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Team-teaching on a Large Multidisciplinary Engineering Mathematics Class: The Lessons We Have Learnt so Far

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Abstract: This paper presents an analysis of team-teaching on a large class first year engineering mathematics module. The teaching team is drawn from several engineering disciplines, and includes both academic staff and postgraduate teaching assistants. An interdisciplinary team was selected because the module designers wished to equip students with insights on the application of mathematics in the various engineering disciplines. Despite the prevalence of large class team-teaching in engineering and other disciplines, the literature on large class teaching in engineering is limited. A key objective of the paper is to make an attempt at addressing this perceived gap by presenting the lessons learnt on large class team-teaching on this first year introductory course on engineering mathematics. Findings from this study indicate that large class team-teaching presents significant management and communication challenges. However, these challenges can be mitigated by timely planning, effective communication and team coordination.

Keywords: team-teaching, engineering mathematics, co-operative teaching, MATLAB, EXCEL, mathematical modelling and analysis.

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1. INTRODUCTION

1.1 Aim

The first and second year introductory science and mathematics modules in Engineering are often delivered through large classes. This is because they cover the essential knowledge and skills that underpins higher level studies in all Engineering disciplines. Increasingly, these classes are delivered through team-teaching, both as a means to expose students to multiple perspective on a subject (Anderson and Speck, 1998), and as a means to make the best use of scarce teaching resources (Armstrong, 1977). However, despite their prevalence, the literature on large class teaching in Engineering with specific reference to team teaching is limited. This paper seeks to address this perceived gap by presenting the lessons that we have learnt on large class teaching following the introduction of a multi-disciplinary, team-taught, first year module in mathematical modelling and analysis at University College London.

1.2 Overview of team-teaching from the literature

Whilst there are several definitions of team teaching, the definition adopted in this paper is the one by Johnson & Lobb (1959, p.59) which is cited in Armstrong (1977): “A teaching team is a group of two or more persons assigned to the same students at the same time for instructional

purposes in a particular subject or combination of subjects." This may involve members of the teaching team collaborating and working cooperatively on all, or only on some aspects of teaching and assessment, including course design (Perry & Stewart, 2005). In the module described in this paper, team members collaborate on module design and review, and on module assessment design and marking, and deliver lectures in sequence. Within workshops, academic staff teach collaboratively with postgraduate teaching assistants, whilst the help desk is run entirely by postgraduate teaching assistants. An important aspect, however, is that all these tasks require coordination, and team communication is paramount.

2. STRUCTURE AND CONTENT OF THE FIRST YEAR ENGINEERING MATHEMATICS MODULE

2.1 Module Objectives

The main driver behind the redesign of the first year engineering mathematics module was the desire to enable engineering students to study relevant introductory concepts in mathematics within an Engineering problem-solving context. The module comprises large class lectures delivered by engineering academics who introduce mathematical concepts and link them to the academic research taking place within the Faculty of Engineering Science. This is followed by workshops conducted within the students' own departments where the concepts taught in lectures are reinforced through small group activities comprising both paper-based and computer-mediated problem solving.

2.2 Curriculum overview

The mathematical concepts covered by the first year engineering mathematics module are similar to those covered by more traditional first year Engineering Mathematics modules. However, unlike the traditional modules, this module reinforces the engineering utility of these concepts by using relevant engineering-oriented titles rather than mathematics oriented titles. Table 1, which summarises the first year engineering mathematics module syllabus, illustrates this concept:

Syllabus Item	**Summary of Intended Learning Outcomes**
Building Mathematical Models	Introduces basic mathematical models and their implementation using EXCEL and MATLAB
Employ assumptions to simplify systems	Introduces the art of estimation and approximation in Engineering analysis and decision-making.
Engineering calculus	Reviews basic mathematical calculus with an emphasis on engineering applications
Engineering uncertainty	Introduces statistics and probability concepts and their significance and application to practical engineering
Analysing data	Introduces data modelling and fitting, including regression analysis, within engineering practice
Representing engineering systems and signals using complex numbers	Introduces the theory of complex numbers as a tool for modelling and analysing bimodal engineering quantities
Describing the world in 3-D, Matrices and Linear algebra	Introduces vectors, matrices and linear algebra and their importance in handling and manipulating multi-dimensional engineering data.
Engineering systems modelling: Calculus and differential equations	Introduces and uses calculus and differential equations to model and analyse dynamic engineering systems

Table 1: Syllabus summary of the first year engineering mathematics module

2.3 Overview of module teaching methods

Historically engineering programmes teach engineering mathematics theory in isolation from engineering practice. Whilst this can help develop an understanding of the mathematical concepts, for engineers it is just as important to understand how to apply this newly acquired mathematical knowledge to solving engineering problems. The first year engineering mathematics module utilises mathematical modelling and simulation techniques as a teaching tool to integrate the acquisition and practice of mathematical concepts. This approach is underpinned by a suite of online mathematical support resources as well as a walk-in student-led engineering mathematics help desk.

The module is delivered in the first term through a blended learning approach that integrates face-to-face weekly lectures, weekly workshops, structured online Moodle resources and mathematical modelling and simulation tools like MATLAB and spreadsheet software. Both lectures and workshops are 2 hours each, with lectures taking place at the beginning of the week, and workshops taking place at the end of the week. Lectures are common to all the engineering disciplines, and their role is to introduce mathematical concepts, and to relate these concepts to relevant research within the engineering disciplines.

Study materials are posted online on the Moodle virtual environment, and students have to complete pre-lecture online quizzes to ensure that they are adequately prepared for the lecture. Students are required to read prior to the lectures, and, in the period between the weekly lecture and workshop, to engage with lecture material through set problem sets.

Workshops are run within the departments. During the workshops, students work in groups to establish solutions to the weekly problem sheets posted by the lecturers on Moodle. The workshop problem sheets comprise short mathematical questions designed to reinforce understanding of mathematical concepts as well as extended problem sets that require the use of MATLAB and EXCEL. In addition, individual departments also provide additional practice material tailor-made to their disciplines. This strategy was adopted as a way of ensuring that students have the opportunity to apply taught mathematical engineering problems within their own disciplines. Table 2 shows the typical student workload across the term.

Learning activity	**Time for activity in hours per term**
Lectures	20
Private Reading	40
Seminars/ problem classes / workshops	20
Required written work	30
Revision	48
E-learning student led contact	30
Total Learning in hours per term	**188**

Table 2: The typical student workload distribution across the first term

2.4 Module assessment

The module is assessed through e-coursework, worth 10%, standard pen and paper coursework, worth 40%, and by an examination, worth 50%. The e-coursework focuses on mastery of fundamental concepts, whilst the pen and paper coursework assesses both mastery of concepts as well as problem-solving skills using MATLAB. The examination focusses only on mathematical concepts, and does not have any MATLAB requirement. There is no direct assessment of MATLAB mastery, but students need to have a certain level of MATLAB proficiency to enable them to answer the problem solving tasks in the pen and paper coursework.

Assessment Item	**Weighting**	**Description of the Assessment**	**Additional Comments**
E-assessment	10%	9 e-courseworks spread throughout the first term. Worth 10/9 % each.	To assess competence in basic mathematical concepts covered in the course
Standard Coursework	40%	4 pieces of written coursework in the term. Worth 10% each.	All the 4 pieces of coursework are marked by postgraduate teaching assistants.
End of module examination	50%	Held in the end of year May/June Examination period	2 hour, closed book, tutor-marked examination
Total	100%		

Table 2: Module assessment weighting

2.5 Student support on the module

Module support is provided thorguh the Moodle Question and Answer Forum and a Help Desk. Students are encouraged to place their queries on the Question and Answer Forum and to respond to each other's queries. In each case an academic staff member or postgraduate teaching assistant checks and confirms all the answers provided by other students before a discussion thread is closed.

The Help Desk runs for 2 hours, three times per week during term-time, and offers informal, face-to-face and friendly guidance on:

- Engineering Mathematics theory and applications
- Mathematical modelling and analysis of engineering systems
- Applications of Matlab and Excel to mathematical modelling, analysis and visualisation

2.6 Module monitoring and review

Module monitoring and review is carried out on an ongoing basis. For instance, each week postgraduate students monitor student engagement and attendance in lectures, workshops and the help-desk. This data is reviewed by all the academics on the programme, and where necessary, corrective changes are agreed upon and implemented. At the end of the year the academics

working on the module carry out an annual module review, and implement any module redesigns in preparation for the next academic year.

3. HUMAN RESOURCES REQUIRED FOR THE DELIVERY AND ASSESSMENT OF THE MODULE

Each lecture is delivered by an engineering academic with expertise on the topic. There are currently 9 lecturers on the module, with 8 delivering a single lecture topic each and one delivering two lectures. There are approximately 600 students on the first year engineering mathematics module. These students are divided into two lecture groups, meaning that each week the designated lecturer has to deliver the same lecture twice.

As mentioned previously, workshops are organised and run by individual departments, and within each department, students are subdivided into workshop groups of not more than 60 students each. Each group is led by an academic member of staff supported by two postgraduate teaching assistants. Mechanical, civil, electronic and chemical engineering have two workshop groups each, whilst biomedical and biochemical engineering have a single workshop group each, giving a total of 10 workshop groups.

Disciplinary groups are used to ensure that students will focus on engineering applications of mathematics that are directly relevant to their own discipline. An upper limit of 60 students per workshop group has been adopted to ensure that each student receives adequate support from the academic staff member and the two postgraduate teaching assistants.

As already discussed, the Help Desk runs for 2 hours, three times per week during term-tim. Each session is led by two postgraduate teaching assistants, which means that 6 postgraduate teaching asssitants are required to run the Help Desk each week. A team of 18 postgraduate teaching asssitants take turns to lead the help desk, meaning that a pair of postgraduate teaching asssitants will do help desk duty once every three weeks.

Electronic assessments are automatically graded, and this process is overseen by a single academic. The academics who deliver the weekly lectures are responsible for preparing the paper-based coursework and the end of module examination. All the pieces of assessment are reviewed by all academic staff working on the module. Paper-based coursework is marked by the postgraduate students who work on the help desk or assist with the workshops, and this marking is moderated by the academics in charge of the various workshop groups. The final exam is marked and moderated by all the academic staff working on the module.

A teaching-focussed academic is responsible for coordinating the entire module. This includes the management of the virtual learning environment, coordinating the preparation of learning resources, scheduling and overseeing learning delivery, student support and assessment processes.

4. EVALUATION OF TEAM TEACHING ON THE MODULE

3.1 Module design

Module design started two years prior to the implementation of the first year module in the academic year 2014-15. The module design team comprised at least two academics from each of the departments. The majority of these academics eventually went on to lecture or lead workshop groups once the module started running in the academic year 2014-15. The overall module design and implementation process was overseen by a team of senior academics drawn from the individual departments.

The main objective of the module design team was to agree on a common syllabus acceptable across all the engineering departments. Issues such as the module coverage as well as the depth of coverage of individual topics had to be resolved. The oversight team of senior academics frequently had to step in to foster agreement and ensure the process of module design proceed.

3.2 Integrating MATLAB into the module

It had been agreed in principle that software tools like MATLAB and EXCEL should be integrated into the module. Different departments had different perspectives on how much MATLAB and EXCEL to incorporate in a first year module on mathematics. Although a compromise was arrived at, this issue was not entirely resolved at the design stage, leading to lecturers adopting varying degrees of MATLAB integration during the first year of teaching. This was further compounded by other workshop leads preparing workshop practice questions requiring a depth of MATLAB competence far in excess of the elementary competence expected of beginners. However appreciative feedback from module coordinators of second term first year courses requiring MATLAB competence, as well as the positive end of year feedback from the majority of the students eventually won over sceptical team members.

3.3 Approach to module lectures

In principle, the design team advocated for a blended learning approach to the delivery of the module that required adequate preparation of learning and assessment resources beforehand. Students had to go through the lecture material and engage with pre-lecture quizzes prior to each lecture. This material also had to be available for workshop leads and postgraduate teaching assistants well before the time students were expected to engage with it. This was quite different from sole non-flipped module teaching where staff could prepare material as they went along. Consequently, a significant number of lecturers missed these deadlines, which meant that both the students and other staff members were inadequately prepared for lectures.

Some lecturers were sceptical of lecture flipping, and preferred instead to use the lecture session as the primary medium for content delivery. This led to some lecturers failing to cover their topics, and overburdened workshop leads who had to go over the lecture material again for the benefit of the students, which in turn led to some workshop sessions failing to offer adequate practice support to students. To overcome this the weekly feedback received for well-prepared and delivered lectures was circulated to all academic staff on the module. In addition, academic staff were encourage to attend lectures and observe their peers.

3.4 Adoption of collaborative active learning methods in workshops

A collaborative team –learning approach whereby students worked on problem sets together and found solutions for themselves was advocated for the module. This was new for both the students and some of the academic staff. Consequently some of the staff reverted back to teacher-centred non-collaborative approaches whereby staff essentially worked through all the problems after giving the class a limited time to practise. Again peer-to-peer staff learning was adopted, whereby staff were encouraged to observe some of their peers who were already acquainted with collaborative learning techniques. In addition, resources for collaborative learning were made available to staff, and the module coordinator co-delivered some of the workshop sessions with the staff so as to pass on the necessary expertise.

3.5 Lack of continuity between lectures and workshops

During the first year lecturers had responsibility for preparing lecture materials and for setting the end of module examination. Workshop leads had responsibility for preparing the workshop materials and the paper-based coursework. Even though a detailed scheme of work had been prepared for each topic, lack of collaboration between lectures and workshop leads led to disparities between what was taught in lectures and what was covered in workshops. A two stage process was adopted to resolve this. First, workshop leads were encouraged to attend some of the lectures, and lecturers were encourage to visit workshop sessions. Secondly, lecturers and workshop leads were encouraged to collaborate in preparation of workshop materials. In this way a more collaborative spirit developed and better coordination between lecturers and workshop leads developed.

The need to interact on the module has led to improvements in both formal and informal interdepartmental communication amongst staff. Prior to this, academic staff only tended to communicate if they had shared research interests, or if they both shared an interest in teaching leading to participation in cross-faculty teaching initiatives. This was because, apart from the first and second year mathematics module which were delivered by the Department of Mathematics, each department conducted its own teaching separately from the other departments. Apart from a duplication of resources, this also restricted the flow of teaching innovations across the faculty. It is expected that as academic staff increasingly interact across departments, more interdisciplinary teaching will take place. With regard to the engineering mathematics modules, it means that there will be more coordinated delivery of teaching, which will ultimately benefit the students.

3.6 Impact of weekly changes to lecturers

During module design, it was felt that each topic should be delivered by an engineering academic who was an expert in that topic, and who could link the topic to his or her area of research. This led to a new lecturer for each topic. Student feedback throughout the term indicated that this change in lecturer on a weekly basis led to a significant number of students getting frustrated. In their qualitative feedback, some students indicated that they had trouble adjusting from one lecturer to another on a weekly basis. It is now collectively felt that the number of lecturers on the module needs to be reduced by ensuring that each lecturer teaches at least two or more consecutive topics.

3.7 Staff-student communications

During the weekly review meetings, attendees often proposed changes to various aspects of the module as informed by observations by staff and feedback from students. Minutes of these meetings were posted to an online repository and circulated to all academics and postgraduate teaching assistants on the module. However, some academic staff didn't attend meetings, and failed to keep abreast of the minutes. This led to confusion amongst students as staff disseminated differing information. To alleviate this it was resolved that the module coordinator would have sole responsibility for communicating to students on important aspects of the module, and that staff would copy in the module coordinator in any communications with students.

5. LESSONS LEARNT

This study suggests when team teaching is implemented on large classes, aspects of module management such as module planning and coordination, staff-student and staff-staff communication, task scheduling and compliance with deadlines become infinitely more important. Tasks have to be planned in detail beforehand, and communicated to both staff and students as clearly and as unambiguously as possible. In addition, to facilitate hand-over from one lecturer to another, lecturers have to ensure that they complete all the specified teaching tasks within the agreed timeframe. If this is not done, there will be knock on effects in subsequent lectures and tutorials.

Whereas in sole teaching modules it is not critical to maintain rapport with fellow academics, in the case of team-teaching rapport and clarity of communication between team-teaching members is absolutely critical. Also, whilst team-teaching helps to give students a multiplicity of perspectives on the taught subject, it is essential that switching of lecturers be minimised to ensure that both lecturers and students are able to establish rapport with each other.

In conclusion, therefore, whilst large class team teaching can present significant management and communication challenges, these challenges can be mitigated by timely planning, effective communication and team coordination.

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