Integrating MATLAB Into First Year Engineering Mathematics:

A Project Management Approach to Implementing Curriculum Change

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***Abstract*— A review and reflection on the curriculum change project carried out at UCL in the academic year 2014-15 to introduce Matlab teaching in the first year engineering mathematics is carried out. The project was guided by findings from the literature on computer algebra systems, and conducted using classical project management techniques. A key finding from this project is that the project success was entirely dependent on evidence-based guidance from the literature and on systematic adoption of proper project management techniques.**

Keywords—computer algebra system; engineering mathematics; mathematical modelling and analysis; Matlab; curriculum change project

I. INTRODUCTION

Computer algebra systems (CASs) are software programs with the ability to carry out mathematical computations both numerically and algebraically. Examples of popular CASs include Matlab, Maple and Mathematica. CASs are increasingly being used in teaching and learning mathematics at all levels of the education system, including at secondary and university level. Just by way of highlighting the extent of use of CASs, a 2008 literature review of CAS use identified 326 peer reviewed papers on CAS use at both secondary and tertiary level [1]. Of these papers, 204 of them focused on CAS use at tertiary level.

Proponents for CAS use in the teaching and learning of mathematics suggest that they help to develop mathematical thinking, concepts and skills[2]. CASs offer a flexible environment for students to easily explore and experiment with mathematical concepts. In addition, CASs enable students to visualize mathematical concepts through such features as graph plotting and animation of mathematical functions[1] . Pedagogically, CASs help to promote greater conceptual understanding of mathematics by taking away the burden of tedious calculations[1] [2].

However, CAS introduction into university level mathematics needs careful thought and considerable planning if it is to be successful [3]. For example, educators may reject the integration of CASs into mathematics teaching if they feel that the curriculum is already so full that it is difficult to make way for additional teaching material. In addition, educators hold different viewpoints on the teaching of mathematics, particularly at first year level, with some viewing the introduction of CASs as likely to reduce the mastery of basic mathematical concepts. Students may also reject the introduction of CASs if they view their introduction as just an extraneous addition that is irrelevant to the teaching of core mathematics. Even as recently as 2014, curriculum designers considering integrating Matlab into their mathematics teaching were still being advised to carefully consider the design of learning and assessment tasks, and in particular, those tasks that are technology-supported [4].

In this paper I discuss and reflect on the introduction of Matlab to the first year engineering mathematics at UCL. This introduction was borne out of a desire to enable students to make connections between mathematical concepts and their applications to the various engineering disciplines at UCL. For instance, by using Matlab, students could easily model engineering concepts without getting bogged down by tedious computational calculations. In addition, we also hoped to enable students to gain a physical understanding of mathematical concepts and equations through using the graphical plotting and visualisation capabilities of Matlab. This redesign of the first year engineering mathematics curriculum is part of the ongoing redesign of the undergraduate engineering curriculum at UCL to provide a core curriculum that integrates mathematics and engineering science in the context of large and current engineering problems [5].

As already noted, CAS use in mathematics learning and teaching is now quite widespread at university level. However, in similar fashion to the initial adoption of any new technology, the greatest reported use of CASs at tertiary level is by individual, enthusiastic practitioners, with system-wide adoption across course programmes and departments being comparatively rare [6]. In contrast, the integration of Matlab into mathematics teaching and learning at UCL has been carried out systematically across six engineering departments. This project therefore offers the opportunity to study and analyse the complexities and challenges associated with implementing CAS use within a faculty-wide engineering mathematics course.

II. Implementation Approach

With the large number of reported implementation of CASs at tertiary level, we decided not to re-invent the wheel, and opted instead for an implementation approach informed by the existing literature. This was particularly necessary in our situation as the introduction of Matlab to first year engineering mathematics was going to impact around 600 students, and 14 academics involved with the delivery of engineering mathematics at first year level across six academic departments. From the literature, a ten-point implementation plan was developed [7].

A. The Ten Step Matlab Integration Plan

1. The integration of Matlab into first year mathematics increases the dilemma of selecting which topics to leave out so as to make room for Matlab. Hence, it is imperative that a criteria for deciding which topics to include and to leave out of an Engineering Mathematics module be drawn up when you introduce Matlab[8].
2. Be aware of the prevailing student dispositions towards both Maths and Matlab, and put in place a plan to mitigate this [3, 9]
3. Highlight the relevance of Matlab throughout the mathematics module[3, 10, 11]
4. Carefully redesign your lectures to ensure that Matlab tuition blends in with mathematics tuition [9, 10, 12].
5. Use a two-step approach in each lecture whereby mathematical concepts are introduced first, followed by the introduction of Matlab concepts[13].
6. Use a scaffolding approach to introduce Matlab by emphasising the use of single line commands in early lectures, and gradually building up to basic Matlab programming in later lectures[3].
7. Provide adequate support for Matlab, including introductory sessions at the beginning of the course, and ready access to Matlab programming support throughout the course [3, 9, 10].
8. Provide continuity between lectures and supporting workshops by ensuring that workshops build up and reinforce mathematical and Matlab material covered in lectures [10].
9. Provide a structured sequence of workshop exercises that require increasing proficiency with Matlab [3, 9].
10. Design module assessments that reflect the inclusion of Matlab in the course[3, 10-12].

B. Structuring of the First Year Course

The first year engineering mathematics course module was structured around ten 2-hour lectures accompanied by supporting workshops. The lectures were common to all the engineering disciplines. Ten topics were identified for coverage, and each lecture was designed to cover one topic. The supporting workshops were run within the departments, who were also tasked with developing the necessary workshop material. This strategy was adopted as a way of ensuring that students worked on course material that was relevant to their own disciplines. The engineering mathematics module was renamed "Mathematical Modelling & Analysis I." This was to encourage students to view the module not only as a mathematics module, but as a module that gave them the skills to use mathematical concepts and software tools like Matlab to model, analyse and solve pertinent engineering problems.

III. Matlab Support for Students

Matlab student support included:

- A cheat sheet with a list of the key Matlab commands to be covered in the course;
- Bespoke instruction videos illustrating how to navigate the Matlab user interface as well as separate videos demonstrating the use of the key Matlab commands;
- A walk-in help desk facility whereby postgraduate teaching assistants were available for three 2-hour sessions each week to offer assistance on both Matlab and Mathematics;
- Weekly progress monitoring and review meetings for all staff involved with the first year engineering mathematics module.

IV. Review of the 2014-15 Academic Year Implementation

The redesigned and renamed mathematical modelling and analysis module was run for the first time in the academic year 2014-15. It was a steep learning curve for both the teaching staff and students alike. This was because it was the first time that mathematics had been delivered in-house, with the exception of the Mechanical Engineering and Electronics & Electrical Engineering Departments. Previously all mathematics teaching had been conducted for engineering departments by the Department of Mathematics.

A. Teething Problems and Resolutions

A direct consequence of this relative inexperience in in-house mathematics delivery was that in the first few weeks, the problem sets focusing on engineering applications tended to be so advanced that students struggled with understanding the engineering context prior to solving the problems. In addition, the solutions to these problems demanded a level of Matlab knowledge that was way beyond the introductory material covered in the introductory videos. This contradicted directly the guidelines in the Matlab integration plan which recommended a gradual, scaffolded introduction of Matlab.

A second problem that occurred was that lecturers found it impossible to cover both the mathematical concepts and

the necessary Matlab functionality during the lecture period. This was symptomatic of a general struggle by academics to achieve a balance between teaching of fundamental mathematical concepts, as in the replaced traditional mathematics module, and focusing on applications to engineering, as required by the new course module. The result was that students only got introduced to Matlab in the supporting workshop sessions. This again was a direct contradiction to the agreed guidelines in the Matlab integration plan which recommended the introduction of Matlab concepts within lectures, and advocated continuity between lectures and workshops.

The result was that students found the course too difficult, and the teaching staff began to doubt the feasibility of running a course that covered both mathematical and Matlab tuition. Five weeks into the course additional Matlab support was provided through the introduction of weekly one hour sessions on Matlab. In addition, discipline-specific problem-sets were revised to ensure that they were at a level that was consistent with the introductory Matlab concepts that the students had covered.

By the end of the first term of teaching both staff and students had adapted to the requirements of the course. Through ongoing discussions between teaching staff, a more realistic pace of introducing Matlab concepts had been achieved. In addition, a realistic balance between the teaching of mathematical course content and engineering applications had been adopted.

B. Review and Modification of the Fist Year of Teaching

Feedback was collected from both students and teaching staff at the end of the first year. Whilst students had found the course to be challenging, they appreciated its usefulness in helping them to engage more effectively with their disciplines. In particular, through appropriate use of Matlab techniques first year students easily demonstrated an ability to engage with more challenging problem sets that were often introduced at second year level. In addition, first year students easily demonstrated a significantly higher level of engagement with their disciplines when compared to the engagement of higher level students at the same point in time.

For the 2015-16 academic year, the following adaptations were made:

- Matlab support lectures would be run throughout the teaching term.
- A standard worksheet was developed for use across all departments for each topic. Each of these worksheets was specifically designed to cover both the topic's mathematical concepts and Matlab applications at the appropriate level.
- Each worksheet was specifically designed to ensure that the average student would manage to go through it within the 2-hour workshop period.
- Students were encouraged to use Matlab routinely to check the correctness of their own paper and pencil computations.

On the basis of these changes, Matlab is now viewed by both staff and students as an integral part of the first year engineering mathematics module. The level of complaints for the 2015-16 academic year is negligible compared to the same period in the 2014-15 academic year.

V. Lessons Learnt

The process to integrate Matlab into first year engineering mathematics was carefully planned with guidance from the literature. However, despite this, teething problems were experienced. The main cause for this was the failure to adhere strictly to the drafted implementation guideline. Reasons for this failure include institutional beliefs and culture pertaining to the teaching of first year engineering mathematics. Going forward, just as in any curriculum change project, careful consideration needs to be made on the potential impact of institutional beliefs and culture on staff and student perceptions on the integration of CASs into mathematics teaching.

Another lesson arising from this project is that teething problems are guaranteed to occur, and a system should be in place to address emerging problems as soon as they are recognised. A key factor in the success of this project was the institution of a continuing programme monitoring and review system that enabled problems to be nipped in the bud, and for adaptations and changes to be implemented before they became insurmountable.

Another aspect which guaranteed the success of the curriculum change project was the unequivocal support from senior management within the faculty. This ensured commitment to the change programme from all staff concerned, despite any misgivings they might have had.

In conclusion, the introduction of Matlab into first year mathematics teaching is not a trivial task, and for success, it should be viewed as a proper curriculum change project, and the necessary project management procedures should be strictly adhered to during the change process. Only then can it be guaranteed to succeed.

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