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Experiences of learning and teaching on a taught Masters course in Engineering: from a didactic approach to a more student-centred learning approach

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Abstract: This paper reports on, reflects on, and evaluates the author's experiences of teaching the *Advanced Control* module on the Masters degree in Advanced Engineering at Dublin Institute of Technology (DIT) over the past four academic years. The teaching approach has evolved from a traditional didactic lecture and laboratory course, with associated assessments, in the first academic year, to the implementation of a more learner-centred approach over the past two academic years. This new approach has been made possible by the appropriate use of real case studies, information technology tools, and web-based virtual laboratories. Assessment methodology has also evolved. In the first academic year, four individually tailored student assignments were set; this prevented plagiarism, while allowing students to work in teams if they wished, as each assignment had a common theme. The assignments were a mixture of traditional examination questions and design problems (which involved limited use of the MATLAB/SIMULINK computer tool). Over the past two academic years, three individual student assignments have been set. Two assignments are primarily based on virtual laboratories on the web, and are assessed by the author using a written report. The final assignment is an individual student PowerPoint presentation on applications of automatic control in bioengineering, computer networks, waste management, and energy efficiency, among other topics. This assignment is peer assessed by the students. An improvement in learning outcomes has been noted using the new approach; formal student feedback has also been positive. The author is committed to deepening the learner-centred approach in the future, with, for example, the inclusion of further industrial case studies, and the progressive implementation of the module in an e-learning environment.

1. Introduction

The Faculty of Engineering of the Dublin Institute of Technology introduced, in September 2002, a one-year full-time programme leading to a Masters degree (M.E.) in Advanced Engineering. The programme can also be taken in a part time mode, over two or more years. The programme was structured in modular form, allowing learners to advance from a Postgraduate Certificate (on completion of three modules) to a Postgraduate Diploma (on completion of five modules) to a Masters degree (on the completion of five modules and a dissertation). Single module certification is also available. Each module had three hours class contact per week, and six hours associated self-learning, totalling 12 ECTS credits per module. For the academic year beginning in September 2004, the requirements of the programme were changed to each module having 2.5 hours class contact per week, and six hours associated self-learning, totalling 10 ECTS credits per module. This brought the programme in line with other such programmes in the DIT. Learners could now advance from a Postgraduate Certificate (on completion of three modules) to a Postgraduate Diploma (on completion of six modules) to a Masters degree (on the completion of six modules and a dissertation). Full details of the current programme are available [1].

The author has taught a module in Advanced Control in the four academic years of the programmes history. Table 1 gives some enrolment data. The scheduling of the module (on Friday afternoon in the 2002-3 and 2005-6 academic years, and Monday evening in the 2003-05 academic years) has encouraged part time students to participate.

Year	2002-3		2003-4		2004-5		2005-6	
Mode; F = Full-time, P = Part-time	F	P	F	P	F	P	F	P
Students enrolled in the programme	17	6	22	13	26	13	NA	NA
Students completing the module	8	0	5	4	8	4	4	3
Total	8		9		12		7	

Table 1: Student numbers in each year (NA = data not available/no data)

The entry requirements for the programme are a minimum of a Second Class Honours degree (2.2 grade or higher) in engineering or a related science programme, or equivalent. Students who chose the Advanced Control module had a variety of educational backgrounds, with first degrees in Electrical Engineering, Electronic Engineering, and Mechanical Engineering predominating. The variety of student educational background meant that the module was taught assuming little prior knowledge of the subject matter; material was covered, however, in a rapid and academically rigorous manner, consistent with the programme award. The module was assessed by coursework and examination; the coursework has a weighting of 30% and the three-hour terminal examination has a weighting of 70%. This is quite a traditional assessment regime. Coursework assessment was done by means of individual student assignments.

Table 2 gives the breakdown of lecture and laboratory hours in each year of the course; the reduction in contact hours for the latter two academic years is noticeable. As learners have already completed a first degree in Engineering (in almost all cases), in which laboratories form a significant part of student effort, traditional laboratory work in the module is limited.

Year	2002-3	2003-4	2004-5	2005-6
Lecture hours	68	64	51.5	51
Laboratory hours	3	7.5	7	5.5
Other hours (tutorial, assignment hours)	7	2	6.5	7
Total	78	73.5	65	63.5

Table 2: Lecture and laboratory hours in each year

The course is structured in four major sections. The first section, *Control Fundamentals*, treats basic ideas under three subheadings: basic process and classical control, system modelling, and identification and tuning fundamentals. The second section, *Identification and Controller Design*, further treats identification issues (in the frequency domain) and controller design in the frequency and time domains. The third section, *Advanced Process Control*, details control techniques that apply to applications, for example, in the chemical and pharmaceutical industries; the control of processes with long time delays is discussed in particular. The final section, *Non-linear, adaptive, and optimal control*, treats advanced topics under these headings. Tables 3 and 4 show the breakdown of teaching hours (i.e. lecture and laboratory hours) devoted to each section of the course over the four academic years.

Year	2002-3	2003-4	2004-5	2005-6
Control Fundamentals	17	19.5	18	16
Identification and Controller Design	18	17	14	19
Advanced Process Control	9	11	15.5	13
Non-linear, adaptive and optimal control	27	24	11	8.5
Total	71	71.5	58.5	56.5

Table 3: Breakdown of teaching hours for each section of the course.

Year	2002-3	2003-4	2004-5	2005-6
Control Fundamentals	24	27	31	28
Identification and Controller Design	25	24	24	34
Advanced Process Control	13	15	27	23
Non-linear, adaptive and optimal control	38	34	19	15

Table 4: Breakdown of teaching hours, in percentage terms, for each section of the course (rounded to integer numbers).

Broadly, the first two sections of the course (*Control Fundamentals* and *Identification and Controller Design)* correspond to material that would be largely covered at undergraduate level in a Control Engineering subject in a variety of engineering programmes. The final two sections of the course (*Advanced Process Control* and *Non-linear, adaptive and optimal control*) are more specialised topics, that would typically be covered in outline (if at all) at undergraduate level. Table 5 summarises the breakdown of teaching hours, in percentage terms, between these two categories.

Year	2002-3	2003-4	2004-5	2005-6
Typical undergraduate material	49	51	55	62
Untypical undergraduate material	51	49	46	38

Table 5: Breakdown of teaching hours, in percentage terms, between two major categories (rounded to integer numbers).

Table 5 shows a consistent trend. The raw figures are, of course, indicative, as the boundary between typical and untypical undergraduate material is fuzzy. The trend is in response to changing student educational background and teaching experience on the course, among other factors; a discussion of teaching and learning experiences on each year of the course is given in Section 2.

The module can also provide the basis for the M.E. dissertation, which has an assessment weighting of 2.5 individual modules. The author supervised four dissertations in 2002-3, two dissertations in 2004-5 and is currently supervising one dissertation (in 2005-6). The dissertation topics are:

2002-3 The estimation of the transfer function of a human operator
The control of the process control training plant (PLINT rig)
The estimation and control of a laboratory heating and ventilation system
Control of a active suspension system for vehicle applications
2004-5 Evaluation of design methods: phase-lead, phase-lag and lead-lag controllers
Control system improvement: direct thermal oxidiser/waste gas steam boiler
2005-6 Further evaluation of design methods for fixed structure controllers

2. Detailed discussion of teaching and learning on the course

The course in the 2002-3 academic year was a traditional, didactic course in Control Engineering, with an emphasis, as Tables 3 to 5 show, on more advanced topics. The CAD package MATLAB/SIMULINK was used extensively in simulation case studies; the simulation programmes were made available to the students. Self-learning by the students of this CAD package was required. Four individually tailored student assignments were set; this prevented plagiarism, while allowing students to work in teams if they wished, as each assignment had a common theme. The assignments were a mixture of traditional examination questions and design problems (which involved the use of MATLAB/SIMULINK). The average mark for the module assignments was 72%, with a significantly lower average module examination mark of 43% (see Table 6). This was disappointing when compared to the average student programme mark (of 72%). Indeed, the external examiners commented on the difficulty of the examination paper. From a student point of view, the strengths of the module, obtained from the standard DIT Student Survey Questionnaire, were the design orientation of the course, the photocopied handouts of the course material and the references to relevant and up-to-date technical papers. No particular weaknesses were identified.

Because of the overall first year experience, the following changes were made in the module for the 2003-4 academic year:

- The overall course material was significantly reduced.
- A greater number of case studies were included in the lectures; most of these case studies were based on aspects of the control of a pilot scale heating and ventilation process available in the laboratory.
- The balance of the material covered was changed modestly, to put a greater emphasis on fundamental topics (see Tables 3 to 5).
- More laboratories were scheduled, and formal instruction was given in the MATLAB/SIMULINK package (see Table 2).
- Five tutorial sheets (with answers to typical examination questions) were distributed in the last five weeks of the lecture course.

In addition, the number of assignments was reduced from four to three, though the nature of the assignments did not change. Table 6 shows a striking difference between part-time student performance and full-time student performance (for the 2003-4 academic year). This is partly explained by noting that 80% of full time students were international, and regrettably had great difficulties with the subject material; in contrast, the part time students tended to hold responsible positions in the control industry, or, in one case, was a research student in control engineering taking the module. Overall, however, student performance showed room for improvement; again, the external examiners commented that the structure and difficulty of the examination paper should be further reviewed. From a student point of view, the strengths of the module, obtained from the Student Survey Questionnaire, were the organisation of the module, the detailed coverage of the course material and the case studies. No particular weaknesses were identified. The main suggestion for improvement was the inclusion of more practical sessions. In further informal feedback gathered towards the end of the module, students suggested that the amount of material covered in the module was greater than other modules on the programme. They preferred the presentation method (overhead projector slides based on the course handouts) to a PowerPoint alternative. In a final comment, it was suggested that each assignment typically took over 20 hours to complete, with some students stating that each assignment took between 40 and 60 hours to complete. However, students suggested that the assignments were a good learning experience.

These comments, and the overall teaching and learning experience, motivated a more searching reflection and evaluation of the module. Such reflection was required in any case, as the module class contact time was reduced by 30 minutes per week. The following changes were made to the module (in addition to previous changes made), for the 2004-2005 academic year:

- The amount of course material was reduced further, with a significant change in the balance of the material toward fundamental topics and towards advanced process control (see Tables 3 to 5). This reflected both the difficulty full-time students were having with the course material, and the increasing part-time profile of students taking the module, with a significant representation of students from the process industries.
- The amount of case studies in the module was increased further.
- The desire for more practical work was addressed by the inclusion of virtual web-based laboratories, which allow a flexible, independent way of learning using the web, and were equally suitable for persons taking the module on a full time or part time basis. Further details of experiences using these web-based laboratories are available [2].
- The assignments were changed to reflect a more learner-centred approach. Three individual student assignments were still set. Two assignments were primarily based on virtual laboratories on the web, and the author assesses a subsequent written report. The final assignment is an individual student PowerPoint presentation on applications of automatic control in bioengineering, computer networks, waste management, and energy efficiency, among other topics. This assignment is peer assessed by the students.

Table 6 shows student performance for the 2004-5 academic year. Full-time student performance has improved, and is now closer to part-time student performance; the author attributes this improvement to the increased concentration on fundamental material, together with a reduction in the number of unprepared students taking the module. From a student point of view, the strengths of the module, obtained from the Student Survey Questionnaire, were the methodology, organisation, and presentation of the course. No particular weaknesses were identified. Again, the main suggestion for improvement was the inclusion of more practical sessions.

The satisfactory outcome of the module in the 2004-5 academic year allowed consolidation of the module in the 2005-6 academic year. There were some changes in the material covered; this was primarily due to the background of both the full-time and part-time students sitting the module, as identification and controller design topics were more in demand. In addition, further virtual laboratories were communicated to the students, to be covered in a self-learning format. From a student point of view, the strengths of the module, obtained from the Student Survey Questionnaire, were again the methodology, organisation, and presentation of the course. No particular weaknesses were identified. Again, the main suggestion for improvement was the inclusion of more practical sessions.

Year	2002-3		2003-4		2004-5		2005-6	
Mode; F = Full-time, P = Part-time	F	P	F	P	F	P	F	P
Students completing the module	8	0	5	4	8	4	4	3
Total	8		9		12		7	
Module examination average (%)	43	NA	23	75	42	50	NA	NA
Module continuous assessment average (%)	72	NA	53	91	71	87	65	76
Total Module assessment average (%)	59	NA	32	80	51	61	NA	NA
Overall Programme student average (%)	72	NA	61	70	56	NA	NA	NA

Table 6: Performance of students in module assessments (NA = data not available/no data)

3. Conclusions

This paper has reported on, reflected on, and evaluated the author's experiences of teaching the Advanced Control module on the Masters degree in Advanced Engineering at DIT over the past four academic years. The teaching approach has evolved from a traditional didactic lecture and laboratory course, with associated assessments, in the first academic year, to the implementation of a more learner-centred approach over the past two academic years. This new approach has been made possible by the appropriate use of real case studies, information technology tools, and web-based virtual laboratories. Assessment methodology has also evolved. The evolution of the module is ongoing; for example, the module changes in the 2006-2007 academic year from a year-long format to a two-semester format, with associated changes in assessment methods. The author is committed to deepening the learner-centred approach in the future, with, for example, the inclusion of further industrial case studies, the piloting of alternative learning methods, such as a problem-based approach, and the progressive implementation of the module in an e-learning environment.

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[1] http://www.dit.ie/DIT/study/graduate/courses/adveng.html [accessed 18 May 2006].

[2] O'Dwyer, A. (2006). "Using virtual laboratories in control engineering education: some experiences", Proceedings of *EdTech 2006: the 7th Annual Irish Educational Technology Users Conference*, Institute of Technology, Sligo, May.