Taking Control

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Abstract — *At the University of Western Sydney the School of Engineering offers a unit in automatic control. In the past the success rate has been below the general university average and steps were taken to improve its impact. Most notable was a slowing of the rate of delivery with an emphasis on the material regarded as fundamentally essential. Practical work to support the material in class was also modified, made less prescriptive, leaving room for more input from the students The theme of the changes made was that of setting up the environment in which the students had more control over the material that needed to learn. Pedagogical steps included the use practical work consisting of computer simulations alternated with real world physical experimentation. The results have generated mixed success, with the observation that what seems to work for one cohort falls flat on the next; more iterations are occurring.*

***Index Terms* —** *automatic control teaching, control education, concept maps, multiple choice tests*

INTRODUCTION

The School of Engineering at the University of Western Sydney, New South Wales, Australia offers first degree programs in a mix of engineering disciplines. Undergraduates may study for accredited bachelor degrees in civil, computer, electrical, robotics & mechatronics and telecommunications engineering. At UWS the teaching periods are referred to as 'sessions' and for the School of Engineering run for 13 teaching weeks, typically in Autumn and Spring. The School offers as well post graduate programs. This paper looks at one of the units in the undergraduate degree program offered in third year of the electrical engineering discipline. The Control Systems unit is a core unit for the electrical engineering cohort and may be taken by students of other programs , such as telecommunications, as an elective. The unit introduces students to automatic control concepts, wherein feedback is used to achieve given performance specifications. The Control Systems unit is of necessity mathematically based, which apparently decreases student motivation.

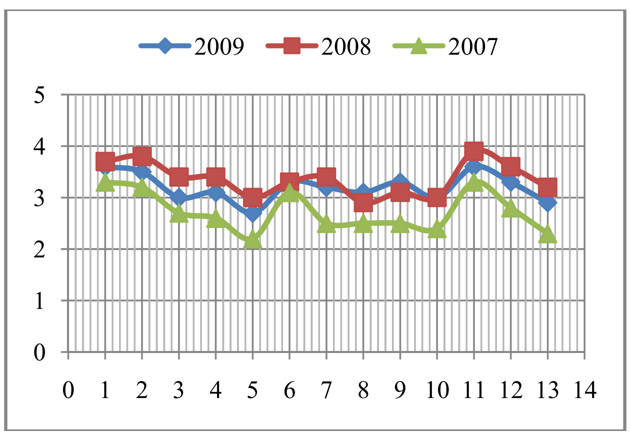

FIGURE 1
COMPARISON OF SFU RESULTS

The Control Systems unit is not, in general, a unit liked by many of the students who have to 'suffer' it. The student feedback on units (SFU) shows that the students find the material difficult to master and often cannot see the relevance of the material presented, despite the use of well accepted textbooks such as Dorf and Bishop, with a plethora of illustrative applications [1]. The results of student feedback on units surveys, as shown in Figures 1, indicate that in general student satisfaction could be improved. The SFU consisted of 13 questions relating to the material presented in the unit, with answers rated 1 to 5, representing 'strongly disagree' to 'strongly agree'. For example, questions asked related to the rate and scope of delivery and the amount of support received from staff. As in control systems, the management issued indicated in the SFU results required appropriate corrective action. Adopting a reflective approach, changes have been made, over several years, to improve the acceptance of the automatic control material [2]. The remainder of this paper describes the attempts made to improve student satisfaction with the delivered material.

WHAT IS CONTROL ENGINEERING?

Control Engineering involves the used of feedback to modify the performance characteristics of some physical process. The feedback is intensionally added and is usually negative. When positive feedback occurs, stability and oscillation problems typically result. Automatic feedback is designed to compensate for departures from the desired result, for example, due to changes in parameters of the system components or due to noise or process disturbances. In all, including feedback leads to improved quality. Applications of automatic control may be found in many disciplines. Feedback may be seen in applications such as space flight, the control of heart rates, the operation of lifts, even student performance [3].

GRADUATE ATTRIBUTES

The courses offered by the School of Engineering have been accredited by the Institution of Engineers, Australia. Students completing the courses are entitled to graduate entry into the Institution of Engineers, Australia, confirming their status as professional engineers. After several more years of experience, chartered status may be acquired. As part of the accreditation process, Engineers Australia stipulated the development of specific graduate attributes. For example, students should have 'an understanding and acceptance of the Code of Ethics', they should have developed 'expertise in a specific discipline of engineering' and 'an appreciation of sustainable design', among other attributes. Such attributes should be observable on graduation.

In like manner the graduate attributes specified by the University must also be addressed. For example, 'the integration of theoretical and practical knowledge to analyze and solve complex problems'. Steps are taken to make the students aware of the graduate attributes and to put emphasis on them during the delivery period. This should also assist in motivating the students in their study of automatic control.

DELIVERY

The unit is presented to the cohort through lectures, tutorials and practicals. Lectures were of 1.5 to 2 hours duration per week. Tutorials were of 1 hour duration per week, and practicals were of 2 hours duration per week. The practical work alternates between physical real world tasks and simulations. The 2 hours of practical work each week maximizes the practical contact that the students experience. In the past, the alternative approach made use of an average of 1.5 hours per week, with one 3 hour activity every fortnight.

There are arguments for and against 2 hours per week of practical work. In all this maximized the contact hours with the students and stayed within the School of Engineering's ruling of a maximum of 5 hours per week face to face contact. The decision was made to make use of two hour practical activities, with the procedures tailored to suit the 2 hour time slot. In practice this was more problematic as feedback via the SFU identified. The comment that was frequently found was that the time needed for the physical tasks was too short, despite the scope of the practical being reduced from the previous 3 hour version. Rather than abandoning the 2 hours per week practicals, the decision was made to extend the physical practical over two consecutive weeks. In that way once the measure of the tasks was understood fully, due to the first 2 hour period, the second half could be used to complete the set tasks.

The topics covered include continuous and discrete time modeling; the notion of negative feedback, error and error reduction; transfer functions, block diagrams, signal flow graphs; state variable methods; time domain responses and stability analysis; Bode diagrams; root locus ; introduction to Nyquist stability; pole placement, full order observers; and an introduction to digital control concepts.

Internet access is provided via a Blackboard site, specially created for the Control Systems unit. The Blackboard site allows postings of material such as lectures, tutorials, practicals, announcements, and so on. A discussion board is also made available for the students to post up materials for discussion among themselves. Students are able to access their marks for various assessments via their "Grade Book" results, allowing the rapid and private communication of results from the unit co-ordinator to the student. Statistics are also made available so that the student can ascertain where his marks lie when compared to the cohort overall. Such information thus allows the student to take corrective action as best they can. The quick turnover of results was regarded as critical to the improvement process.

ASSESSMENT

A combination of continuous assessment and final exam was used to evaluate the knowledge gained by the students. The marks are broken up into practicals 20%, class tests 15%, weekly homework 15% and final examination 50%. At the start of the session, students are given copies of the 'Unit Outline' and 'Learning Guide'. Most of the detail is contained within the Learning Guide. In general full time engineering students complete 4 units per session, with each unit having a weighting of 10 credit points (CP). The 40 CP per week are intended to represent a 40 hour working week. With 5 hours of contact per week, students are intended to spend 5 hours per week in independent study. The weekly home-works are intended to take up some of the independent study hours.

USE OF SIMULATIONS

The philosophy was adopted that the computer would be used to assist learning and not be taken as the primary source of information. It was to provide the means to fine tune "back of the envelope" estimates and to obtain higher accuracy. The point was emphasized that computerized results must always be critically reviewed by a knowledgeable user able to discern the reasonableness of the results. There was always the "GIGO" situation (garbage in, garbage out) to look out for and avoid. As useful as the simulations were, they were not a substitute for physical component level tasks.

While simulations were not a replacement for physical tasks, they provided an excellent means to visualize results. The MathsWorks software suite of Matlab/Simulink was used. This software was available on the university's computer system in several locations and so the students could avail themselves of its use outside the scheduled practical sessions. Some students invested in the 'Student Edition of Matlab & Simulink' [4][5]. Students were able to attend the simulations sessions with most of the tasks completed; they only had to demonstrate and explain their results to have the particular task marked off as completed. If the task took longer to complete than expected, the work could be completed outside the usual practical session and then be checked off at the next scheduled practical session.

USE OF REAL WORLD PHYSICAL EXPERIMENTS

There has always been a large dependence on practical applications in the laboratory and this practice has continued throughout the changes made over the years. Simulations using Matlab have been added to the physical practicals in an attempt to reinforce the material experienced during physical testing. The graphical interface allows the students to focus on the control concepts.

In conjunction with Matlab simulations, students spend time in the laboratories working on physical tasks. The School of Engineering has always had a history of face to face time devoted to "hands on" activities. Typically a third of the contact hours are devoted to hands on experimentation. The objective of the physical practical tasks is always to reinforce the theory discussed in lectures. For the physical laboratory tasks, typically the students work on their own or in pairs, depending on the available number of apparatuses. For the Matlab simulations, students work on their own.

The physical tasks consist of thermal system modeling, P-control of a thermal system, an RC phase shift oscillator and a positional servomechanism. The description of the tasks are designed to encourage the student to design the measurement and control components on their own, within the context of the lecture material. In essence, the student is encouraged to take charge of the problem delegated. The Matlab assessments are designed to supplement the lecture material, for example, by examining impulse and step responses, state variable conversions, block diagram reductions, steady state error illustrations, the use of 'ode solvers', among other aspects.

NEED FOR CHANGES IN DELIVERY

Anecdotal evidence from students indicated an unsuitable approach adopted by many of the students towards their automatic control studies. The methodology adopted was to cruise along until near the end and then to make an intensive effort, for example, during the 'study vacation' period just before the start of the final examination. Discussions and informal interviews with students indicated this was a popular approach, even after some 3 years of tertiary study. The option of reading widely and making use of other sources, beside the lecture material and the set textbook, did not appear on the radar. So changes were needed.

Some means was required to encourage students to spread their study over the entire teaching session, and not just cram at the end. Some means was needed that encouraged the students to work continuously throughout the teaching session and to be suitably rewarded as result in a timely period. The decision was made to introduce weekly homework problems. There would be 5 multiple choice problems given out each week via the Blackboard site created for the unit. The problems would be posted each week and the answers from the students would be submitted at the start of the next lecture. The students answers would be graded that day and the results posted up, complete with statistics, later that same day. This was possible since the questions were multiple choice and quick to grade.

Students would thus have timely feedback on their efforts and be able to ascertain how they performed with respect to the rest of the cohort via the released statistics. Along with the multiple choice home-works, the students had to sit for 3 multiple choice quizzes, approximately equally spaced in time throughout the 13 teaching weeks; quizzes occurred in weeks 4, 9 and 12. Again the results and statistics, were made available in a timely manner shortly after the quizzes were completed. The quizzes were completed in class and not online. Discussion of the correct answers of the homework and quiz questions was delayed to a later time in the session. It turned out that the most advantageous time to supply and discuss the correct answers to the homework and quiz questions was shortly after each assessment, viz at the start of the next had been completed rather than at some later time.

The Learning Guide included an extensive reading list and students were encouraged to make use of alternative sources of information. The textbook would be regarded as a starting point and could be elaborated upon by examining the approaches of other sources to identical material. In this way the students are also gaining skills in lifelong learning, learning to compare and contrast the way material is presented. 'Read widely' being the axiom recommended.

TUTORIALS

The tutorials occurred once a week for 1 hour. They were principally guided problem solving sessions. Discussions were encouraged and students asked to complete problem solving steps at the whiteboard. Steps in the solution could be discussed and pertinent aspects examined. As each student completed his/her portion, he / she was free to select another volunteer to step up to the board to carry on the solution. In general such procedures went off smoothly; the SFU did not report adversely on this aspect.

A new approach was also adopted with the use of 'concept maps' to aid the solution process during the tutorial. Figure 2 below is an example. Rather than being given a complete worked solution, the students were introduced to a concept map approach. Intermediate results and the final answer were given but the intermediate steps omitted, aside from pointers in the form of a concept or mind map. The students would just need to follow through the procedures indicated in the concept map to arrive at the intermediate answers and ultimately at the final answer. In this way, the students would make the solution their own; they would in essence take control of the learning needed along the way. Some students, for example, would explain that the concept map as given could be rearranged, redrawn or in some or other way improved so as to arrive at the desired result in a quicker or more logical manner!

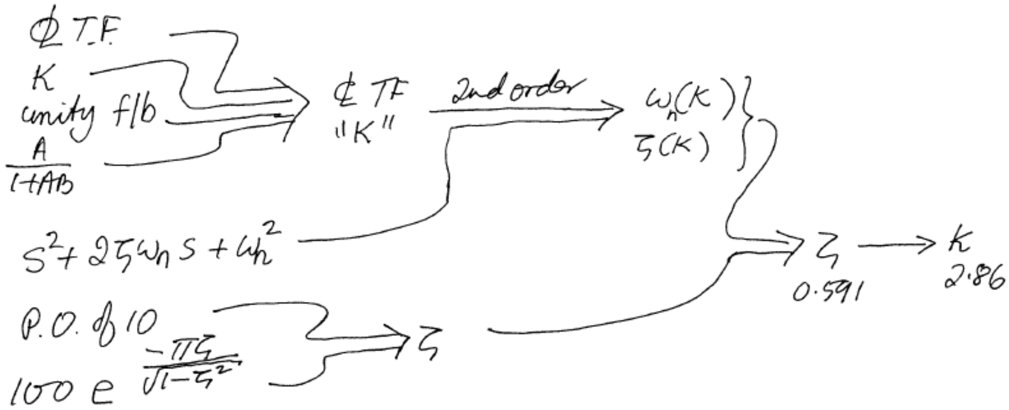

FIGURE 2
USE OF CONCEPT MAPS

CRITERIA BASED ASSESSMENT

The University has made a gradual change away from norm bases assessment to criteria based assessment [6]. Students thus receive the Learning Guide and Unit Outline at the start of the session. Criteria are included in the Learning Guide to encourage self learning and independent study. Criteria are explained, at the outset, detailing how marks would be awarded for the assessment tasks. For example, for the practical work, the students are made aware that a practical book must be submitted at the end of the session. It must contain all the practical work completed during the session – both physical tasks and simulations. Its made clear that, while the practical book will be judged overall, only one task will be graded in detail, selected by lot. A checklist is made available as to how the marks will be awarded.

The final mark will be scaled by the number of Matlab assessments completed and signed off. So it is in the interests of the student to complete all the physical tasks as well as the Matlab tasks, since the physical task that will be graded is not known. At this point in time, the criteria based assessment approach has not yet been tested in the teaching of the Control Systems unit; this however is to occur in the 2010 delivery.

CONCLUSIONS

Making use of the information in SFU was the starting point in making changes to the Control Systems unit. Several changes were made, starting with the scope of the material covered. One of the major criticisms by students was that the amount of work required for the unit. The scope and rate of delivery were reduced and carefully keyed in with the practical work. In this way the relevance of the theory could be demonstrated in the practical tasks.

In general students must be able to envisage how the material being presented would be applied once they have graduated in order to be fully motivated to study. The motivation to study automatic control, through real life examples, needed to be reinforced much more compared to what had been done to date. Real world examples need to be discussed in class and examined in the practical sessions, with an emphasis on preparation for life as a professional engineer. This is, naturally, not a straightforward matter as the variety of work that professional engineers engage in tends to vary.

The delivery of the Control Systems unit tried to create an environment in which the student was able to take charge of their learning, to in essence, put themselves in control of their learning. In this objective the work has been successful in part. Regrettably what seemed to work for one cohort, for reasons unknown, would not seem to work as well for the following year's cohort. For the Control Systems unit, until recently the Unit Outlines were the starting points. In the latest version with the adoption of criteria based assessment, the starting points are the Learning Guides / Unit Outlines. Keeping up with the weekly assessments and the multiple choice quizzes was rewarded with a progressive accumulation of marks. The use of the concept maps appears to have the desired effect, where students create their own revised versions and come up with solutions to problems that originate from their own efforts, giving them ownership, rather than working through the solution of someone else. To maximize the benefits, the students need access to the answers to the homework problems and quizzes shortly after they have completed their attempts at answering, and not at a later time in the session.

With respect to future iterations, there is the question of the use of online quizzes. The advantage of the in class test is that all students complete the test under the same known conditions, something that may be entirely achievable with online versions. The use of other sources by students, aside from the textbook and lecture material, seemed to have an impact and encouraged in many students, though by no means all, independent learning and even the start of lifelong learning habits. While uniform understanding across the class was not achieved, some of the disconnect between automatic control concepts and their application had been mitigated.

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