Adoption of Computational Modelling in Introductory Engineering Course Modules: A Case Study

Abel Nyamapfene
University College London, Gower St, Bloomsbury, London WC1E 6BT, UK
a.nyamapfene@ucl.ac.uk

Abstract

This study seeks to explain the adoption and use of computational modelling and simulation across introductory engineering modules following the advent of the Integrated Engineering Programme (IEP) curriculum framework in 2013. Rogers' (2003) diffusion of innovations theory served as the theoretical framework for this study. Findings from the study suggest that there is a correlation between academics' views and perceptions of active learning methods and their adoption of computational tools in their teaching. In addition, the study also suggests that the adoption of computational tools at both individual and departmental level bears some correlation to their perception of, and commitment to the values espoused by the IEP.

Introduction

The objective of the study reported here is to analyse the extent and pattern of adoption of MATLAB and other computational tools within introductory engineering modules at University College London (UCL). The study also seeks to identify whether the adoption of computational tools within engineering teaching bears any relationship to the introduction of the Integrated Engineering Programme (IEP) curriculum framework in the Faculty of Engineering Sciences in 2013 (Mitchell et al., 2019).

The IEP specifically led to the introduction of computational modelling within first and second year engineering mathematics modules. Hence, the main assumption underpinning this study is that the inclusion of MATLAB tuition within engineering mathematics teaching in 2013 served as a catalyst for the adoption of computational modelling as a teaching tool in introductory engineering modules.

Context and assumptions underpinning this study

Prior to 2013, the department of mathematics was responsible for delivering mathematics tuition on behalf of the majority of engineering disciplines within the Faculty of Engineering Sciences. However, in 2013 mathematics tuition was brought in-house was to ensure that students would study mathematics within the context of engineering (Nyamapfene, 2016). Since then, MATLAB has been used as a mathematical modelling tool to reinforce the connection between engineering mathematics and the fundamental concepts underpinning their studies in the engineering disciplines. The teaching and use of MATLAB within engineering mathematics teaching has enabled students to use MATLAB graphics and visualisation features to gain a physical understanding of the basic mathematical concepts and equations that underpin the study of engineering. In so doing, it has enabled students to use their mathematical knowledge to explore the basic engineering principles underpinning the various engineering disciplines taught at UCL without being bogged down by tedious mathematical calculations and computations.

The inclusion of MATLAB tuition within the engineering mathematics modules has helped to equip students with the basic MATLAB skills needed for computational modelling and simulation in other engineering modules. In addition, MATLAB is widely used by engineering academics within the faculty in their research. Consequently, the integration of MATLAB tuition within the engineering mathematics modules ensures that MATLAB is a tool that both academics and students are familiar with.

Research design

Prior to this study there was already some evidence that following the decision to integrate MATLAB with first and second year engineering mathematics, there has been a corresponding increase in the use of MATLAB and other computational tools in introductory engineering modules. This study sought to establish whether or not this relationship is causal. Moreover, the adoption of MATLAB across the engineering disciplines has not been uniform, and hence one objective of this study is to establish the reasons for this variability. To this end, I sought to establish individual academics' motivations for adopting computational modelling in their modules. I also investigated whether or not there were any departmental factors that had an influence on academics' decisions to adopt MATLAB, or any other computational tool, as a teaching tool within the early-stage foundational engineering course modules. As part of this study, I also investigated the extent to which the introduction of MATLAB and/or other computational tools has affected the structure of learning and assessment activities within modules.

To guide this study, I chose the following research questions to frame the study:

RQ 1 What has motivated academics to adopt computational modelling within introductory engineering modules?

RQ 2 How has the introduction of computational modelling affected teaching and assessment within the modules that have adopted it?

RQ 3 What are the departmental characteristics that correlate with increased adoption of computational modelling within introductory engineering modules?

Method

To address these research questions, I adopted a qualitative case study approach that incorporated interviews with academics across five engineering departments in the Faculty of Engineering Sciences at UCL who had adopted MATLAB and/or other computational tools in their teaching in first and second year engineering modules. I used Roger's diffusion theory of innovation (Rogers, 2010) as the theoretical framework to guide me in specifying the research questions, methodology and data analysis techniques that I utilised in this study.

According to Rogers, diffusion "is the process by which an innovation is communicated through certain channels over time among the members of a social system." Rogers also identified five innovation attributes that predict the innovation's rate of adoption by an individual or group of individuals. These attributes are relative advantage, compatibility, complexity, trialability and observability. Using this as a basis, and with reference to guidance for formulating innovation diffusion questionnaires from Atkinson (2007) and Sonnenwald et al. (2001), I came up with a series of interview questions for the study.

To identify the participants for this study, I went through all the module descriptions for first and second year undergraduate engineering modules in the Faculty of Engineering Sciences and identified all those modules that explicitly made reference to any one of the following terms: MATLAB, computational modelling, computational simulation, or that made references to specific computational software other than MATLAB. From this set of modules, I identified and retained engineering principles modules that made specific reference to MATLAB or any one of the computational tools in their descriptor. For example, I retained modules such as "Introduction to Thermodynamics" as long as they made reference to some computational tool in their module descriptor. However, I removed from the list any modules whose main focus was the introduction of one or more computational tools. For example, I removed from the list modules such as "Introduction to Programming" and "Computational Tools for Chemical Engineering."

Study Findings

A key outcome of this study was that academics who adopted computational tools as teaching aids in their introductory modules in engineering tended to have had more involvement in the conceptualisation, design and implementation of the Integrated Engineering Programme than those who did not. Specifically, those academics who taught on the engineering mathematics modules also tended to have replicated the use of MATLAB or other equivalent computational tools on their other modules. In addition, they were also more likely to be involved in, or to have attended a number of teaching and learning seminars hosted by the faculty or by the UCL Arena Centre for Research-based Education, which is responsible for academic staff development. Adopters were also more likely to state that they had adopted computational tools in their teaching as this was consistent with their views and philosophies of teaching. All these features are consistent with the descriptions for early adopters of innovation as discussed by Rogers (2010).

Those who adopted computational tools in their teaching were also more likely to have simultaneously adopted one or more forms of student-centred, active learning methods in their teaching as well. Reasons given for this were that computational modelling went hand in hand with active learning. In addition, these adopters also tended to use collaborative group work in their teaching and assessment practices. In addition, whilst the traditional engineering module tends to be assessed more or less exclusively by the closed book end of module exam, modules run by adopters tended to have significant amounts of both formative and summative assessment. Again, these practices are consistent with the IEP ethos.

The study also found some correlation between departmental commitment to the values of the IEP and their adoption of computational tools in their teaching. Departments committed to the IEP ethos also tended to have a larger number of modules utilising computational tools in their teaching. Additionally, such departments tended to have organisational structures that supported the introduction of such tools. For instance, such departments tended to run generic computational modelling course modules to enhance the computational skills of their students. They also tended to have dedicated teams of PhD students to support students in the use of MATLAB and other computational tools deemed essential to their discipline.

References

ATKINSON, N. L. 2007. Developing a questionnaire to measure perceived attributes of eHealth innovations. *American Journal of Health Behavior,* 31**,** 612-621.

MITCHELL, J. E., NYAMAPFENE, A., ROACH, K. & TILLEY, E. 2019. Faculty wide curriculum reform: the integrated engineering programme. *European Journal of Engineering Education***,** 1-19.

NYAMAPFENE, A. Integrating MATLAB Into First Year Engineering Mathematics: A Project Management Approach to Implementing Curriculum Change. 2016. IEEE.

ROGERS, E. M. 2010. *Diffusion of innovations*, Simon and Schuster.

SONNENWALD, D. H., MAGLAUGHLIN, K. L. & WHITTON, M. C. Using innovation diffusion theory to guide collaboration technology evaluation: work in progress. Proceedings Tenth IEEE International Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises. WET ICE 2001, 2001. IEEE, 114-119.