A SELF-DIRECTED LEARNING APPROACH TO SIGNAL PROCESSING EDUCATION

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ABSTRACT

This paper describes a self-directed, project-based learning scheme implemented in an introductory Signal Processing course at the University of New South Wales. The course was structured around a major laboratory project in which students were required to research course material, understand the relevant theory, and apply this in order to arrive at a solution. Lectures were delivered via pre-recorded DVDs, allowing students to self-pace their absorption of new content and allowing teaching staff to concentrate on specific student issues during face-to-face classes. Evaluation of the course structure by the lecturer and instructors suggested that students gained a better conceptual understanding of signal processing theory than in previous years. Students were generally positive towards the process, but found it difficult to adjust to.

Index Terms— Signal processing education, self-directed learning, DVD-based learning, problem-based learning, educational technology

1. INTRODUCTION

Investigations into student learning have shown the importance of students taking ownership of their learning [5,8], and the benefits of being able to learn signal processing at their own pace [1-4]. These have been major themes of an ongoing educational technology and methodology project in signal processing spanning several years [1-4], of which the main objectives are:

(i) Proposing new teaching methods to allow students to exercise greater control over their learning experience, addressing specific problems from student feedback;
(ii) Implementing new technologies designed to convey the richness of the classroom experience to students engaged in self-directed study;
(iii) Experimenting with the novel technologies in a variety of different teaching modes during the regular teaching semester; and
(iv) Evaluating both the new educational technology and the delivery modes they facilitate, over a series of courses.

The introduction of lectures on DVD [2] gave students some control over their learning process, in that they could choose their learning environment and pace of study, a factor in self-directed learning which can be of great benefit in helping motivate adults to learn effectively [8].

Problem-based learning (PBL) is a methodology that has been employed in a diverse range of fields, aiming to provide a student-centred, active, problem-centred approach to learning [7,9]. 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 (see Fig. 1).

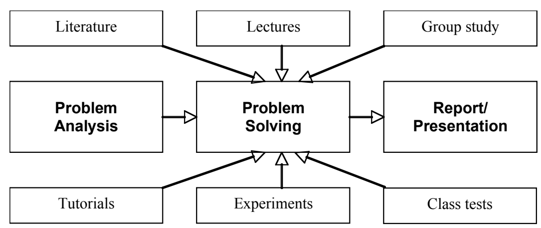

Figure 1. Problem-based learning [6] similar to that implemented herein

In this paper, we report on a self-directed learning approach that combines DVD-based learning (conferring the ability to view/review lecture material and freeing face-to-face teaching time for specific questions or problems [2]) with aspects of PBL. This proposed project-based learning is structured principally around the laboratory work, with all other elements subordinate to it. In this paper we use the term 'project-based learning' to acknowledge that some PBL principles were not strictly adhered to, for reasons of continuity with previous successful teaching approaches. Specifically, traditional experiments were not included since the main project involved extensive laboratory work, and while group study was encouraged, it was not mandatory.

2. METHODOLOGY AND COURSE DESIGN

2.1. Course Delivery Structure

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 worked through a number of concepts with short, practical examples that tended to create a number of isolated examples of the analytical theory learnt in lectures.

Seeking to employ a form of PBL in signal processing, the entire structure of the 3rd year Digital Signal Processing course was revised to centre on 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 derived directly from lab work. The remaining marks came from 2 in-class analytical quizzes, coming half-way through and at the end of the semester.

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 the total number of pre-recorded lectures on DVD and recommendations of good reference text books. Our existing DVD-based flexible content-delivery system for signal processing education [2] lends itself naturally for use in project-based learning, where it is desirable that the students be given more power over how they access content that is relevant to the problem and course learning outcomes. Thus, 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 this data, to work out how to integrate these resources and apply them to the problem at hand (cf. Fig. 1).

Face-to-face lectures were completely replaced by pre-recorded lectures on DVD, lecture notes and an optional free-form discussion class. Students could attend this class and raise questions on concepts encountered in the laboratory or from studying DVD-based or other materials. This discussion hour was complemented by a one-hour tutorial class each week, where set analytical problems were discussed.

2.2. Laboratory Project

The aim of the laboratory project was to enable 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. As an introductory DSP course, syllabus topics include transform methods, LTI systems, time and frequency representations of signals, sampling and reconstruction, analogue and digital filter design, and multi-rate processing. To directly address a number of these areas, and implicitly cover the remainder, students were required to develop and implement in MATLAB a 16-band spectrum analyser, as seen in Fig. 2. This was to be used to analyse an 8kHz audio signal, perform multi-rate processing, and track the signal power in each band over time. For the second part of the project, students had to choose between a rectifier based approach (shown in Fig. 2) and a de-modulator based approach using a digital oscillator to track power.

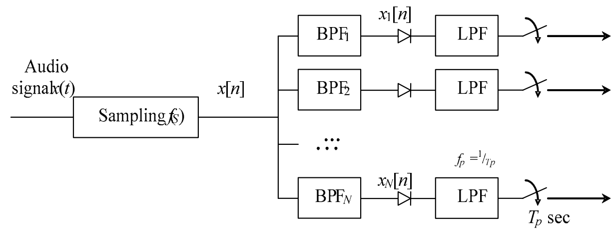

Figure 2. Block diagram of laboratory project

The laboratory project was set out in distinct stages, to introduce concepts in a logical order. For example, sampling and aliasing were addressed first, before filter design and analysis or multi-rate processing. 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 the project. In this way, students' work on the project resembled somewhat the experience of a professional engineer. 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.

The first element of the project was to experiment with signals and concepts of sampling. The effects of aliasing were of significant interest, as this was something that needed to be considered at a number of points throughout the project. Students were then required to implement a range of digital filters, in order to understand how, say, a Butterworth filter differed from an FIR filter, and be able to implement them to filter signals in a number of frequency ranges. At the end of this stage they chose a particular method for filter design, and implemented all 16 filters. The checkpoint assessed them on how well they understood the plethora of design methods they had come across, and their rationale for their design decision.

The next task for students was to communicate the filtered signal information effectively from the 16 separate band-pass signals. Students were encouraged to think creatively about how they might best show what information their system was capable of producing, and what that signified about the signals they were processing. Two separate approaches to tracking signal power based on de-modulation and calculating the power envelope pushed them further not only in their technical skills but also trained them in selecting between alternative approaches to the same task. Common questions put to students by lab tutors were concerned with not only communicating technical information to colleagues, but also how to demonstrate and explain the results to those not versed in specialised engineering language. An optional stage was offered to motivated students to extend the spectrum analyser to include a synthesis bank, a task beyond the scope of the syllabus but clearly related to the subject material.

2.3. Assessment

Instructor roles for this format of the laboratory were significantly different to the usual role of a lab instructor. Given the shift in learning responsibility from instructor to student inherent in self-directed learning, tutors became more guides than teachers. Their role was largely to provoke thought, to question decisions, to point students in the right direction, and to provide advice. Tutors were instructed to rarely answer a technical question directly, rather to seek to elicit a solution from the students themselves. Tutors were trained in performing such a role before the semester began, and had weekly meetings throughout the semester to assess any problems that arose from the laboratory sessions.

Student progress was assessed at regular checkpoints throughout the semester (roughly every two weeks), allowing students to present what they had worked on, to explain the concepts and theory required, and to defend the design decisions they had made. Taken cumulatively, these checkpoints constituted 45% of the total course assessment. At the end of the semester students gave a 10-minute presentation on their design and results to a panel of laboratory tutors, and then answered 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.

3. EVALUATION

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, three main evaluation methods were identified:

(i) Lecturer/tutor comments: Although these provide some deeper insights than marks or questionnaire preference rankings, these are subjective and also depend on teaching staff's memories of previous years.

(ii) 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.

(iii) Student questionnaires

3.1. Lecturer/Tutor Feedback

Many of the laboratory tutors have many years of experience in teaching this signal processing course. After assessing the final presentations in groups, there was broad 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 verbal assessments in previous years, no doubt partly due to the requirement of having to explain their design decisions in terms of theory throughout the semester.

3.2. Pass Rates

Student pass-rates for this course have been recorded over a number of years, with comparisons made between traditional delivery modes and new teaching approaches (as seen in Table 1 of [2]). Here we compare between the DVD-based lecture delivery in 2006 and the introduction of the project-based lab and DVD lecture delivery in 2007. Notably, students performed slightly more poorly at the week 14 exam (54% pass rate) than in previous years (66% in 2006), whereas they were comparable earlier on in the semester (56% at week 9; 60% in 2006). Overall, however, pass rates were relatively consistent (approx 90% over 2005-2007). It is therefore interesting to note that this semester a number of students who in an examination situation performed relatively poorly were better able to practically apply and understand theory in the laboratory than their exam results would seem to indicate.

3.3. Student Questionnaires

Student response to the self-directed, project-based approach was gauged by surveys conducted 4 times throughout the semester, in weeks 4, 9, and 14 (twice). The survey consisted of 10 questions, rated on a scale of 1 (strongly agree) to 5 (strongly disagree). The number of respondents (total enrolment of 118) for each survey was 104, 69, 89 and 74. The disparity between the total enrolment and participation rates is due to attendance at class when the survey was conducted. Five questions were specifically about the project-based laboratory work (time spent preparing, preference for the marking scheme, ease of finding materials etc); and five questions concerned the pre-recorded lectures on DVD.

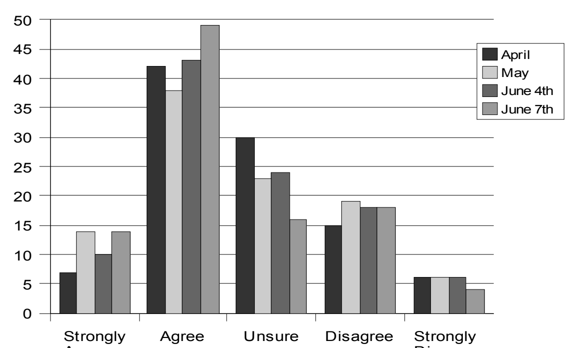

Figure 3. Student responses to: "I feel I was able to achieve the level of understanding I wanted for topics that used only the pre-recorded DVD and the discussion class with the lecturer"

In general terms, students appreciated the DVD lecture delivery mode, found being able to review lectures useful, 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 (see Fig. 3). Similar responses were found in previous years [2].

Responses to the project-centric approach were a little more mixed. Students strongly preferred the different marking scheme, which placed more value on laboratory work than on the final exam. Considering the course as a whole, the self-directed learning approach was found to be an acceptable alternative to traditional courses (such as the majority of other subjects taken), with over 50% in each survey indicating agreement or strong agreement (Fig. 4).

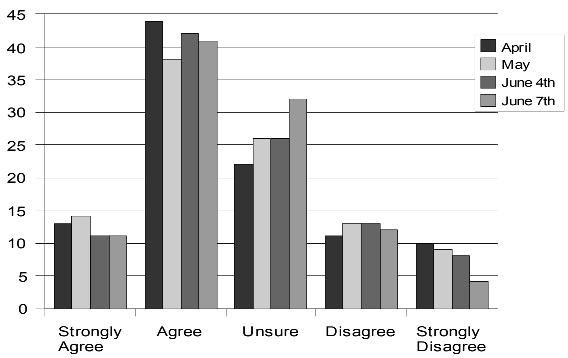

Figure 4. Student responses to: "I found PBL+DVD an acceptable alternative to the traditional method of teaching"

Over the duration of the semester, some views on the effectiveness of the teaching approach seem to have shifted (see Fig. 5). Early on, responses to the statement "I learn more from the problem-based learning lab compared with a structured lab" were quite evenly distributed (April survey: 32% agree/strongly agree (A/SA), 31% unsure (U), 37% disagree/strongly disagree (D/SD)). By the end of semester, however, responses shifted towards the positive (June 7th survey: 47% A/SA, 32% U, 20% D/SD).

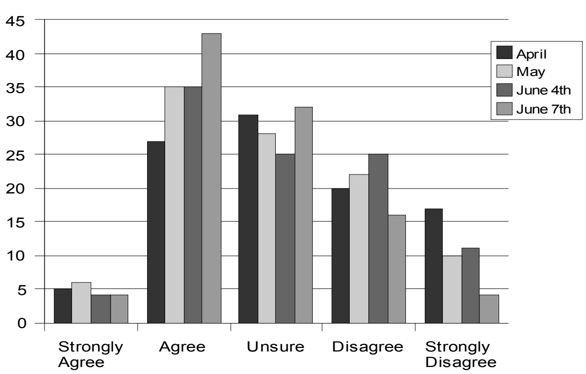

Figure 5. Student responses to: "I learnt more from the problem-based learning lab compared with a structured lab"

Many students found the structural course changes very challenging. As the first subject 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 indicated they had difficulty identifying or even locating the required information.

4. CONCLUSION

This paper has reported on the implementation and evaluation of a self-directed approach to signal processing education that combines DVD-based lecture delivery with a variant of PBL. The result does not conform completely to strict PBL guidelines, but uses helpful aspects of the methodology to create an environment where students are challenged to take responsibility for their own learning. Evaluations indicate that students learned more thoroughly the concepts involved in elementary signal processing, although further, more detailed investigation is needed to clarify this result. Student perception of the self-directed learning moved from initial unease, to gradual acceptance over the duration of the semester. They found the research required for the lab work initially difficult and time-consuming, especially as it was a different approach to learning than other university subjects.

5. REFERENCES

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