutors became more guides than teachers. Their role was largely to provoke thought, to question decisions, to point students in the right direction, to provide advice. Tutors were instructed to rarely answer a technical question directly, rather to seek to elicit a solution from the students themselves.

Student progress was assessed at regular checkpoints throughout the semester. These checkpoints were designed to allow students to present what they had worked on, to explain the concepts and theory required, and to rationalise the design decisions they had made. A checkpoint occurred roughly every two weeks. Taken cumulatively, these checkpoints constituted 40% of the course assessment. At the end of the semester, a final presentation on the project was required. Students were given 10 minutes to present what they had done and the results they gained to a panel of laboratory tutors, and then had an opportunity to field questions. Limits were placed on the number of overhead slides that could be shown, requiring students to talk more freely about their design, and the relevant benefits and drawbacks. The breakdown of the assessment is as follows:

Class Exam 1 (Week 7)	: 15%
Class Exam 2 (Week 13)	: 15%
Lab Quizzes	: 10%
Lab Presentation (Week 14)	: 15%
Ongoing Lab Assessment	: 45%

Each class examination was of duration 1 hour and 15 minutes.

4. Course Evaluation

4.1. Tutor Feedback

Many of the laboratory tutors have long experience in teaching this signal processing course. After assessing the final presentations in groups, there was general agreement that the standard of comprehension of course material was higher than in previous years. Students clearly understood the big picture of what they were doing, and the potential applications thereof. Their understanding of core concepts was much sharper than in previous years, no doubt partly due to the requirement of having to explain their design decisions in terms of signal theory throughout the semester.

4.2. Student Questionnaires

Student response to the course structure was gauged by progressive surveys conducted 4 times throughout the semester, in weeks 4, 9 and 14. The survey consisted of 10 questions, and respondents were asked to circle a response on a scale of 1 (strongly agree) to 5 (strongly disagree). The number of respondents (out of a total enrolment of 118) for each survey is detailed in Table 1.

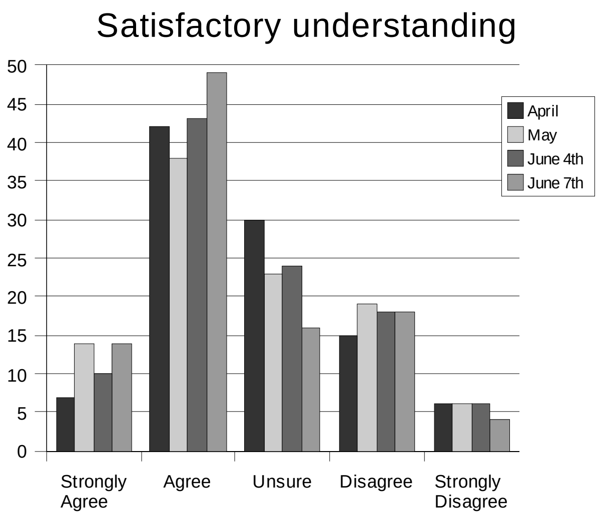
Responses from students were illuminating. The survey questions covered a few areas of the course: 5 questions were specifically about the project-based laboratory work (such as the time spent preparing, preference for the marking scheme, ease of finding materials); 5 questions concerned the pre-recorded lectures on DVD.

TABLE 1 SURVEY RESPONDENTS

Survey Date	Number of Respondents
April 19 (Week 4)	104
May 3 (Week 9)	69
June 4 (Week 14)	89
June 7 (Week 14)	74

In general terms, students strongly preferred the DVD lecture delivery mode. A majority of students appreciated being able to review lectures, and considered it an acceptable alternative to live lectures. Most students felt they achieved their desired level of understanding of topics using only the pre-recorded DVD and the discussion class with the lecturer. Overall, responses were very positive to this lecture delivery mode, in keeping with previous years (see Figure 2).

The responses to the project-based lab were a little more mixed. Students strongly preferred the different marking scheme, in which laboratory work and class tests had primacy over a final exam. When considering the course as a whole, students found the self-directed learning approach an acceptable alternative to traditional courses, with over 55% in each survey indicating they agreed. Over the course of the semester, some views on the course structure seem to have shifted. Early on responses to the statement "I learn more from the problem-based learning lab compared with a structured lab" were quite evenly distributed (May survey: 27% agree, 31% unsure, 21% disagree). By the end of semester, however, responses shifted towards the positive (June 7th survey: 43% agree, 32% unsure, 16% disagree). Many students found the structural course changes very challenging. As the first course students come across in the degree program to require such a responsibility for self-directed learning, many found this aspect difficult. Although all the required materials were provided upfront, many students had difficulty identifying or even locating the required information, an experience reflected in their survey responses (see Fig. 3).



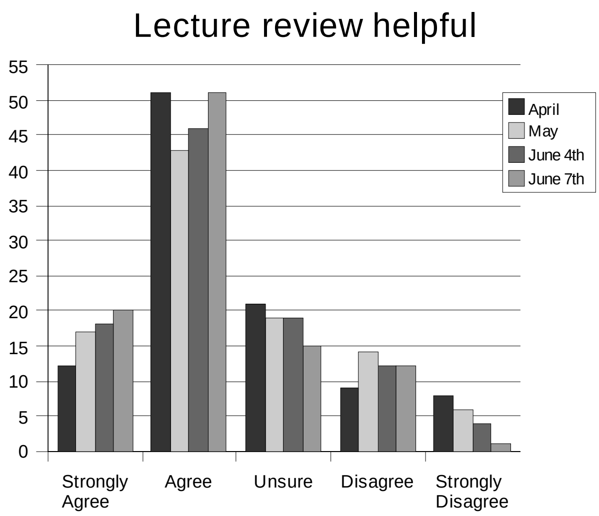


Figure 2. (a) Student responses to the statement "I feel I was able to achieve the level of understanding I wanted for topics that used only the pre-recorded CD and the discussion class with the lecturer".

(b) Student responses to the statement "I liked the opportunity to review the DVD-based lectures because understanding all the material in a live lecture environment is rather difficult".

It appears from these responses that students liked the format of the course, but considered themselves to not be very good at the process. Difficulty in finding materials led to unease early on about whether the project-based learning process would provide benefit. Over the semester, however, as students became more used to the self-directed style of learning, they evidently came to appreciate how the course was structured. Possibilities for addressing these problems include offering more resource material and listing more references, making students from the previous year available to give current students new to project-based learning advice on how to approach the course, structuring the learning process in the first week or two somewhat to try to give students a gradual introduction to the learning style, and offering extra help in the first couple of weeks to ensure that prerequisite knowledge and MATLAB skills are not limiting the students' ability to get started.

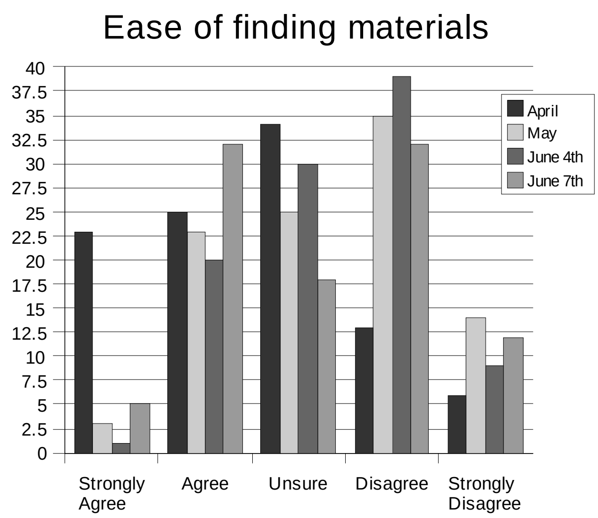


Figure 3. Student responses to the statement "It is easy to find the relevant learning materials for the problem-based leaning lab".

4.3. Pass Rates

Student pass-rates have been recorded over a number of years, with comparisons made between traditional delivery modes (live face-to-face lectures) and other approaches (see Table 2). It is worth detailing the course structures for each year so comparisons can be made: 2003 had a fully 'traditional' framework, with standard lecture, tutorial and laboratory components. 2004 saw the introduction of an electronic whiteboard for tutorial discussions, so that students could retain that discussion information. DVD recordings were introduced in 2005 as a supplement to live lectures: after each lecture, the recording would be made available for review purposes. The DVD lecture delivery mode was fully implemented in 2006, and 2007 saw the introduction of a project-based lab along with DVD lecture delivery, as described above. Note that each year has incrementally increased the emphasis on self-directed learning in the course.

TABLE 2 COMPARISON OF MID-TERM AND FINAL EXAM PASS RATES
FOR DIFFERENT COURSE STRUCTURES

	Students	Week 9 (May)	Week 14 (June)	Final Pass Rate
2003 (Traditional)	121	48.7%	not held	81.0%
2004 (Whiteboard)	118	43.8%	70.1% (comp.)	86.4%
2005 (Mixed Mode)	129	37.4%	72.0% (comp.)	89.9%
2006 (DVD-based)	113	66.1%	60.0% (optional)	85.1%
2007 (Project based learning + DVD)	118	56.0%	54.0% (compulsory)	90.0%

It is evident from the pass rates of analytical exams over the past several years (Table 2) that students performed slightly more poorly during the semester than in previous years, which tends to contradict the tutor comments in section 4.1. This can be explained in part due to the different course structure between the years (which emphasises project-based learning rather than the solution of isolated analytical problems), and in part due to the fact that the tutors were commenting on students' understanding and linkage of concepts that may not necessarily correlate with a high examination mark. Overall, however, pass rates are relatively consistent. It is therefore interesting to note that this semester a number of students who in an examination situation performed relatively poorly did much better in the laboratory work than their exam results would seem to indicate. That is, approximately 10 students who would have failed the course on the basis of their mathematical analytical skills performed at a credit level in their technical implementation. This lends weight to the tutor's observation that the overall grasp of concepts and the ability of students to understand them and put them into practice were quite high in this cohort of students. It also suggests that over-emphasis of examination-style assessment is not an appropriate approach for this course.

6. Conclusion

The outcome of this trial of project-based learning, combined with self-paced DVD lecture delivery, was that some students were observed by tutors to learn concepts involved in elementary signal processing more thoroughly. This was perhaps at the expense of some small level of technical analytical ability, with class exam pass rates marginally lower than previous years. The overall pass-rate, however, was consistent with previous years. Students' perception of the self-directed learning was initially uneasy, with gradual acceptance over the course of the semester. They found the research required for the lab work difficult and time-consuming, especially as it was such a different approach to learning than other courses in their program. Positive comments from tutors on student understanding of the course material suggest that this approach should be further trialled, with attention paid to the areas of difficulty noted herein.

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