CETL-MSOR Conference 2015

Conference Proceedings

Edited by Dr David Green

sigma Σ network for excellence in mathematics and statistics support

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UNIVERSITY of GREENWICH

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CETL-MSOR Conference 2015

The University of Greenwich
8th - 9th September 2015

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Acknowledgements

CETL-MSOR 2015 would not have been possible without the hard work of the organising committee: Tony Croft, Michael Grove, Duncan Lawson, Trevor Hawkes, Moira Petrie and Tony Mann. Thanks are also due to Daryl Davies for the administrative support he provided to the conference, Chantal Jackson for the production of the conference promotional materials and proceedings, and finally David Green for editing and collating these proceedings.

Published by the **sigma** Network

March 2016

www.sigma-network.ac.uk

ISBN: 978 1 911217 04 6

Content Editing: David Green

Design and Layout: Amy Bishop - Creative and Print Services, Loughborough University

Printed by Loughborough University

Editor's Notes

The 10th annual CETL-MSOR Conference was held in September 2015 at the University of Greenwich, London. There was a record number of delegates in attendance and a wide range of excellent talks and workshops on offer, and these Proceedings reflect this high standard. Keynote talks were given by Professor Les Ebdon (OFFA), Professor John MacInnes (University of Edinburgh) and David Bowers and the **sigma** Hub Co-ordinators. There was also an excellent keynote session showcasing the student intern projects funded by **sigma**.

All presenters were offered the opportunity to submit a written paper for these Proceedings. In addition, a large number of abstracts and presentations have been made available via **www.sigma-network.ac.uk/cetl-msor-2015.**

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Curriculum and beyond: Mathematics support for first year life science students

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Abstract

The move into higher education is a real challenge for students from all educational backgrounds, with the adaptation to a new curriculum and style of learning and teaching posing a daunting task. A series of exercises were planned to boost the impact of the mathematics support for level four students and was focussed around a core module for all students. The intention was to develop greater confidence in tackling mathematical problems in all levels of ability and to provide more structured transition period in the first semester of level 4.

Over a two-year period the teaching team for Biochemistry and Molecular Biology provided a series of structured formative tutorials and "interactive" online problems. Video solutions to all formative problems were made available, in order that students were able to engage with the problems at any time and were not disadvantaged if they could not attend. The formative problems were specifically set to dovetail into a practical report in which the mathematical skills developed were specifically assessed.

Students overwhelmingly agreed that the structured formative activities had broadened their understanding of the subject and that more such activities would help. Furthermore, it is interesting to note that the package of changes undertaken resulted in a significant increase in the overall module mark over the two years of development.

Introduction

Challenges

The transition to higher education is a challenge for students in all areas of academia. New students, often from a range of educational backgrounds, are asked to adjust to very different teaching and assessment styles and to a more challenging curriculum (Hart and Baxter, 2003). In the life sciences students often adjust rapidly to the biology elements of the curriculum but struggle with the chemistry and mathematical aspects.

Formative exercises are a well-recognised method of supporting areas of the curriculum in which students report struggling (Yorke, 2003) and are influential in the retention of students (Yorke, 2001). There is a broad discussion on the definition of formative, and the importance of divorcing the formative and summative activities within a unit of learning (Rust, 2002; Nicol and Macfarlane-Dick, 2006).

Broadly speaking a well-structured formative program will: clarify and explain the performance criteria; engage the students in self-assessment and encourage reflection; provide signposts to the students about performance; encourage discussion between students and staff; provide a positive experience and deliver effective feedback to both staff and students (Nicol and Macfarlane-Dick, 2006). The major challenge is to build a series of opportunities which enable students to self-differentiate and engage at different points, while not being disadvantaged for doing so.

Supporting learning

Biochemistry and Molecular Biology is a first year module with 450-500 students per year. Within this module there is a particular emphasis on enzyme kinetics as there are a number of experimental, mathematic and conceptual skills associated with this topic which are fundamental to many other areas of study. The focus of this work is a lab report assessment based around the enzyme kinetics experiment undertaken by the students, with a large number of marks for mathematical processing and graphical skills. The diversity of student intake means that we needed to develop a flexible support structure for students struggling with mathematical ability. We achieved this through a structured and interleaved system of curricular and extracurricular formative activities highlighted in Figure 1.

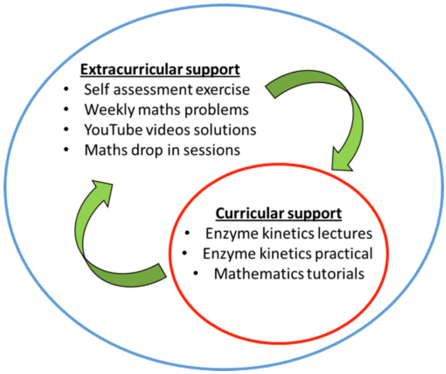

Figure 1: Diagrammatic representation of the curricular and extracurricular activities available to students to support development and confidence in mathematical skills for the Biochemistry and Molecular Biology module. The activities were designed to be flexible and interwoven, giving support across the piece.

In-module support

The curricular support begins with a series of tutorials containing materials designed to challenge students of all levels. These were run in a student centred manner with students encouraged to work together on the problems. This problem based, student led approach is often more successful with this skills based and practically focused learning (Hmelo-Silver, 2004). Following on from these the students were provided with some lecture based reinforcement of the concepts and mathematical processes involved, much of which was also provided in the guidance materials for the enzyme kinetics practical.

Out of module support

Extracurricular support needs to feed directly into the curricular element. In part this was achieved with a series of online mathematical problems written to feed directly into the taught elements. YouTube videos were made in which the solutions to these problems were explained, delivering a mock face-to-face experience which the students were free to review multiple times.

Finally, a series of drop in sessions were provided with the intention of supporting students across all modules; however experience suggests that the greatest impact of these in semester 1 is in the Biochemistry and Molecular Biology module. A self-diagnostic assessment exercise was provided to students at the start of semester 1 to help students identify their support needs.

Aims

In this report we aim to evaluate the impact of the work done to support students in developing numeracy skills in the first year Biochemistry and Molecular Biology module.

Methods

Program of work

458 level 4 (first year) undergraduate students on the Biochemistry and Molecular Biology module were given a formative mathematics assignment related to enzyme kinetics. Students either self- or peer- marked the assessment in tutorial classes. Approximately two thirds of the tutorial classes were provided with paper surveys to complete; these anonymous surveys captured the pre-University qualifications of the students, and 6 Likert-type responses to the statements:

> *"I feel that this formative exercise has increased my understanding of the subject."*
>
> *"I would like to undertake more formative assessment in the future."*

Ethical approval was given by the University of Westminster Ethics committee VRE1415-0839.

Statistical analysis

The student results on the module were taken from the Student Record System and reported as means ± s.d. where 2012/13 n=446, 2013/14 n= 478 and 2014/15 n=458. The cohorts were compared by one-way Anova, where $p<0.05$ was considered to be a significant change.

Results

Educational background of the students

The range of entry qualifications in the student intake is an important factor in considering the areas of support required. Figure 2 shows the entry qualifications of the students in the 2014/15 cohort.

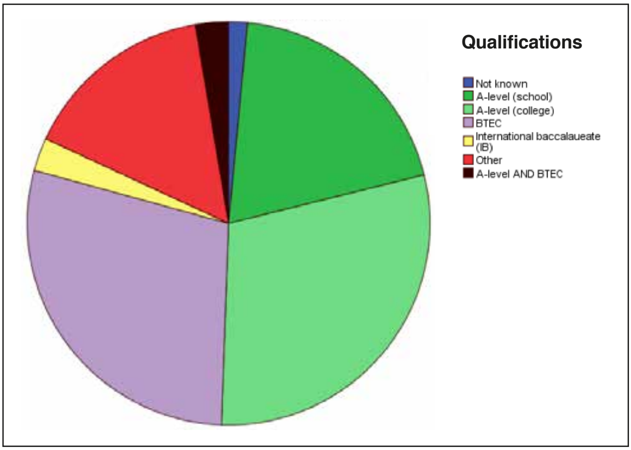

Figure 2: Entry qualifications of students taking part in the formative maths tutorials. n=52 A-level school; 78 A-level college, 73 BTEC, 7 International baccalaureate, 40 other, and 7 BTEC + A-level.

Numeracy self-assessment – Extracurricular support

The numeracy self-assessment (Appendix 1) is a short online question set designed to evaluate a student's current level of confidence. In 2014/15 106 of the 407 Blackboard VLE registered students (26%) attempted the self-assessment test.

Numeracy drop in sessions – Extracurricular support

In the 2014/15 academic year 15 numeracy drop in sessions were held in the first semester. These drop in session had a curriculum of their own, although they were used by students for support in module assessments. The attendance at these varied from week to week, but were consistently attended by 18-36 students per week, with a peak of 42 coinciding with the enzyme kinetics coursework submission.

YouTube interaction – Module linked extracurricular support

In total 12 videos were made to support students in tackling the formative problems, and were uploaded to YouTube. The mean number of views for each video was 116 with a range of 66-320. The videos worked through the problem from first principals and each problem corresponded with a skill required in the enzyme kinetics practical. Each problem also addressed skills which were further developed in the timetabled tutorial.

Maths Tutorial and Kinetics Practical – Curricular support and development

The maths tutorials are timetabled sessions in which students work through a series of problems based around amount of substance (moles), concentrations and dilutions. The problems were tackled by the students in working groups, and solutions presented at timed intervals throughout. Turnout at tutorial session was between 75-85%.

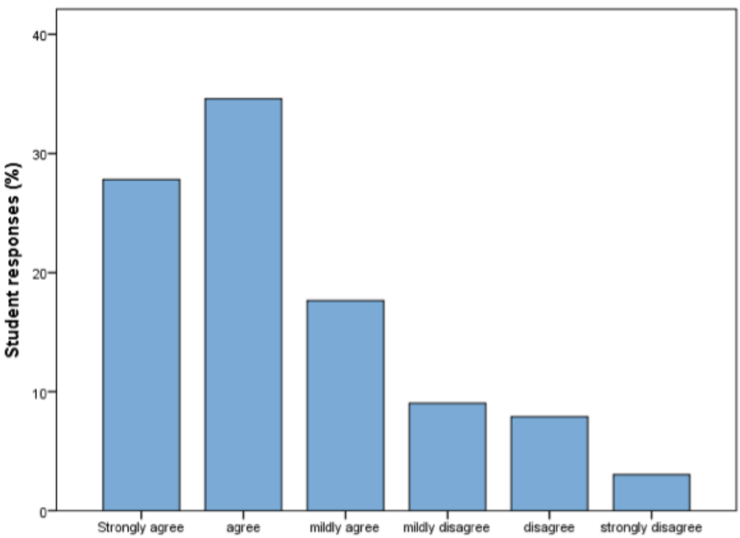

Figure 3: Likert-type responses to the statement "I feel that this formative exercise has increased my understanding of the subject" amongst the FSLS400 Biochemistry and Molecular Biology class (n=266).

The students' responses to a questionnaire designed to assess the impact of the tutorial activities were measured by Likert response and are shown in Figure 3. Over 70% of students felt that the formative exercises had helped them to understand the subject and gain confidence with the mathematics.

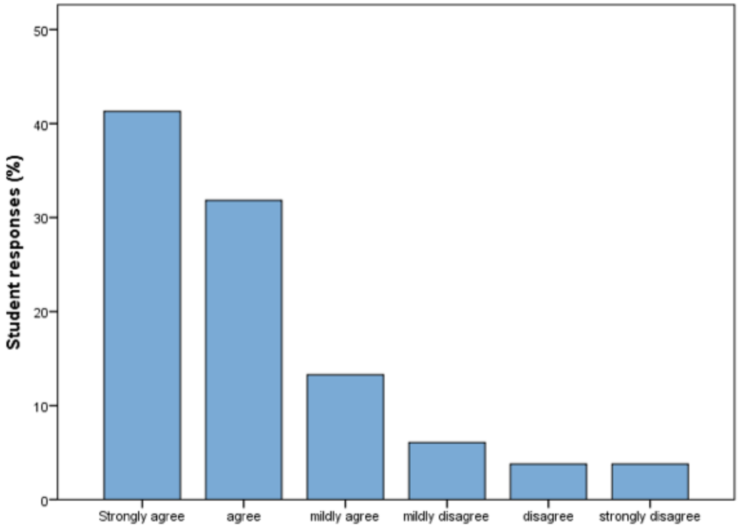

Figure 4: Responses to the statement "I would like to undertake more formative assessment in the future" amongst the FSLS400 Biochemistry and Molecular Biology class (n=264).

Student willingness to participate in further formative assessment of this type were assessed by Likert scale response and are shown in Figure 4. This suggests that more than 85% of students would like more formative assessment to help support their studies and can therefore see the value of undertaking such tasks.

Student success

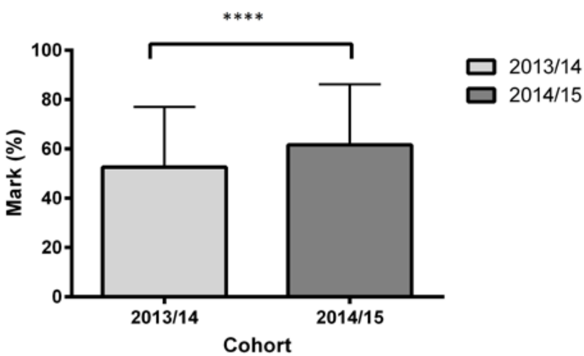

*Figure 5: FSLS400 Level 4 Biochemistry and Molecular Biology; mean ± s.d. mark for the kinetics practical assessment (20% of the module). **** p<0.0001 when 2013/14 (n=478) is compared to 2014/15 (n=458) by unpaired students t-test.*

Over a period of years a number of interventions have been made to support students in the development of their mathematical ability. This has had a significant ($p<0.001$) positive effect on the overall marks for the enzyme kinetics practical as can be seen in Figure 5.

Discussion

Benefits of formative support

It is widely accepted that formative assessment is generally thought to have positive effects on learning (Yorke, 2003), although there does seem to be considerable debate amongst teaching academics as to what formative assessment is and what it does. Formative assessments are, however, found by evaluation to be effective in developing all areas of the curriculum, including content to skills (Gijbels and Dochy, 2006; Black and Williams, 1998; Sadler, 1998;).

In this study we have utilized a formative programme of activities to develop some of the numeracy skills essential for life sciences. Through a series of curricular and extracurricular activities we sought to engage the students and encourage the development of self-regulated learning practices through a structured series of curricular and extracurricular activities (Nicol and Macfarlane-Dick, 2006).

The very first requirement was that students displayed some insight into their strengths and weaknesses and undertook a self-assessment exercise to evaluate their numeracy skills. Students scoring below the threshold were recommended to attend the numeracy drop in sessions, which had a separate curriculum of their own. 26% of the students in this cohort took this test, which is disappointing. Attendance at the drop in sessions was also lower than anticipated, but as predicted, peaked around the time of the kinetics practical assessment in Biochemistry and Molecular Biology.

In addition to the drop in sessions, a series of online problems were provided and engagement with the online formative problems was measured through views of the YouTube videos. The average view number was 116 for each for the 12 videos, while for some the number was as high as 320. Unlike the self-assessment test and numeracy drop in, it is difficult to estimate the number of students who used this resource, as the system records all views not only unique views. However, this resource sparked the most conversation between staff and students, who reported that the videos were of a great help. It is possible to tentatively suggest that this is an effective method of communicating with students, if not necessarily concluding that the student have learned effectively.

The material presented online fed directly into the timetabled, curricular tutorial session, in which the numeracy skills directly required for assessment were introduced. Attendance at these sessions was variable, but was never less than 75%. Students reported mixed feelings about the tutorials, with some wanting more and some wanting fewer. The high attendance may be attributable to the direct linkage with assessment, or it may have been because they are held early in semester 1.

Student success

Over the course of three consecutive academic years, there has been a stepwise improvement in the average score for the enzyme kinetics practical component of the Biochemistry and Molecular Biology module at level 4 ($p<0.001$). This would suggest that there has been an overall improvement in the learning achieved by the students on this module.

It is difficult, however, to pinpoint the causal factor, as two major variables are altered each year; the first and most obvious is the cohort of students taking the module, and the second is the teaching team, which varies slightly from year to year. In addition, alterations made in assessment briefing material and marking schemes may have contributed to this improvement. Despite this, it is clear from our analysis that the students found this approach to learning of help, and felt that it contributed positively to their learning.

Conclusion

It is a feature of formative material that a number of students will not engage, or engage late in the process, unless there is a mark attached (Rust, 2002). Indeed, our own assessment is that almost 90% of students reported that they were more likely to complete a piece of work if there were marks attached (data not shown).

The combination of curricular and extracurricular activities ensures that all students, regardless of their level of engagement, have an opportunity to undertake some formative training in the desired area. This does mean that the impact of the learning will vary from student to student, but that students who are insightful and more aware of their weaknesses are provided a structured approach to work through their challenges. In addition, the mixture of online and classroom based activities ensures a level of equality between students who find it more difficult to attend drop in session due to outside commitments and those who are available. Teaching staff and students alike felt that this approach provided a positive learning experience for students, and module staff did not consider it added excessively to their teaching burden.

References

Black, P. & Wiliam, D (1998a) Assessment and Classroom Learning. Assessment in Education, 5(1), 7-71.

Gijbels, D. and Dochy, F. (2006). Students' assessment preferences and approaches to learning: can formative assessment make a difference? Educational Studies, 32(4), pp.399-409.

Hart, S. and Baxter, A. (2003). From FE to HE: Studies in Transition: A comparison of students entering higher education with academic and vocational qualifications. Widening Participation and Lifelong Learning, (2), pp.18-29.

Hmelo-Silver, C. (2004). Problem-Based Learning: What and How Do Students Learn? Educational Psychology Review, 16(3), pp.235-266.

Nicol, D. and Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: a model and seven principles of good feedback practice. Studies in Higher Education, 31(2), pp.199-218.

Rust, C. (2002). The Impact of Assessment on Student Learning: How Can the Research Literature Practically Help to Inform the Development of Departmental Assessment Strategies and Learner-Centred Assessment Practices? Active Learning in Higher Education, 3(2), pp.145-158.

Sadler, D. (1998). Formative Assessment: revisiting the territory. Assessment in Education: Principles, Policy & Practice, 5(1), pp.77-84.

Yorke, M. (2001). Formative Assessment and its Relevance to Retention. Higher Education Research and Development, 20(2), pp.115-126.

Yorke, M. (2003). Formative assessment in higher education: Moves towards theory and the enhancement of pedgogic practice. Higher Education, 45, pp.477-503.

Mathematics learning support across a multi-campus institution: A prototype of virtual support

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Abstract

In this paper, a study on Mathematics Learning Support (MLS) that was undertaken across three institutes intending to form the Technological University for Dublin is outlined. This study consisted of a survey that was circulated to both staff and students in each of the three institutes. The survey had two objectives. Firstly, it sought to identify the students' needs for MLS in each of the three institutes. Secondly, it sought to ascertain the preferred method of provision of MLS, on a scale ranging from exclusively online to exclusively in person. Following on the results of this survey, it was decided to prototype a virtual MLS drop-in service. The operational details of the prototyping of this virtual drop-in service and the feedback obtained from the students involved are presented in this paper.

Introduction

In recent years an increasing number of students in Irish Higher Educational Institutions (HEIs) are taking courses with mathematical and statistical elements. This is in part due to the widespread recognition that mathematics underpins the STEM disciplines and the emphasis placed by the Higher Educational Authority (HEA) on producing graduates who are highly literate in mathematics (Expert Group on Future Skills Needs 2008, HEA 2011). Hand in hand with this increase however has come the so called 'Maths Problem'- that is an apparent decline in the mathematical proficiency of incoming first year students across HEIs in Ireland and elsewhere (Gill et al. 2010). In fact, it is widely acknowledged that the absence of a solid foundation in mathematics can be one of the key inhibitors for student progression in higher education (HEA 2010).

As part of the response to this problem, Maths Learning Support Centres (MLSCs), defined by Lawson et al (2003) as 'a facility offered to students (not necessarily of mathematics) which is in addition to their regular programme of teaching through lectures, tutorials, seminars, problems classes, personal tutorials, etc.' have been set up in the majority of HEIs in Ireland (Gill et al. 2008). In fact a soon to be published study involving 32 Irish HEIs has shown that 84% of these now offer some form of MLS (Clancy et al. 2015). It is therefore clear that MLS has now become an integral part of the higher educational framework.

The upcoming merger of the three institutes intending to form the Technological University for Dublin: the Dublin Institute of Technology (DIT), the Institute of Technology Blanchardstown (ITB) and the Institute of Technology Tallaght (ITTD), represents a significant change in the Irish Higher Educational landscape. It is important that the MLS provision in each of these institutes evolves in a manner that best suits the needs of the students across the three Institutes. The work reported in this paper represents a first step in this process.

Methodology and Participants

The initial stage of this study consisted of a survey of both staff and students in each of the institutes. It was decided to survey staff who are involved in teaching mathematics or statistics modules and students who had engaged with some form of MLS. The survey was conducted online and consisted of three main questions:

1. Which discipline do you teach under/are you studying?
2. In your opinion, what are the three main topics that students would require MLS for?
3. Please indicate your preference for how this MLS would be delivered?

For Q3, answers were given on a five point scale, ranging from 'Exclusively Online' to 'Exclusively in Person'. A total of 45 staff responses and 118 student responses were received. The breakdown of responses per institute are given in Tables 1 and 2. It should be noted here that DIT, with approximately 20,000 students enrolled, is a much larger institute than both ITB and ITTD, with approximately 4000 students each.

Institute	DIT	ITB	ITTD	Unspecified
No. of Staff Responses	16	18	9	2

Table 1. Breakdown of Staff Responses by Institute

Institute	DIT	ITB	ITTD	Unspecified
No. of Staff Responses	34	67	16	1

Table 2. Breakdown of Student Responses by Institute

Results of the Survey

In this section we give the results to Q2 and Q3 of the survey. The results from staff and students are given separately and then compared.

It should be noted that the results to Q2, on the topics that students would most need MLS with, are given just in terms of number of responses, as more than one answer to this question was allowed. Many individual responses to Q2 were received, for clarity it was decided to group these responses into five main areas: Basic Algebra (e.g. logarithms, indices), Calculus, Preliminaries (e.g. fractions, basic numeracy, percentages), Probability and Statistics and an Others category. Topics that were included in the Others category include trigonometry, vectors, Fourier and Laplace transforms, geometry, financial mathematics, linear algebra, among others.

The responses to Q3, on the method of provision of MLS, are given as a percentage of total respondents.

Staff

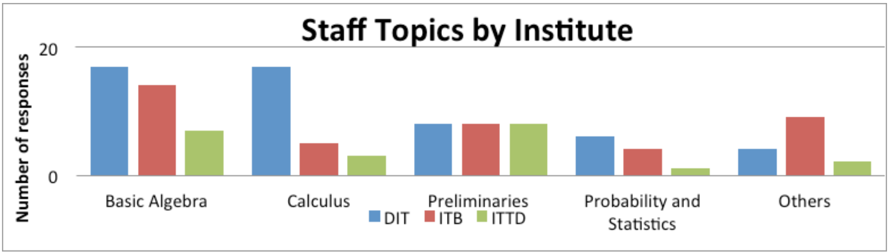

Figure 1: A breakdown of the staff responses to Q2 across each of the Institutes

Overall the most common topic that **staff** indicated students would require extra support with was Algebra, followed by Calculus. In DIT the most common topic indicated was Calculus, in ITB it was the Others category and in ITTD the most common topic indicated was Preliminaries.

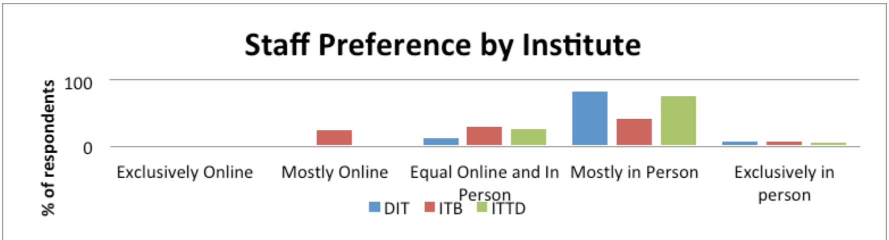

Figure 2: A breakdown of the staff responses to Q3 across each of the Institutes. Preferences are given as a percentage of total responses.

71% of total **staff** surveyed indicated their preference for the delivery of MLS to be provided either mostly or exclusively in person. This was highest in DIT, with 88% of staff indicating this preference, and lowest in ITB with 47% of staff indicating their preference to be given mostly or exclusively in person. 24% of ITB staff would prefer the MLS to be provided mostly online, while 0% of both ITTD and DIT staff opted for this option. This may be explained by the fact that in ITB some modules are delivered completely or partially online and therefore staff in ITB may be more familiar with this medium of delivery.

Students

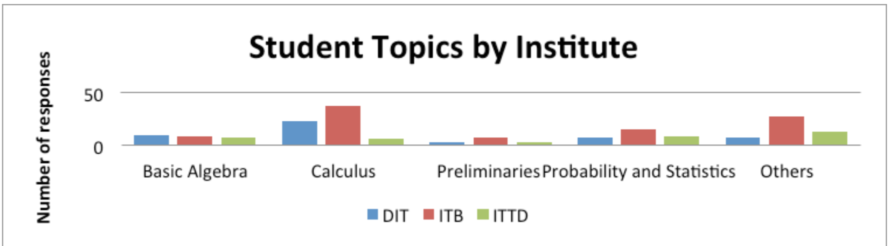

Figure 3. A breakdown of the student responses to Q2 across each of the Institutes

The overall most common topic that **students** indicated that they would need extra support with was Calculus; individually Calculus was most commonly chosen in DIT and ITB, while in ITTD the most common topic category was the Others category.

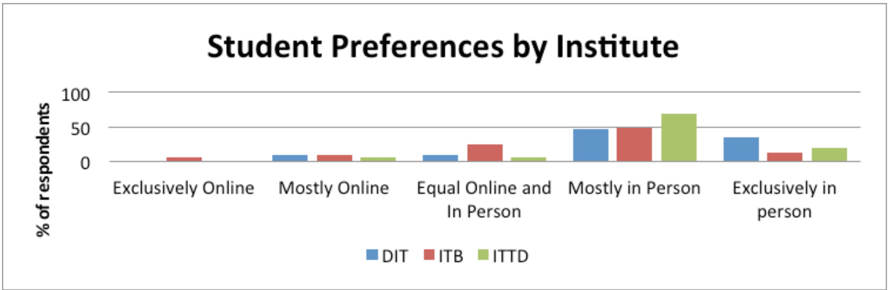

Figure 4: A breakdown of the student responses to Q3 across each of the Institutes. Preferences are given as a percentage of total responses.

69% of total **students** surveyed indicated that the preference for the delivery of MLS to be provided either mostly or exclusively in person. This was highest in ITTD, with 88% of students indicating this preference, and lowest in ITB with 60% of students indicating their preference to be provided mostly or exclusively in person. Again it worth noting that only ITB students indicated a preference for MLS to be provided exclusively online, which may again be a reflection of their familiarity with online delivery of lecture content.

Comparing the total student and staff responses, we find that the responses to Q3 are mostly in agreement. However it is interesting to note the difference in opinion between the groups in regards to Q2, the topic that they believe students would most need extra support with (see Table 3 for details).

	Basic Algebra	Calculus	Preliminaries	Probability and Statistics	Other
Staff	34%	22%	19%	12%	13%
Students	13%	37%	7%	16%	26%

Table 3: Comparison of the total student and staff responses to Q3

Of particular note is the fact that the most common topic chosen by students was Calculus, while Basic Algebra was the most common topic that staff chose. One possible interpretation of this is as a misconception on the students' behalf, whereby they are struggling with a module involving Calculus but the root causes for this difficulty may lie in issues with Basic Algebra.

Feedback on prototype of Virtual Drop-in service

While the majority of staff and students surveyed had a preference for in person support, there was some desire that some form of MLS be provided online. In a recent large scale report on student engagement with MLS in Ireland, it was found that 83% of students surveyed rated the drop-in service as worthwhile while 56% of students rated ICT facilitated support as worthwhile (O'Sullivan et al 2014). Inspired by this and the results of our survey, we decided to prototype a virtual drop-in service, where we would hope to replicate the in-person experience as much as possible in a virtual environment.

In order to implement this, three Wacom Intuos Tablets were purchased, one for use in each institute, and the Adobe Connect software package was used. The first trial involved staff members from each of the institutes; this was then followed by two trials involving seven students in total. The first of these involved students in ITTD receiving support from a staff member in DIT, and the second involved students in ITB and a staff member in ITTD. Feedback was sought from the students, including their opinions on the advantages and disadvantages of the virtual drop-in over the traditional experience and any suggestions they may have on improving the virtual drop-in experience.

Overall students were positive towards the concept of the Virtual Drop-in service, however they felt that the technical issues that arose during the trials, such as feedback and slow connection issues, would need to be addressed in order for this service to be implemented successfully. A representative selection of the feedback received from the seven students involved in the prototype is presented below.

Overall Impression

'Great idea, software was a little clunky and internet connection or lack of was a hindrance, But can easily be taught and overcome.'

'It has potential but I feel unless it becomes more streamlined I could see students becoming more frustrated than helped.'

Advantages

'It will help people learn or ask questions easier who are shy or ashamed to do so in class.'

'… the virtual drop-in gives a larger scope of time and geographical location.'

Disadvantages

'If the lecturer on virtual drop-in uses different techniques to solve questions as opposed to classroom lecturer, it may be confusing and take longer to help solve a problem.'

'… may get overloaded with students who don't bother going to class as they see this system as a substitute for class attendance.'

Suggestions for Improvement

'Use external microphone and speakers or headphones to eliminate the echo effect'.

'Web cam/Web cast with the cameras facing whiteboards on either side of the link.'

'A platform for posting question and receiving answers in a timely fashion.'

Conclusions

In this paper we have outlined the results of a survey of staff and students in three institutes soon to form a new merged entity. The majority of staff (71%) and students (69%) surveyed would like to see MLS provided either primarily or exclusively in person. However there was a significant preference that some portion of MLS be delivered online. As a result of this preference among both staff and students, a prototype of a virtual drop-in service was developed and was tested with students and staff from the different institutes. These students were mostly positive towards the concept of virtual drop-in, but had some concerns on the technical side of the service. They also offered some useful suggestions on how this service could be improved.

References

Clancy, M., Cronin, A., Cole, J., O'Shea, D and Breen, C. (2015) An Audit of MLS in Irish HEIs, Unpublished

Expert Group on Future Skılls Needs. (2008) Statement on Raising National Mathematical Achievement. Accessed via http://www.skillsireland.ie/media/egfsn090616_statement_on_activity.pdf (August 2015)

Gill, O., Johnson, P. and O'Donoghue, J. (2008) An Audit of Mathematics Support Provision in Irish Third Level Institutions. CEMTL (Regional Centre For Excellence in Mathematics Teaching and Learning), University of Limerick.

Gill, O., O'Donoghue J., Faulkner, F. and Hannigan A. (2010) Trends in performance of science and technology students. International Journal of Maths Education, Science and Technology, 41, 323-339.

HEA (2010) A Study in Progression in Irish Higher Education. Accessed via http://www.hea.ie/sites/default/files/study_of_progression_in_irish_higher_education_2010.pdf (August 2015)

HEA (2011) National Strategy for Higher Education to 2030. Retrieved August 2015 from http://www.hea.ie/sites/default/files/national_strategy_for_higher_education_2030.pdf

Lawson, D., Croft, A.C. and Halpin, M. (2003) "Good practice in the provision of mathematics support centres, learning and teaching in mathematics, statistics and operational research." LTSN Maths, Stats & OR Network, Accessed via http://www.mathcentre.ac.uk/resources/Good%20Practice%20Guide/goodpractice2E.pdf (August 2015).

O' Sullivan, C., Mac an Bhaird, C., Fitzmaurice O. and Ní Fhloinn, E. (2014) An Irish Mathematics Learning Support Network Report on Student Evaluation of Mathematics Learning Support: Insights from a large scale multi-institution survey. NCE-MSTL.

Mathematics Learning Support in Ireland in 2015

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Abstract

The provision of mathematics learning support in higher-level institutions on the island of Ireland has developed rapidly in recent times with the number of institutions providing some form of support doubling in the past seven years. The Irish Mathematics Learning Support Network aims to inform all mathematics support practitioners in Ireland on relevant issues. Consequently it was decided that a detailed picture of current provision was necessary. A comprehensive online survey was conducted to amass the necessary data. The ultimate aim of the survey is to benefit all mathematics support practitioners in Ireland, in particular those in third-level institutions who require further support to enhance the mathematical learning experience of their students. The survey reveals that the majority of Irish higher-level institutions provide mathematics learning support to some extent, with 65% doing so through a support centre. Learners of service mathematics are the primary users: first-year science, engineering and business undergraduates, with non-traditional students being a sizeable element. Despite the growing recognition for the need to offer mathematics learning support almost half of the centres are subject to annual review. Further, less than half the support offerings have a dedicated full-time manager, while 60% operate with a staff of five or fewer. The elevation of mathematics support as a viable and worthwhile career in order to attract and retain high quality staff is seen by many respondents as the crucial next phase of development.

Introduction

While mathematics learning support (MLS) in higher education institutions (HEIs) is now considered by many to be as much a part of the teaching and learning structure as lectures or tutorials, it is, in fact, a relatively new development. The first MLS initiative in the UK occurred in the 1990s, while the first mathematics learning support centre (MLSC) in Ireland opened in 2001. It is generally perceived that the number of HEIs providing MLS has increased significantly in the intervening years. In 2008 Gill et al (2008) conducted a complete audit of the number and type of MLS in Ireland; Perkin et al carried out a similar audit for the UK in 2012 (Perkin, Lawson, and Croft, 2012)

The Irish Mathematics Learning Support Network (IMLSN) was established in 2009 to act as an informative community of practice for all those with an interest in the provision of mathematics and statistics support at third-level education in Ireland. The IMLSN constantly seeks to maximise the benefits of the IMLSN to MLS practitioners. In order to inform the way forward it was decided that an up-to-date comprehensive picture of the extent and nature of MLS provision at third level on the island of Ireland in 2015 was needed. An online survey, consisting of over 50 questions, was conducted to gather this data; this paper contains a summary of some of the key results.

Level of Support

Appropriate contacts were identified in 32 HEIs, including universities, institutes of technology, further education colleges and teacher training colleges, and invited to complete the online survey. There was a 97% response rate – 31 out of the 32 institutions responded – so the survey provides a comprehensive picture of the current situation. The survey was divided into the following five categories: The mathematics support service, Staffing and tutors, Types of support available, Users of the service and Records and reporting.

In 2008 the number of HEIs providing MLS in Ireland was 13 (Gill, Johnson and O'Donoghue, 2008). By 2015 this figure had grown to 26, a doubling of service providers in seven years. Those currently without any form of MLS gave a lack of funding as being the main barrier; further, three of these stated that they have no current plans to provide MLS in the near future.

The 2008 audit revealed that 11 out of the 13 institutions providing MLS had a MLSC; six of these were part of an academic centre providing other forms of support, while nine had drop-in facilities (no requirement to pre-book) (Gill, Johnson and O'Donoghue, 2008). By 2015 the number of institutions with a MLSC had risen to 17. So while the number of HEIs providing MLS has doubled, there are only six additional MLSCs. Interestingly, in almost half (45%) of those 17 institutions, the centre is subject to annual review.

In 76% of cases the MLS is available to all students. The remaining MLS offerings provide limited access ranging from first-year students only to undergraduates only.

Types of Support

Analysis of the type of MLS provided has been divided into two categories: in-person support and online. It was considered that the extent and form of online support warranted separate attention. The current demand for, and benefit of, online support will help to inform the development of this type of MLS into the future.

Figure 1 below details the in-person MLS services provided by 25 Irish HEIs. Analysis is divided into three categories: drop-in, appointment based and workshops for small groups. It is evident from Figure 1 that a drop-in service is the most common form of in-person MLS provided, with 88% of respondents indicating that they offer this service. It is worth noting that four respondents indicated that the in-person support in their institution is entirely comprised of a drop-in service. Interestingly, two MLSCs do not offer a drop-in facility. Workshops on specific topics are also very popular with 64% of respondents offering this type of support. Only one respondent selected the workshop category alone. In most cases workshops are organised following a combined request from students and their lecturer (39%) or are initiated by the MLSC manager (32%). Only three respondents stated that workshops are run as a result of a direct request from students. An appointment-based service is offered by 44% of Irish MLS offerings. None of the respondents selected the appointment-based category without selecting at least one of the other two options.

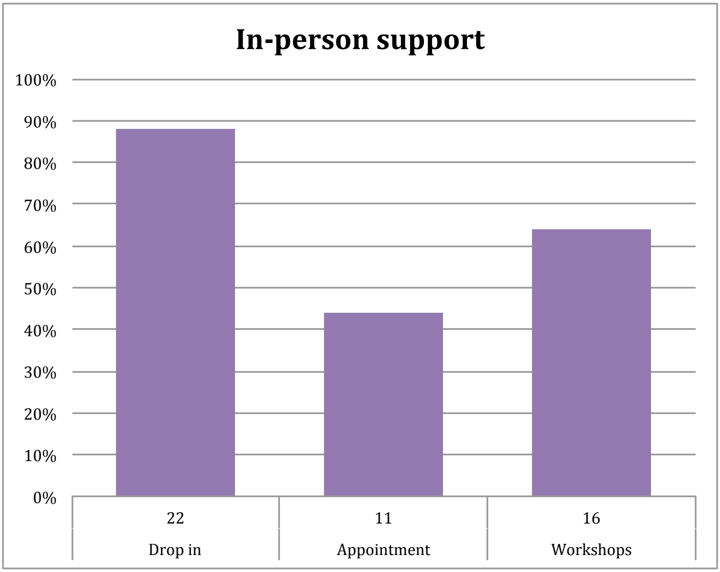

Figure 1: There were 25 responses to the question: What in-person services are provided by your MLS offering? Tick all that apply. The number of respondents that selected each option is given along the horizontal axis, while the percentage of total respondents to this question that selected each option is given along the vertical axis.

When asked to list, in order of popularity, the form of mathematics support most frequently used by students the overwhelming majority (81%) stated one-to-one support as students' favoured choice.

When asked what support services are most effective for student learning, 62% of respondents placed one-to-one with a tutor top of the list. However, in all but two cases these answers were not evidence based. Only two out of the 21 respondents to this question stated that their response was based on data analysis. Contrastingly, these two respondents reported different results: one stated, that based on student feedback, small group tuition work was best, while the other said one-to-one was the most effective aid to student learning.

Online support has many forms from simply supplying access to lecture notes, past exam papers, links to useful websites, etc., to the use of commercial mathematical software such as Maple or MATLAB. The more advanced information and communications technology offerings use a computer-based tutorial and assessment system such as CALMAT.

In 2008 nine MLS offerings provided some form of online support, with only four of those having a dedicated website (Gill, Johnson and O'Donoghue, 2008). By 2015 the number providing online support had risen to 12, an increase of 33% in the seven years. Respondents were given six categories of online supports to choose from and could select as many options as were relevant. The responses are summarised in Figure 2, the number of respondents that selected each category is given on the horizontal axis. It is apparent from this figure that the main form of online support consists of links to external websites such as MathCentre or Khan Academy and video tutorials. It is also worth noting that eight of the respondents indicated that their MLS offering includes a dedicated website, with six indicating that they maintain a dedicated

VLE page. No MLS offering provides a virtual drop-in service, only one provides social media support while six provide email/message board support.

Figure 2 further shows the percentage of all MLS offerings providing each of the online supports as a percentage of the total number of MLS offerings in Irish HEIs.

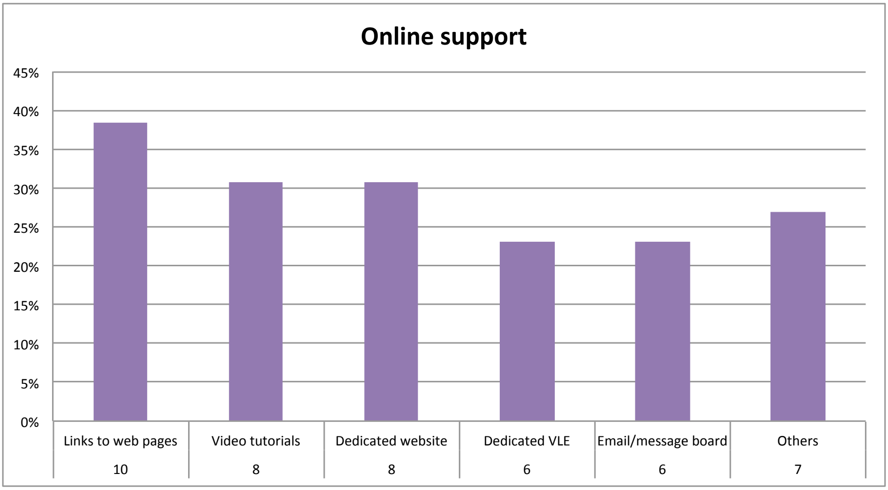

Figure 2: Respondents were asked to list the various types of online support offered by their MLS. They were given a list of six categories from which to choose and could select as many options as were relevant. The number of respondents that selected each category is given on the horizontal axis, while the percentage of total MLS offerings providing that type of online support is given along the vertical axis. For example: 10 HEIs listed "Links to web pages" as a type of online support offered, this equates to 38% of all Irish MLS offerings.

It should be noted that 11 out of the 14 MLS providers that currently have no online service plan to provide such a service in the future.

The majority of MLS providers believe face-to-face support is preferable to online support. There were 13 responses to the question: "What do your student visitors think of online MLS compared to face-to-face MLS?" with nine claiming that students find face-to-face more beneficial. One provider quoted the results of a survey that had 82% of users stating that they found "talking with a tutor as the most useful resource in the MSC". Another stated that their end of year survey revealed that 97% of students had not made use of the online resources. Most providers prefaced their answer with the statement: "from chatting with our students". Four respondents felt a combination of both services is the most effective.

Staffing and Tutors

Staffing details are divided into two categories: manager/coordinator and additional staff (exclusive of manager/coordinator). Out of the 26 institutions that provide some form of MLS, 25 provided details of their managerial arrangements. Nine said the role of manager is full-time; seven said a lecturer carries out the role of manger as part of their duties; three have voluntary managers, while the remainder has various mixed arrangements. The 2008 audit (Gill, Johnson and O'Donoghue, 2008) indicated that: six institutions had full time managers; three said a lecturer carried out the role of manger as part of their duties; two had voluntary managers, while the remainder had various mixed arrangements. Thus, while the number of institutions offering MLS has doubled from 2008 to 2015, the percentage having full-time managers has fallen from 46% to 36%. It is also worth noting that the percentage of voluntary managers in that period has fallen from 16% to 12%.

The following details refer to the number and type of staff employed in Irish MLS offerings in addition to the manager/coordinator. The relevant survey question listed seven staff categories and asked respondents to give the number of staff from each category employed in MLS at their institution. Respondents could select as many categories as was relevant. Figure 3 records the number of institutions that source staff from the various categories.

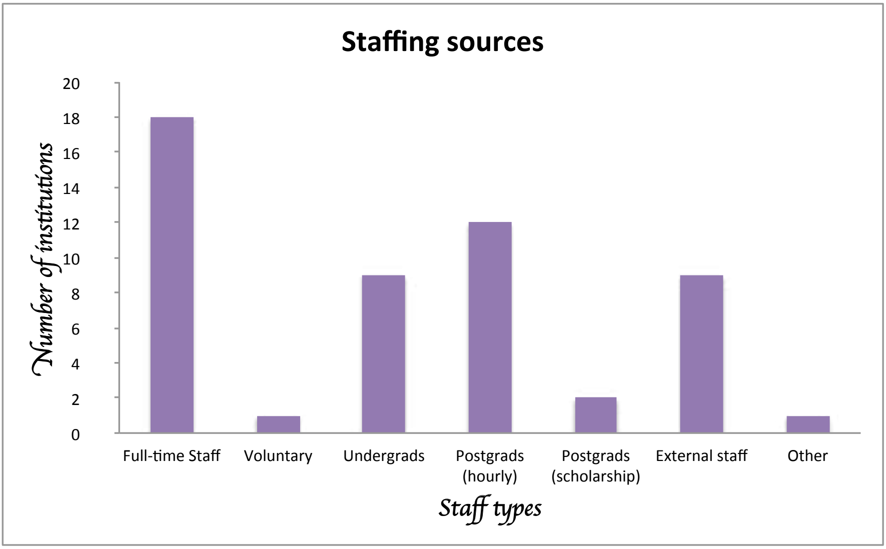

Figure 3: This figure shows the number of institutions sourcing staff (excluding manager) from each of the staff categories. Respondents were asked to list the various staff categories currently working in their MLS provision. Respondents could select as many categories as was relevant. For example, 18 MLS offerings source some or all of their staff from full-time institutional staff; only one MLS offering had voluntary staff, etc.

It is evident from Figure 3 that the primary source of tutoring staff in MLS offerings in Irish HEIs is institutional staff and students. This highlights a key difficulty for some offerings: the ability to procure and keep good tutoring staff. In many institutions, due to work constraints, most staff members are simply unable to contribute hours to MLS. Further, not every institution has a continuous supply of capable students from which to source tutors. For example, many institutional types do not have a postgraduate scholarship scheme; hence do not have this category of student available to tutor in their MLS offering. The survey confirms that only the university sector has tutors from this category employed in MLS. Hence, the type of tutoring staff used appears to be influenced by institution type.

Out of the 13 institutions that employ MLS staff from one staff category only: ten use full-time institutional staff only, two use undergraduates only and one uses hourly-paid postgraduates only. Figure 3 highlights the fact that only one institution has some voluntary staff.

The survey also reveals details of MLS staffing levels. Figure 4 records the results. It can be seen from Figure 4 that the majority of Irish MLS offerings are quite small with 60% operating with a staff of five or fewer. In fact the survey reveals that 16% of MLS offerings are ran by at most two in-house staff.

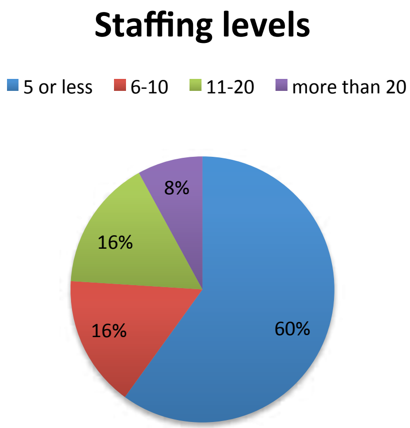

Figure 4: Respondents were asked to record the number of each staff category currently working in their MLS provision. The results were divided into four intervals: 5 or less, 6-10, 11-20 and more than 20. Figure 4 shows the percentage of MLS offerings having that level of staff. For example, 8% of MLS offerings operate with a staff of more than 20.

Securing and retaining enough suitable tutors is an issue for many providers. When asked how their MLS could be improved 54% of respondents referred to tutors. Suggestions include: more tutors, permanent tutors, staff/tutor training. In fact, only two out of the 22 responses to this question listed "more funding" ahead of "more tutors" as the priority for improvement. This issue was not confined to adequate tutor numbers, but rather securing and retaining well-trained tutors. It was suggested in several responses that tutors be given permanent contracts and a better salary so as to "encourage the good tutors to stay longer and see it [MLS] as a viable career". It is worth drawing attention to the findings of a recent UK report by Tolley and MacKenzie [2015], which provides a detailed account of the views of 23 UK HEIs' senior management on MLS. All those interviewed recognised the crucial role played by MLS in students' satisfaction, retention, achievement and employability. Further, there was a real awareness of the needs of specialised staff working in MLS; several suggested the need for appropriate training leading to some kind of professionally accredited status.

User Profile

The survey provides detailed information on MLS user needs and type. It is the authors' intention to create a clear user profile that will help inform the development of MLS offerings in Ireland and abroad into the future. The details are too numerous for this summary paper, but the following will provide a basic outline. First-year undergraduates make up between 45% and 70% of users in the majority of institutions (68%) with the exception of two institutions who have 95% and 100% respectively from first year. A number of providers state that they specifically target first-year students as part of a retention drive. All disciplines are represented, with the majority of users being science, engineering and business students in that order. Non-traditional students are key users of MLS services with one institution stating that between 61% and 100% of their users are non-traditional.

Conclusion

The survey reveals that the majority (97%) of third-level institutions on the island of Ireland provide some form of MLS services. It is also clear that there has been no definite pattern of development to date; in the majority of cases development has been budget and/or staff led. MLS services in many HEIs are provided by a small number of dedicated, passionate staff – in two cases the service is run by a single staff member. There was a strong feeling by MLS practitioners that the profile of MLS services needs to be raised within the academic community. The survey highlights the belief that the next phase of development involves the establishment of MLS as a viable and rewarding career. As stated earlier, the main aim of this survey is to benefit all mathematics support practitioners in Ireland, and in particular to determine what the IMLSN can do to help. When asked what Irish MLS practitioners most needed from the IMLSN the following response sums up many practitioners' feelings: Keep raising the profile of MLS and the centres. Keep pressure on institutions and government to recognise the need to properly support us.

References

Gill, O., Johnson, P. and O'Donoghue, J. (2008) An audit of mathematics support provision in Irish third level institutions. CEMTL (Regional Centre for Excellence in Mathematics Teaching and Learning), University of Limerick.

Perkin, G., Lawson, D. and Croft, T. (2012) Mathematics learning support in higher education: the extent of current provision in 2012. The National HE Stem Programme, University of Birmingham. Accessed via http://www.mathcentre.ac.uk/resources/uploaded/52789-mls-in-uk.pdf (August 2015)

Tolley, H. and Mackenzie, H. (2015) Senior management perspectives on mathematics and statistics support in higher education. **sigma**, Loughborough University. Accessed via http://www.sigma-network.ac.uk/wp-content/uploads/2015/05/sector-needs-analysis-report.pdf (August 2015)

Acknowledgments

The authors are truly grateful for the funding support of the National Forum for the Enhancement of Teaching and Learning to help carry out this project.

Endnotes

[i]Students undertaking mathematics modules as part of an undergraduate degree, but whose chosen degree is not mathematics.

[ii]By non-traditional student we mean any student who corresponds to any one or more of these categories: mature (aged 23 years or more on January 1st of their year of registration), international, from a lower socio-economic background, distance learner, or with a disability.

The development and evolution of an advanced data management system in a Mathematics Support Centre

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University College Dublin

Abstract

The interest in why and how to collect data from students visiting a Mathematics Support Centre is ongoing within the community. A related issue is what intelligence to collect and the need to ensure this process is both robust and effective.

In this paper we give a history, dating back to 2004, of the process of data collection within the Mathematics Support Centre in University College Dublin in Ireland. We describe the evolution of what we consider to be a sophisticated mathematics support data management system, which we piloted in the second semester of 2014-15. We finish by discussing how feedback received from lecturers and MSC tutors during 2014-15 has resulted in further improvements to the system.

Introduction

In the early days of mathematics support in the UK and Ireland, the primary function of data collection was to justify a centre's existence in order to secure permanent funding for the resource and/or the coordinator (Lawson, Halpin and Croft, 2001 and 2002; MacGillivray and Croft, 2011). Perhaps for this reason, most support centres now collect data on student visits as a matter of course. Generally centres have records relating to the number of attendees, their associated academic programmes, and some level of detail on the problems with which they present. Some centres use Excel, Google Drive or pen and paper, to record and analyse this data. This paper will outline the evolution of the data collection process in the Maths Support Centre (MSC) in University College Dublin (UCD), Ireland – from pen and paper records when the centre was first opened in 2004, to what we now regard as a sophisticated data management system (DMS). We will describe the DMS we have developed and will discuss how feedback from MSC tutors and lecturers has led to further improvements in the system.

Data collection efficiency

From 2003/04 to 2008/09 data collection in the UCD MSC consisted of tutors recording by hand into a log-book (Figure 1) the student name, module, and the topic for which help was sought. Due to a limited budget, only a very basic analysis of the data was undertaken each year, primarily to ascertain the number of annual visits, number of visits from each module, and percentage of student visits from each stage/year of study. In these first six years of the UCD MSC the average number of visitors per year was 954.

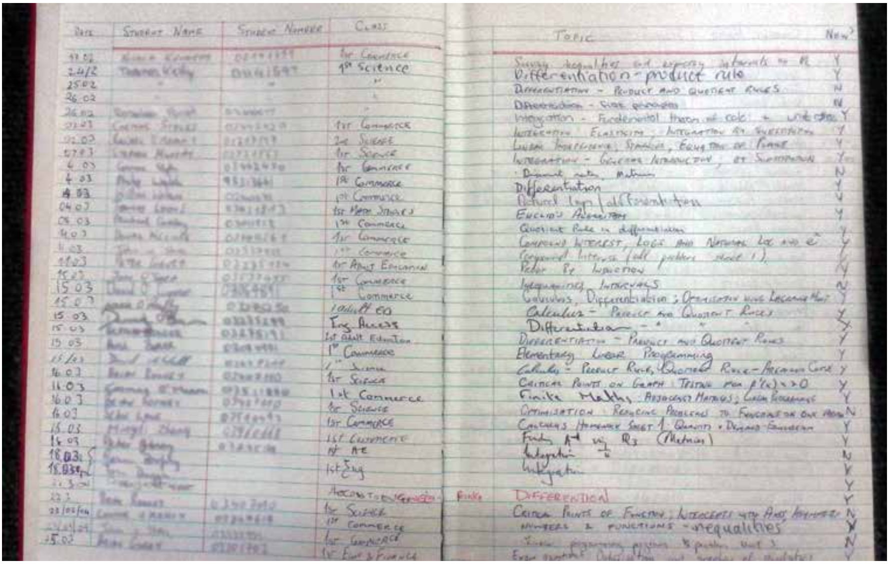


Figure 1: The original MSC log book

In 2009 the then manager Nuala Curley and mathematics lecturer, Dr Brendan Quigley, created an electronic data management system which consisted of four parts: (i) the student log-in (Figure 2), (ii) the tutor editor, (iii) the history log, and (iv) the administrator's account. The lecturers from the School of Mathematical Sciences also had the facility to access the anonymised feedback on each student visit, relating to his or her module(s). This database was hosted on the School's server and the pages were accessible via the School's Teaching and Learning webpages via a secure protocol.

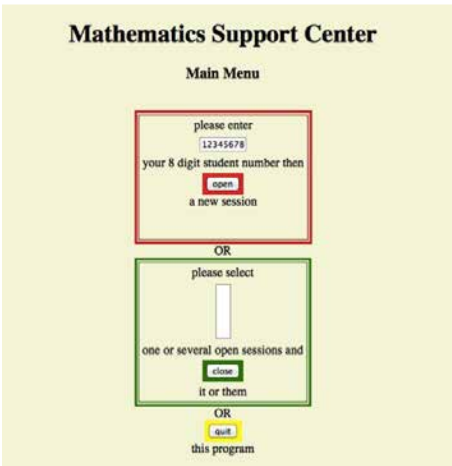
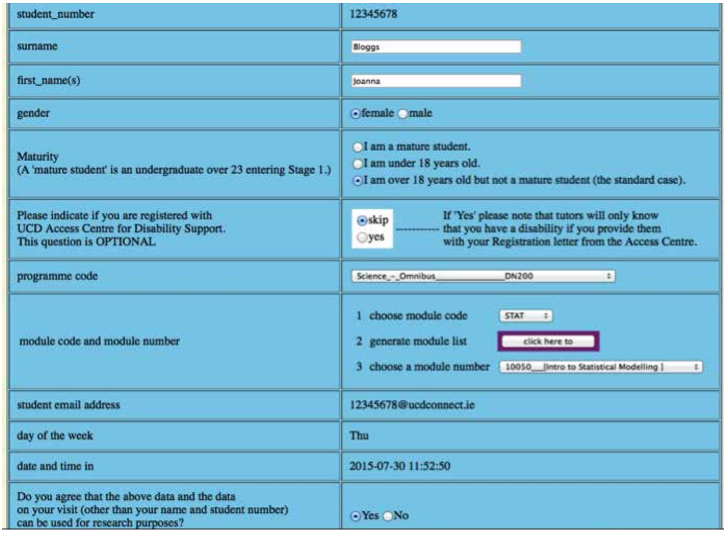


Figure 2.1
The 'old' student log-in



student_number	12345678
surname	Bloggs
first_name(s)	Joanna
gender	female male
Maturity (A 'mature student' is an undergraduate over 23 entering Stage 1.)	I am a mature student. I am under 18 years old. I am over 18 years old but not a mature student (the standard case).
Please indicate if you are registered with UCD Access Centre for Disability Support. This question is OPTIONAL	skip yes ---------- If 'Yes' please note that tutors will only know that you have a disability if you provide them with your Registration letter from the Access Centre.
programme code	Science_-_Omnibus_ DN200
module code and module number	1 choose module code STAT 2 generate module list click here to 3 choose a module number 10050__[Intro to Statistical Modelling]
student email address	12345678@ucdconnect.ie
day of the week	Thu
date and time in	2015-07-30 11:52:50
Do you agree that the above data and the data on your visit (other than your name and student number) can be used for research purposes?	Yes No

Figure 2.2 The 'old' student log-in

The first time a student visited the MSC, he or she had sixteen fields of information to complete, including items such as surname, first name, gender, programme code, module code, email address, and mathematical attainment prior to entering UCD. The student was also asked for his or her consent, or not, to use the data relating to the visit for research purposes.

This entire process involved the student navigating through three separate windows, two of which are illustrated in Figure 2. Experiments conducted in 2013/14 showed that students were taking anywhere from 75-180 seconds to log in to the system and they often required help from tutors to complete the process.

On subsequent visits to the centre a student had to input their student number and select the relevant module on logging in. If the student was seeking support relating to two modules, on receiving help for the first module, the student was then required to log out of the system, and log back in again in order to seek assistance with the second module. Apart from this being tedious, queues formed at the log-in machines when the MSC was busy and, ultimately valuable tutoring time was lost at the expense of trying to collect reliable data.

Issues of reliable data

As the electronic data collection process was based on the student self-reporting and selecting information there were many issues with the reliability of the data. For example, one lecturer noted that during one semester, only 50 of the 81 visits attributed to her module were in fact genuine. Reasons for these errors included students not knowing their module codes or titles. It became clear in a number of instances that some students were simply choosing the first module that appeared at the top of the drop-down list.

The student was also required to manually log out of the system when the session was over. Understandably, many would forget this step. Consequently, it would not be until some time later that a tutor or the manager would notice that the number of students logged in exceeded the number present in the centre. This meant that the “length of visit” time for each student might not be reliable. This statistic is important for a number of reasons. It not only provides hard data to the university management on how long a student spends at the MSC on average, but also enables MSC management to verify anecdotal evidence that queries in some areas require a lot more tutor time than others.

Another problem was the issue of the student not logging in to the system at all. During both semesters of 2013/14 the MSC manager (the first author) conducted an experiment whereby on one day each week he would check the system to see how many students were logged in, and then count the students in the room. On average, over this 20-day experiment, the actual number of students present was underestimated by 22.5% in the system. While every effort was made to highlight the procedure of logging in (via pop-up signs, sandwich boards and posters), the number of recorded visits was very likely an underestimate of the true figure.

Since the academic year 2009/10 the average number of annual visits to the MSC has been 4,535 – a five-fold increase on average annual visits for the first six years of operation. With such a large volume of students, from a wide range of modules, programmes and levels, coming through our doors, it became a priority for us to redesign the DMS. The manager, in conjunction with the expertise and good will of Dr Raja Mukherji developed the new DMS over Christmas 2014. This was trialed during the second semester of 2014/15. We will now describe the system and explain how input from the manager, tutors and lecturers, has resulted in further improvement to it.

The new system

We now describe the DMS as we are about to start the academic year 2015/16. On visiting the centre, the student is required to input just two pieces of data - his or her student number, and whether he or she consents or not, to the anonymised data collected on the visit being used for research purposes (see Figure 3).

When the student number is entered, the student is given a three-letter code, which represents their place in the queue. These codes are displayed on a large projection screen in the MSC so tutors and students can see who is next in the queue. When the student’s turn arrives, the tutor asks the student which module they are seeking help with and starts the session (see Figure 3). This development has made a huge difference in solving the problem of students’ visits at the MSC going undocumented or recorded inaccurately.

This process also means that the time the student spends waiting to be seen by a tutor is not counted towards their ‘duration of visit’ statistic. However, the time spent queuing is captured to help inform management what the average waiting time is throughout the day and semester. A feature we are trialling this upcoming semester is to display the “time to see a tutor” statistic on the projection screen.

Figure 3.1: The new Data Management System

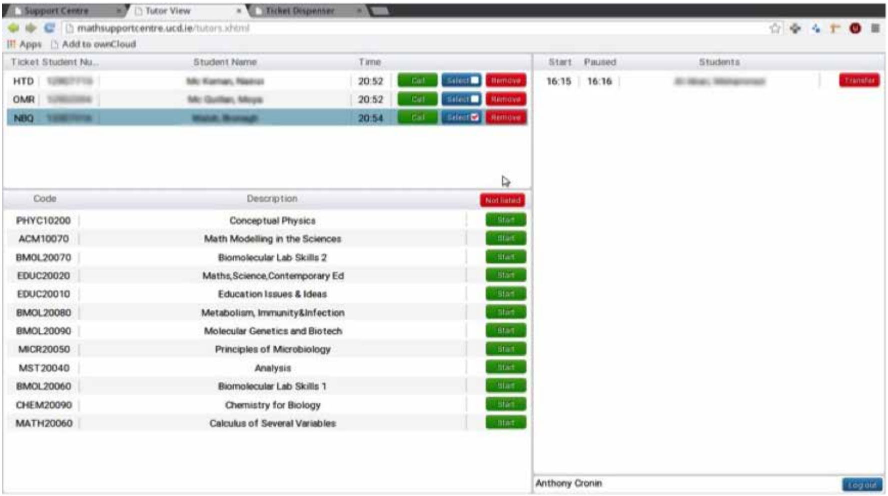


Figure 3.2 The new Data Management System

When the visit ends, the assisting tutor completes the session by clicking ‘finish’ on their console. The tutor then enters feedback into the DMS relating to the nature of the student’s query and a short description of the support provided (see Figure 4). Over the last eighteen months, significant effort has gone into training the tutors on how to write these feedback entries. Much of this is due to Nuala Curley, who is conducting research into what constitutes a quality tutor entry, and she has worked closely with the MSC tutors to ensure the validity of these entries. A description of her work to date can be found in Curley and Meehan (2015a, 2015b).

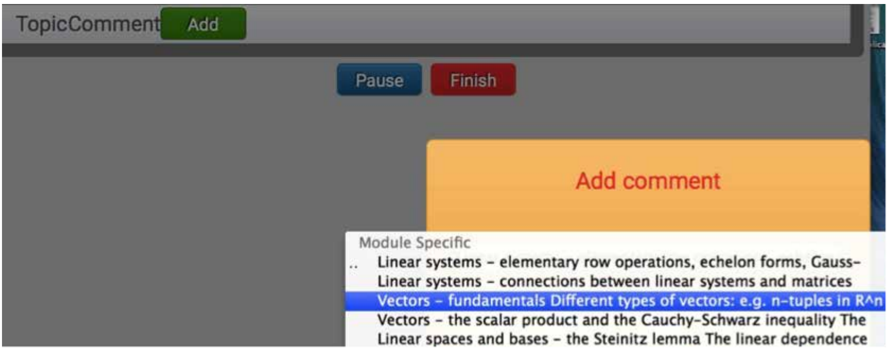


Figure 4: The tutor’s screen

Essential in the development of the new DMS was gaining access to the university’s central registry student database. This means that when the student inputs his or her student number into the DMS, the system then synchs with this central database, enabling us to see exactly which modules the student is registered to. Further data such as programme, year of study, gender, nationality, prior mathematical achievement, mature/traditional status et cetera can then be accessed later via the central database if required for statistical analysis. The move away from students self-reporting their details is an important step in the recording of reliable data.

MSC tutors' and lecturers' feedback on the DMS

Throughout the piloting of the new DMS, the MSC tutors have provided invaluable feedback to the manager and developer on how to improve the system, particularly in relation to the queuing features of the system. In a focus group conducted with ten tutors in May 2015, we also received useful suggestions on how the inputting of the qualitative tutor entries might be improved. For example, some tutors suggested topics could be chosen from a drop-down list of most common problem areas.

Another research project being undertaken in the MSC aims to examine how useful the MSC feedback is to lecturers, and to ascertain if, and how, this feedback impacts on their practice. In semester one of 2014/15 thirteen lecturers of large first- or second-year mathematics and statistics classes agreed to take part in our study, with each participating in three one-to-one interviews in the fourth, eighth, and fifteenth week of the semester. The results of this study will be reported elsewhere. However in relation to the DMS we gained some important feedback.

A significant outcome of the first interview was that many lecturers were not accessing the MSC feedback for their modules because the process was too onerous – it required the web administrator to issue them with a password, which many admitted forgetting. Many stated that while checking the MSC feedback for their modules is important to them, it often slips their minds during busy teaching periods. To solve both of these issues, the DMS is now set up to send all lecturers an automated email each Friday, detailing the anonymised feedback entries for their module as recorded in the MSC that week (and preceding weeks).

Another initiative we plan to pilot this semester is to have a small number of lecturers input the learning outcomes for their modules into the DMS. These will then appear as drop-down menus when the MSC tutor inputs the student feedback for that lecturer's module (see Figure 5 below). The tutor will also have the opportunity to add a free-form response if desired.

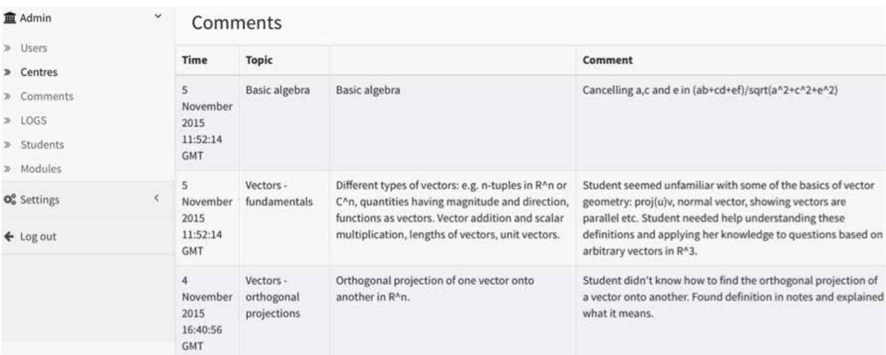


Figure 5: Lecturers' Learning Outcomes

Conclusions

In a busy centre such as ours, it is our hope that by having a reliable database which allows us to make evidenced-based decisions, we can provide a more efficient service, and most importantly, can take a more proactive, and less reactive, approach to mathematics support.

References

MacGillivray, H. and Croft T. (2011) Understanding evaluation of learning support in mathematics and statistics. International Journal of Mathematical Education in Science and Technology, Vol. 42, (No. 2): 189-212.

Curley, N. and Meehan M. (2015a) The challenge of collecting useful qualitative data on students' visits to a Mathematics Support Centre at a university in Ireland. Proceedings of the British Society for Research into Learning Mathematics, Adams, G (Ed), 35(1) 25-31.

Lawson, D., Halpin, M., and Croft T. (2001) After the diagnostic test: What next? Evaluating and enhancing the effectiveness of mathematics support centres. MSOR Connections, Vol. 1 (No. 3): 19-23.

Lawson, D., Halpin, M., and Croft T. (2002) After the diagnostic test: What next? Evaluating and enhancing the effectiveness of mathematics support centres part 2. MSOR Connections, Vol. 2 (No. 1): 23-26.

Beyond these shores: The conundrum of the successful graduate who experiences difficulties with maths

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Abstract

There are a range of disciplines that have close links with professional, or regulatory, bodies that mandate specific maths-skills elements as part of the degree programmes and which require evidence of mathematical attainment before recognising members. For example, Chartered Engineers, Teachers (QTS), Registered Nurses (NMC), Pharmacists (RCP), Radiographers (SOR) and Psychologists (BPS). However, within these professions there is a complex and possibly contradictory picture; there are relatively large numbers of academically-successful individuals who have well documented problems with mathematics. Despite this, these graduates go on to become successful in their careers. Their experience of coping with difficulties with mathematics could help others who are following similar educational trajectories. Currently, four graduates who fit this profile, and who have been working in their fields for more than 5 years, have been interviewed. The interviews were focused around the construction of a personal mathematics educational timeline (Adriansen, 2012). There is something compelling about individual's stories and they have been linked with aiding change, or even transformation, in others. In addition they have the potential to uncover the unexpected (Hodkinson and Hodkinson, 1997). Whether it be seeking to improve curriculum design or improving mathematics skills support, it could be useful to know more about the experience of people who have emerged as "numerate graduates" (Durrani and Tariq, 2012, p. 3), despite encountering difficulties. This paper summarises the research approach and aims. It draws on the stories heard thus far and considers the implications for higher education.

Introduction

This paper reports on a research study which is in progress and is focused on graduates who work in a field where mathematics skills are a component of their professional accreditation yet they self-identify as having difficulty with mathematics. The research is being undertaken as part of a professional doctorate located in the field of higher education mathematics support. In-depth interviews have been held with four participants so far focused around the construction of a mathematics educational timeline and the associated stories (Adriansen, 2012). Follow-up interviews were then scheduled for each participant which were effectively a continuation of the first in-depth interview, allowing the interview process to "take place over an extended period of time" (Yin, 2009, p. 107). This also allowed for reflection on the part of the researcher and the participant.

Similarly to the experience of Thumpston and Coben (1994), who found "a queue of people wanted to talk to us" (p. 32), there has been no shortage of volunteers wanting to share their experiences. As a result, a de facto network-based snowball sampling method effectively materialised and has been used to recruit participants to date. It is anticipated that 10 participants will be interviewed in total. The criteria for participants is that they should have at least 5 years' experience in regulated, graduate professions that have a mathematics requirement for their members. To date, two teachers (A and B) and two nurses (X and Y) have been interviewed.

In the sections that follow, some of the participants' comments will be presented before considering why their stories matter and why the research methods have been chosen. This will be followed by a brief consideration of some of the themes evident in the participants' stories before concluding with a consideration of one of the key objectives of the study and how it may serve the mathematics support agenda within a higher education setting.

Participants' voices

Drawing directly on the words of the participants (verbal or written) prioritises their voices and stories. For example, participant X clearly had some strength of feeling when she said "I don't think your maths education prepares you for maths that you need in your life, it's irrelevant. I'm maybe a bit more self-taught … I don't use anything that I learnt at school". Participant A said "I think I took longer to understand things than people around me … we need smaller class sizes". She was explicit about the fact that her needs were not met by the educational experience she had, and that she thought there was a solution. In a similar way, participant Y was adamant that at "Approx Yr2 (aged 7) I identified I was 'rubbish' at maths". Her mother and her teacher played down her fears but, as a result, it felt to her that she was on her own and there was no help available.

Their experiences clearly produced very strong feelings in all of the participants and these were often manifested in the expression of negative emotions during the interviews. Participant B exhibited this when he wrote "shit teachers + lack of contextual application = poor experience??" at the end of his time line. The use of a swear word in this case communicated strong feelings which have clearly persisted for a great many years.

All of the candidates struggled with the relevance of mathematics. Participant Y felt that addressing this is the key to improving mathematics education and suggested that educators should be "relating maths at a much earlier age to where these skills are useful".

Stories matter

There is the opportunity for the participants' stories to open up avenues for further inquiry. It is not uncommon for specific scenarios to function as gateways to reveal broader issues. In fact, most professional practice recognises there is some value to the anecdote as an informal case study. In this situation, the participants represent a compelling conundrum: they have been successful in education and in their careers but they have been 'unsuccessful' in mathematics. They make a special or interesting case because, if nothing else, they do not necessarily see themselves as the "numerate graduates" (Durrani and Tariq, 2012, p. 3) that they have been classified as being. It is hoped that their unique perspectives may be illuminating, and could be of benefit, to current students as well as to educators. By prioritising their voice we are more likely to find out if this is so. Furthermore, as well as exploring and analysing their stories it is hoped that there may also be some benefit to simply re-telling their stories to others. This would involve learning from their coping strategies and considering their suggestions for improvements to education.

Prioritising participants' stories in this way fits with many of the driving principles behind the rise of mathematics-support initiatives in higher education. These initiatives help address the hidden problem of people who progress through 'the system' but still have difficulties (Hodgen et al., 2014). Furthermore, it introduces the idea that graduates may be considered stakeholders in the system. This is because there is an accountability theory underpinning the idea of stakeholders which is that if they are not satisfied then there will be a consequence (Bryson, 2003, p. 8). This marries with the complexity of actually identifying the stakeholders who "should be satisfied, or involved, or otherwise wholly taken into account" (p. 8). Alumni generally and specifically, in this case, are not routinely considered to be stakeholders in higher education. There seems to be a case for this to change or at least for this stance to be revisited. Given the well documented and ongoing problems with mathematics education in some sectors, their inclusion has the potential to be an agent for change.

Narrative analysis

Narrative analysis is an analytical approach which is useful for an investigative or exploratory case study (Yin, 2009, p. 28), which is how this inquiry is being framed. The constructed nature of an individual's experience, as presented in a story of their own telling, has been called a mathematical life history and these have been used to give insight into the influence of complex social, political and institutional factors at work in education (FitzSimons and Godden, 2002). In addition, narrative analysis allows us to respect the individual and take account of their experience and be aware of the environment and influences they are subject to. This links to the concept of prioritising the student voice in higher education and acknowledges that there is an emotional and social context to learning and to maths skills development (Martino and Zan, 2011, p. 472). These aspects can be richly explored using this approach.

Given the dearth of existing research into this group, narrative analysis also has the potential to throw up the unexpected (Hodkinson and Hodkinson, 1997). In fact as a method it specifically promotes efforts to avoid pre-judging the outcome of the inquiry. It also promotes the awareness of, and articulation of, any forms of bias on behalf of the researcher that can realistically be identified. Finally it has been linked with aiding change, or even transformation, in others, particularly in the field of adult education (National Numeracy, 2013).

Within mathematics education, choosing a qualitative methodology can appear anti-empirical. However, given the open-ended nature of the inquiry it is argued that the approach is in fact taking care to avoid 'rushing' into use of statistical techniques which could lead to the phenomenon of 'inflated' social science findings that have been hitting the headlines recently. Avoiding using mathematics inappropriately represents a cautious approach, particularly given that the utility of the study is largely based on the premise that there may be unknown outcomes. In addition, pursuing new avenues can help improve and inform mathematics education and hopefully help to avoid the tendency for replication of existing structures and approaches. Narrative analysis also suits engagement with critical theory and is influenced by action research and reflective practice, which are grounded in the professional sphere.

More stories

Bringing the focus back to the participants' stories, there was a specific coping strategy that participant Y has developed. It is the concept of the 'learning pit' and she created it in order to help herself and her daughter cope with the anxiety they experience as part of the learning process. She talks to her daughter about the learning pit and how being stuck in the learning pit is a natural part of learning even though it makes you feel bad and you do not think you will get out. She takes previous learning experiences, such as learning to ride a bicycle and relates them to the current situations, such as struggling with division. She talks about the need to be aware that things feel very uncomfortable in the pit when you cannot do the new things you are being presented with. She contrasts this with being out of the pit, when you have mastered something and feel confident. She explicitly discusses the concept that “we need tools to get out of the learning pit”. These vary according to the situation. She has found it very beneficial and has managed to turn around some situations in her daughter’s education that mirrored her own and initially made her panic and think “oh no it is happening again”.

All the participants felt strongly that unnecessary pressure should not be put on students who do not cope well with mathematics. Being made to feel bad for getting it wrong was a recurring theme which highlights the social context to learning. Participant A remembers not being allowed to leave the class at the end of the day without answering a mathematics question correctly so on these occasions she was always the last to leave the class. She still sees this pressure being applied in schools and gave an example involving hot air balloons. Teachers allocate a cut-out hot air balloon for each student and it rises up the wall every time they learn a new multiplication table. It may be motivating for the students who are racing to the top but it can be mortifying for the student whose balloon gets left behind. It can cause them to just switch off and disengage, as she did.

This brings us onto another common theme among the participants. In a spiral curriculum you simply cannot move on until you have succeeded at your current level. Participant X said “I couldn’t keep up” and participant Y mentioned the panic she experienced when a teacher would introduce a new topic but she was still really struggling with the previous one. She felt like there was an unrelenting tide of knowledge she could not master and she was getting more and more behind and could never catch up. In fact, when the analogy for the curriculum is considered as a helix then the picture that comes to mind is of the participants being dropped into a learning pit that is shaped like a well shaft and they just go round and round at the bottom, in the dark, while their class mates rise steadily towards the distant light.

These are just some of the emerging themes that come from the initial, light-touch reflection on the interviews that have been conducted so far. Considerable further analysis is required. However, it has already become apparent that these stories resonate with mathematics education professionals and it can also be demonstrated that there is considerable accord with the existing literature too.

Conclusion

One of the objectives of this study is that it will ‘seek to investigate the utility of these experiences to individuals currently developing their mathematics skills or currently supporting others to develop’. To this end, we have seen that there are themes emerging from the data which will need to be explored in greater depth but show promise in this regard. However, more generally, the process of developing a better understanding of any one person’s educational journey should enrich an educator’s practice. Furthermore, on a practical level, it is hoped that one outcome will be stories that can be shared with current students to inspire, engage and support them in their own journeys.

In addition to the themes discussed already, there are others that have not been articulated so clearly by the participants but still seem to be emerging. One of these is the role of the participant in resisting. Their individual agency was very limited as children and they seem to have found themselves in roles where they were having to resist the systems and structures around them which were not serving them well. In addition, there was not always a happy ending to their stories and hard work did not always pay off. These can make for slightly uncomfortable reading but they are intriguing nonetheless. They too need further detailed analysis but, again, there is clear relevance and therefore hopefully utility with regard to the experience of those who are currently in higher education.

References

Adriansen, H.K. (2012) Timeline interviews: A tool for conducting life history research. Qualitative Studies, 3(1): 40-55.

Bryson, J. M. (2003) What to do when stakeholders matter: A guide to stakeholder identification and analysis techniques. A paper presented at the London School of Economics and Political Science.

Durrani, N. and Tariq, V.N. (2012) The role of numeracy skills in graduate employability. Education and Training, 54 (5), pp. 419-434.

FitzSimons, G. E. and Godden, G. L. (2002) "Review of research". In: Coben, D., O'Donoghue, J. and Fitzsimons, G. eds. Perspectives on adults learning mathematics: research and practice. Mathematics Education Library, 21. London: Kluwer Academic Publishers. pp. 13-46.

Hodgen, J., McAlinden, M. and Tomei, A. (2014) Mathematical transitions: a report on the mathematical and statistical needs of students undertaking undergraduate studies in various disciplines. The Higher Education Academy.

Hodkinson, H., and Hodkinson, P. (1997) Micro-politics in initial teacher education: Luke's story. Journal of Education for Teaching: International research and pedagogy, 23(2), pp. 119-130.

Martino, P.D. and Zan, R. (2011) Attitude towards mathematics: a bridge between beliefs and emotions. ZDM The International Journal on Mathematics Education, 43 (4) August, pp. 471–482.

National Numeracy (2013) Case Studies. National Numeracy Organisation [Online]. Available from: <http://www.nationalnumeracy.org.uk/resources/90/index.html> [Accessed 23 March 2014].

Thumpston, G., and Coben, D. (1994) "Getting personal: Research into adults' maths life histories." In Proceedings of Inaugural Conference of Adults Learning Maths – A Research Forum, 22-24 July 1994 at Fircroft College, Birmingham, UK. D. Coben (Ed.). Goldsmith's College, University of London. pp. 30-33.

Yin, R. K. (2009) Case study research: design and methods. London: Sage.

Using qualitative data collected in a mathematics support centre to predict and provide "just-in-time" support for students

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Abstract

In September 2013 we embarked on a project to develop a process of recording accurate qualitative data on each student visit to the Mathematics Support Centre in University College Dublin. Our aim was to record the topic for which each student sought support and use these to identify the most common basic mathematical difficulties experienced by visitors to our centre. In the first semester 2014-2015 we undertook an extensive eight-week qualitative data collection. This data collection period resulted in entries recorded, and coded by mathematical area, for over 2,000 student visits. In this paper we will describe how we analysed the data and explain how we realised that examining mathematical difficulties by module, rather than by mathematical code, would enable us to design and deliver "just-in-time" module-specific support. We finish by discussing future directions for our research.

Background

The increasing importance of quantitative skills across multiple programmes at third level has been identified by many authors, among them Steen (2002) who states that "in today's world, the majority of students who enrol in post-secondary education study some type of mathematics. Tomorrow, virtually all will" (p.304). This is evident when one examines the nature of student visits to the Mathematics Support Centre (MSC) in University College Dublin (UCD). Opened in 2004, the MSC is now embedded as a university-wide resource, is funded centrally by the university, and has a mission of "Maths Support For All UCD Students". UCD is the largest university in Ireland with approximately 26,000 students. Over the last three years there have been on average 6,000 visits per annum to the centre, with approximately half of these from first year students, and just under a quarter from each of second and third year students. The remainder of visitors are either Access students, fourth years or postgraduates.

However even this does not fully capture the diverse nature of the visitors. Students seeking support may be studying on mathematical sciences degree programmes; may be taking mathematics modules as part of another programme of study for example, Agriculture, Business, Engineering or Science; or indeed, may be undertaking degree programmes in areas such as Geography, Psychology, Medicine or Social Science, where mathematics modules are not core to the programme, yet often mathematical or statistical knowledge is required during the degree. An interesting statistic is that in 2013-2014, 21% of the total 5,721 visits were from this latter cohort.

In September 2008, the MSC designed a web application to maintain an electronic record of each student visit to the centre. Background data collected on the student's first visit included student number, module code, and programme of study. For subsequent visits the module for which the student was seeking support was recorded. On completion of each session, the

MSC tutor added to the database details of the topic he or she had covered with the student. We will refer to these tutor comments as topic entries. Once entered on the database, the module lecturer was then able to access these anonymous topic entries electronically if he or she wished.

Like many mathematics support centres in the UK and Ireland we are naturally limited in the support we can provide by the physical space and tutors available (funding!). Given the high volume, and diverse nature, of visits to the UCD MSC we have been forced to tackle the issue of how/if we can maintain a high-quality service in a more efficient way. In 2013 we decided to take an evidenced-based approach to support provision, and set about analysing the MSC data collected since 2008 with the aim of identifying the most common mathematical difficulties experienced by students across the variety of programmes. We hypothesized that if we could do this, then we could source (from Khan Academy or Math Centre) or develop suitable resources (most likely online videos and worksheets) in these areas of mathematics, and consequently provide a more efficient service to students.

Obviously diagnostic testing, as carried out in many third-level institutions in Ireland and the UK, is believed to be effective in identifying and highlighting widespread areas of mathematical weakness (Lawson, 2003; Faulkner, 2010) . It is normally limited to first year classes with significant mathematical content. Hawkes and Savage (1999) recommend that all students embarking on mathematics-based degree courses should take a diagnostic test on entry and they emphasized the importance of follow-up support for students in need of help. However if we consider that in 2013-2014, students visited the centre from sixteen first year modules not even offered by the School of Mathematical Science, then diagnostic testing will not help us in getting a full picture of the mathematical issues experienced by first years. That is why we wanted to take a more grounded approach to identifying common mathematical difficulties.

Data collection

An initial analysis of the topic entries prior to September 2013 revealed broad areas of mathematics and statistics where students were presenting with difficulties. This analysis led to the development of a list of eighteen broad codes, for example, “algebra”, “differentiation” and “trigonometry”. However a more in-depth analysis proved very difficult as many of the entries were lacking in the level of detail required to properly diagnose the problem areas. The following are some typical topic entries lacking in detail prior to 2013: “Trigonometry”, “Limits”, “Matrices”.

To accurately identify students’ underlying mathematical difficulties, we required more specific and detailed tutor entries. Therefore we decided to work with the tutors to ensure qualitative entries were recorded as accurately, and as efficiently, as possible. A data collection process was piloted in semester 2 of 2013-2014, and in September 2014 we commenced our data collection for the study. This involved eight weeks of intensive collaborative work with the tutors to ensure the quality and authenticity of the data collected. On recording each qualitative entry, the MSC tutor also coded the topic entry using at least one of thirty codes. Our efforts and those of the tutors over the last eighteen months to collect this data as efficiently as possible, along with the complete list of codes, are outlined in Curley and Meehan (2015).

Preliminary analysis of data

In January 2015 we began an analysis of topic entries collected. There were 2,012 entries to our database over the eight weeks. Many of these topic entries were assigned more than one code by the MSC tutor who inputted the entry. Here are some examples of topic entries and associated codes.

1. Plotting functions. Student was not aware of method: Finding roots and critical points. Plot sin function between amplitudes. Solve ode using integrating factor method. Needed complete explanation. {diff} {int} {g} {fun} {diffeq}

2. Student had a question regarding moment of inertia, real issue was in conversion from Cartesian to circular coordinates. Did a simple example to explain. [NC: Tutor drew rt angled triangle with sides x,y,r and showed sin(theta) = x/r implies x = r sin(theta) and showed this on a circle.] {trig}

3. Student came in with a problem with indices. The student was confused between 2^{1/3} and 2^{-3}. The student thought that 2^{1/3}=1/(2^3) but was fine once it was explained. [NC: tutor wrote cube root(2) = 2^(1/3); 2^(-3) = 1/2^3.] {ind}

The coding in the first entry refers to problems with differentiation {diff}, integration {int}, graphing {g}, functions {fun}, and differential equations {diffeq}. The second example is a question on trigonometry {trig}, and the third a problem with indices {ind}. Note that for ease of recording mathematical content, a number of the MSC tutors entered it in pseudo-LaTeX form. The information recorded in the square brackets after "NC" indicates additional explanations added by the first author during the data collection process, after consultation with the relevant tutor. More details can be found in Curley and Meehan (2015).

The first step in the analysis involved the first author reviewing the codes assigned by the various tutors to each topic entries. Since 23 tutors worked in the MSC that semester, it was important to ensure consistency in the coding. She examined the entries under each code, and decided if they should remain, be deleted or recoded. In addition if it did not represent a basic problem area she re-coded the entry as "advanced" {adv}. The chart shown in Curley and Meehan (2015, p.6) represents the major codes and number of entries in each, at the completion of the above process.

The second step in the analysis of the data involved the second author and Dr Anthony Cronin, manager of the MSC, verifying the coding process undertaken by the first author. On examining the entries under each code, the difficulty in deciding if a topic entry represented a basic mathematical difficulty, in the absence of knowing the module from which student belonged, became apparent. We decided to change approach and examine the entries by module instead.

Module-specific analysis

We focused our analysis on the topic entries for thirteen large first-year modules and three large second-year modules. We define as large any modules with numbers varying between ninety and five hundred students. We refer to the first year modules as M1-1 to M1-13 and the second year modules as M2-1 to M2-3. Examining entries by module, made it much more apparent where the trouble-spots lay, for example:

M1-2: Student had difficulty in solving equations involving trigonometry, fractions and basic algebra{trig} [NC: Tutor said main problem resolving vectors. NC] {vec}.

M1-2: Force diagram. Use cos and sin to break forces to component parallel and perp to plane. Also listing perpendicular and parallel force when calculating force balance {vec},{trig}

M1-2: Working on … problem involving splitting vectors into components parallel and perpendicular to a slope. Just having difficulty visualizing the problem, was not having any issues with the maths itself {vec},{mod}

It is clear from the above examples that some students in this module were having difficulty with resolving vectors.

We also observed that even if the same basic difficulties arose in two different modules, they usually occurred at different times in the semester. For example in M1-3 and M2-1, students visited the MSC with problems relating to the Normal Distribution. However these visits occurred a month apart. Our analysis enabled us to not only identify the types of issues students in a particular module were presenting with, but also when in the semester they were experiencing them. This has led us to design and develop "just-in-time" supports in the form of Hot Topics.

We have run Hot Topics in the past - they usually are scheduled in the evening, students must sign up in advance, and attendance is limited. In 2015-2016 we will take an evidenced-based approach to predicting what support is needed, and when, for each of the large first year modules. In conjunction with the lecturer, we will design and schedule Hot Topics to provide "just-in-time" support for students who require it. In this way we aim to take a more proactive, and less reactive approach, to student support.

Conclusion

We see two directions for future research. The first is the use of the archived topic entries to predict and provide "just-in-time", module specific support as described above using Hot Topics. The second, though not discussed in detail in this paper, relates to tutor training. There is evidence from a focus group interview with ten tutors in May 2015, that during the eight-week data collection phase, the process of recording topic entries to the required standard, caused them to reflect on their practice. We believe this has future implications for tutor training.

References

Curley, N. & Meehan, M. (2015) The challenge of collecting useful qualitative data on students' visits to a Mathematics Support Centre at a university in Ireland. Page 1. Adams. G. (Ed.) Proceedings of the British Society for Research into Learning Mathematics, 35(1), February 2015, 25.

Faulkner, F., Hannigan, A., & Gill, O. (2010). Trends in the mathematical competency of university entrants in Ireland by leaving certificate mathematics grade. Teaching Mathematics and its Applications, 29(2), 76-93.

Hawkes, T. & Savage, M. (1999) Measuring the Mathematics Problem. The Engineering Council.

Lawson, D. (2003) Changes in student entry competencies 1991–2001. Teaching Mathematics and its Applications, 22(4), 171-175.

Steen, L. A. (2002) Revolution by stealth: Redefining university mathematics, The teaching and learning of mathematics at university level. Springer, 303-312.

Post-16 Mathematics Reforms: A level and Core Maths

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Abstract

We consider the forthcoming reforms in post-16 Mathematics provision and the relevance of these to HE, examining the structure and content of the new A-levels in Mathematics and Further Mathematics, including the emphasis on problem solving, and compulsory elements in mechanics and statistics. We also consider the new Core Maths qualifications, including discussion of why they were introduced, who they are for, how Core Maths fits into the HE landscape, and when they will be common currency.

In this paper we advocate that the realisation of the aims of the current reforms of pre-university mathematics, including AS and A level Mathematics and Further Mathematics, and Core Maths, will have significant impact on and benefit to HE, particularly for programmes in mathematics and statistics, as well as in STEM (Science, Technology, Engineering, and Mathematics) subjects more generally, and of course other users of mathematics and statistics in business, health, and social sciences.

Post -16 Mathematics reforms

In 2013 the A Level Content Advisory Board ALCAB (2013) was established 'to review the content of A levels in Mathematics and Further Mathematics, and provide advice to the Government's Department for Education (DfE) and to the Office of Qualifications and Examinations Regulation (Ofqual) on the content for preparation for the leading universities'. The recommendations were published in December 2014 (DfE, 2014a,b). ALCAB's primary aim was 'to provide modern A levels that: contain the necessary material; will be interesting to learn and teach; will serve HE and employment'. That last part is crucial and acknowledges the very wide group of end-users of both AS and A level Mathematics and Further Mathematics. While wishing to ensure that the new A levels would be 'fit for purpose' and serve the undergraduate mathematics community well, particularly at leading universities, ALCAB also wanted to ensure that the current increase in numbers taking AS and A level Mathematics was sustained, and that the success of AS and A level Further Mathematics, much of which is down to the success of the Further Maths Support Programme, continues. ALCAB argued that "Meeting the concerns of both groups of end-users is difficult to achieve within a single A level; some would argue that their needs are mutually incompatible. However, we believe that the existence of further mathematics qualifications makes it possible to design a provision that addresses both. The support and nurturing of further mathematics must therefore be taken very seriously."

With all that in mind, and notwithstanding the issues over which it had no control: teacher supply, teacher expertise, CPD provision, and assessment of the new qualifications, ALCAB sought to develop A levels whose main aims are to: build from GCSE; introduce calculus and its applications; emphasise how mathematical ideas are interconnected; show how mathematics can be applied to model situations mathematically; make sense of data; understand the physical world; solve problems in a variety of contexts; and, above all, prepare students for further study and employment in a wide range of disciplines.

To achieve these aims ALCAB recommended that the content of the single mathematics A-level be fully prescribed. This would ensure all students had covered the same content, from which they could build upon with some degree or reliability in HE or employment. It also allowed two of the fundamental applications of mathematics, statistics and mechanics, to be introduced. It is also highly desirable to go into considerable detail with the recommended content, which is lacking in the current content. The content would also need to ensure that co-teaching of pure mathematics between the single A-level and AS-level further mathematics can be achieved.

In terms of the subject content, the major change from existing AS and A levels, is in statistics. The recommendation is for greater use of real, large data sets, and that this should permeate the teaching, learning and assessment, with more emphasis than currently upon understanding, interpretation of data and making inferences from data. This shift of emphasis should be of benefit to many end-users.

This will, of course, require substantial investment in CPD for teachers, and HE could play a part in this through the network of Maths Hubs.

Beyond the detailed subject content, ALCAB wished to establish an ethos to the new A levels, and these are exemplified in three ‘Overarching Themes’ (OTs) that encapsulate the knowledge and skills that students should be required to demonstrate: OT1 Mathematical argument, language and proof; OT2 Mathematical problem solving; OT3 Mathematical modelling; and that these must be applied, along with associated mathematical thinking and understanding, across the whole of the detailed content.

It is important for both undergraduate programmes in mathematics, but also for the wider group of end-users in HE, that mathematics is not just seen as a collection of techniques to be mastered. The OTs should permeate the teaching of the subject content, so that ‘the whole is more than the sum of its parts’. ALCAB had no remit over assessment, but it hoped that assessments would reflect these wider intentions. Indeed, it identified a number of issues with the current A levels which are intrinsically connected to assessment:

- the mathematical thinking of the most able students is not developed;
- A* grades are not for genuine mathematical ability - A* should be for demonstrating understanding and flair, and not for doing routine calculations accurately, and assessments should be developed accordingly;
- current statistics content is mainly about doing routine calculations as opposed to interpretation and understanding;
- some students lack transferable skills;
- tasks mainly test speed and accuracy rather than actual mathematical ability;
- examinations are too short to allow for in-depth and searching questions;
- examinations have become repetitive and predictable;
- many questions are too highly ‘scaffolded’;
- more searching questions are required which involve problem solving and require deeper understanding through demonstrating interpretation.

While ALCAB has sought to address some of these issues in its recommended content, further work will be required with all stakeholders to realise the full potential of the new A levels as these issues relate not only to assessment but also delivery, structure and governance.

The next crucial step to releasing the full potential of these recommendations is in the hands of the Awarding Organisations and Ofqual. Ofqual (2014) published draft Assessment Objectives (AOs), on which there has been a public consultation, and revised AOs will be published in Autumn 2015, with guidance. It is the AOs that the Awarding Organisations will be working with to prepare specifications for submission, and subsequent approval by Ofqual. It is therefore essential that the AOs reflect the intentions of ALCAB's recommendations on content, and particularly the OTs. The current version of the draft AOs for A level Mathematics, each with a weighting of 30-40% for distribution of marks, has the main headings: AO1 Use and apply standard techniques; AO2 Reason, interpret and communicate mathematically; AO3 Solve problems within mathematics and in other contexts; with additional exemplification for each AO available (reference). Crucially, AO2 and AO3 have the additional constraint: 'Where problems require candidates to 'use and apply standard techniques' or to 'solve problems' independently a proportion of those marks should be attributed to the corresponding assessment objective'. Inclusion or otherwise of this statement necessarily has a significant influence on the nature of any likely assessments.

Clearly AO2 and AO3 map onto, respectively, OT1 and OT2, and the wording, additional exemplification, and weightings in the finalised AOs will be crucial to realising the OTs. To that end, Ofqual have been working further on these draft AOs and also guidelines for the Awarding Organisations, particularly in respect of mathematical problem solving which is integral to these reforms. For example, some attributes of assessment that a problem solving task might include are ones where: there is little or no scaffolding; the mathematical process(es) required for the solution is not explicitly stated ; there are multiple representations; the information is not given in mathematical form or in mathematical language; there is a choice of techniques to be used; the solution requires understanding of the processes involved rather than just application of the techniques; two or more mathematical processes are required, or different parts of mathematics may be required to be brought together to reach a solution.

There is much work to be done, but the realisation of ALCAB's intentions, in full, should bring substantial benefit to all end-users, including HE students in STEM and other disciplines.

So HE should be well-provided for in the medium term, or will it? In fact, this is far from the case. Since 2010 many influential reports have concluded that the UK needs substantially more students continuing with mathematics post-16 and that neither AS and A level mathematics are appropriate to be able to fill this need – see Hodgen et al (2010, 2013), ACME (2011, 2012, 2013), Hillman (2104) Moreover, HE has significant needs itself which AS and A level Mathematics will not meet - see Hodgen et al (2014).

Much of this gap can be amply filled by the new Core Maths qualifications (CMSP, 2015). In the summer of 2015 approximately 93,000 sat A level Mathematics, whereas typically around 200,000+ post-16 students do not continue with mathematics beyond GCSE. The Technical Guidance for Core Maths (DfE, 2014c) explains that AS and A level mathematics:

'extend students' experience of mathematical techniques significantly, developing advanced analysis of mathematical problems and construction of related arguments and methods of proof'

whereas Core Maths:

- 'consolidates and build on students' mathematical understanding at GCSE;
- develops further mathematical understanding and skills in the application of maths to authentic problems;
- provides a sound basis for the mathematical demands that students will face at university and within employment across a broad range of academic, professional and technical fields;

- prepares students for the varied contexts they are likely to encounter in vocational and academic study and in future employment and life, for example, financial modelling and analysis of data trends;
- fosters the ability to think mathematically and to apply mathematical techniques to variety of unfamiliar situations, questions and issues with confidence;
- is likely to be particularly valuable for students progressing to higher education courses with a distinct mathematical or statistical element such as psychology, geography, business and management, such qualifications will also be valuable for any student aiming for a career in a professional, creative or technical field.'

The three objectives summarise very neatly all Core Maths qualifications:

- 'deepen competence in the selection and use of mathematical methods and techniques;
- develop confidence in representing and analysing authentic situations mathematically and in applying mathematics to address related questions and issues;
- build skills in mathematical thinking, reasoning and communication.'

All the reports highlighted make it clear that Core Maths will bring significant benefits to HE, but this will require a strong signalling from HE that they welcome applicants with Core Maths. The HEA report alone (Hodgen et al, 2014) finds 85,000 students are admitted into university in the UK each year to study: Business and Management, Chemistry, Computing, Economics, Geography, Sociology and Psychology, and all require mathematics and/or statistics to some extent, and other disciplines have similar needs, including biological sciences, medicine and dentistry, architecture, building and planning, and various technology degrees, with the numbers of students affected of the order of 200,000 p.a. Unsurprisingly, many students arrive at university with unrealistic expectations of the mathematical and statistical demands of their subjects, and lack of confidence and anxiety about mathematics/statistics are problems for many students.

As argued in Hillman (2014): 'There is a chicken and egg situation here: higher education institutions won't make post-16 maths a required qualification or even provide a more subtle signal that it is necessary or desirable, because in a competitive market for students to do so would be to rule out large numbers of applicants. So there is still not sufficient incentive for students to choose maths qualifications, particularly in the context described earlier of constraints on the growth in numbers opting for the full A level and changes to the status of the AS level. With the introduction of Core Maths, there is potential to break this log jam.'

A typical 'wish list' of skills that HE would like their students to have include: know, understand and use existing GCSE material with confidence; solve problems in a variety of contexts; make logical and reasoned decisions; communicate; generalise; interpret; make deductions; use technology; modelling; algebraic manipulation; and a 'wish list' of topics that they would like their students to be more confident using and applying would include: fractions, ratios, percentages, and decimals; inequalities; graphs; algebra; probability; correlation; hypothesis testing; and summary statistics. These skills and topics are found in abundance in Core Maths.

So how does HE cope now? Two obvious remedies that are put in place are: mathematics and statistics support centres; and additional courses to re-teach GCSE and applying this in context. With entrants having followed Core Maths, and so better prepared for the demands of their course, there is clear scope for utilising these resources more effectively in supporting their students. The largest gain will be in improving graduate employability, a topic firmly at the top of every university's agenda. Either way, Core Maths is 'win-win' for HE.

The Core Maths Support Programme is working with universities and schools/departments in the target group, with the intention to encourage as many universities and courses to welcome applicants offering Core Maths or AS/A level Mathematics.

Widespread endorsement by relevant university schools/departments is needed to motivate schools and colleges to offer it, pupils to take it, and their advisers to support them in doing so, and by doing so the ‘log jam’ referred to by Hillman will be broken, we will no longer be in a ‘chicken and egg’ situation, and students will start reaping the benefit of Core Maths throughout their studies and into employment, and HE generally will benefit by having better prepared, more proficient students, with improvements to attainment and graduate employability.

References

ACME. (2011). Mathematical Needs: Mathematics in the workplace and in Higher Education. Advisory Committee on Mathematics Education. Accessed via http://www.acme-uk.org/media/7624/acme_theme_a_final%20(2).pdf (2 September 2015)

ACME. (2012). Post-16 Mathematics: A strategy for improving provision and participation. Advisory Committee on Mathematics Education. Accessed via http://www.acme-uk.org/media/10520/20121217acme_post_16_strategy.pdf. (2 September 2015)

ACME. (2013). Report from the expert panel on core mathematics. Advisory Committee on Mathematics Education. Accessed via http://www.acme-uk.org/media/13699/final%2007october2013,%20expert%20panel%20on%20core%20mathematics%20report.pdf. (2 September 2015)

ALCAB, (2013). ALCAB – About us. Accessed via http://alcab.org.uk/about/. (2 September 2015)

CMSP (2015). Awarding organisations. Accessed via http://www.core-maths.org/information/awarding-organisations/. (2 September 2015)

DfE (2014a). GCE AS and A level mathematics. Accessed via https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/388815/GCE_AS_and_A_level_subject_content_for_mathematics.pdf. (2 September 2015)

DfE (2014b). GCE AS and A level further mathematics. Accessed via https://www.gov.uk/government/publications/gce-as-and-a-level-further-mathematics. (2 September 2015)

DfE. (2014c). Core maths qualifications: technical guidance. Department for Education. Accessed via https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/327965/Core_Maths_Technical_Guidance_-_July_2014_amended__PT_.pdf. (2 September 2015)

Hillman, J. (2014). Mathematics after 16: the state of play, challenges and ways ahead. Nuffield Foundation. Accessed via http://www.nuffieldfoundation.org/sites/default/files/files/Mathematics_after_16_v_FINAL.pdf. (2 September 2015)

Hodgen, J., Pepper, D., Sturman, L., and Ruddock, G. (2010). Is the UK an outlier? An international comparison of upper secondary mathematics education. Nuffield Foundation. Accessed via http://www.nuffieldfoundation.org/sites/default/files/files/Is%20the%20UK%20an%20Outlier_Nuffield%20Foundation_v_FINAL.pdf. (2 September 2015)

Hodgen, J., Marks, R., and Pepper, D. (2013). Towards universal participation in post-16 mathematics: lessons from high-performing countries. Nuffield Foundation. Accessed via http://www.nuffieldfoundation.org/sites/default/files/files/Towards_universal_participation_in_post_16_maths_v_FINAL.pdf. (2 September 2015)

Hodgen, J., McAlinden, M., and Tomei, A. (2014). Mathematical transitions: a report on the mathematical and statistical needs of students undertaking undergraduate studies in various disciplines. Higher Education Academy. Accessed via https://www.heacademy.ac.uk/sites/default/files/resources/HEA_Mathematical-transitions_webv2.pdf. (2 September 2015)

Ofqual (2014). Developing new GCSE, A level and AS qualifications for first teaching in 2016. Accessed via http://webarchive.nationalarchives.gov.uk/20141110161323/http://ofqual.gov.uk/documents/developing-new-qualifications-first-teaching-2016/. (2 September 2015)

Computer-aided assessment of numeracy and algorithms

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Abstract

The first part of this paper will describe the development of questions on employability aptitude testing of numeracy skills, and adult numeracy more generally. Although the underlying mathematics is nearly always based on the idea of proportionality dealt with at GCSE level or even below, for adult learners, issues of context and realism of the questions are explained. Another important feature for employability aptitude testing is the abstraction of word problems to their mathematical formulation (usually fraction manipulation) and this is thought to be a major cause of student difficulties. The maths e.g. database has therefore been expanded to allow students to practise various topics such as the reading and interpretation of tables, charts and graphs, and doing money calculations involving pay slips and currency conversion. The second half of the paper describes newly-developed computer-aided assessments to underpin the content of a second-year computer science Algorithms module. Questions have been developed on operation count and asymptotic order, fitness functions, heuristic and algorithmic search, sorting and the travelling salesman problem. Effective question design for this content is rather different to that for more usual mathematical topics and required the development of new question types: selection, list ordering, pseudocode arrangement and keyword insertion.

Background

This work enhances the maths e.g. computer-aided assessment engine to cover more basic mathematics and statistics that often form a significant body of requests to our Mathematics and Statistics tutors at Brunel University's Academic Skills Service (ASK). The same content is also widely needed for various employability tests that require numeracy and mathematical formulation skills, specified by our Careers Service to mimic, but improve on, commercially-available tests. Thus we have provided about 50 CAA question spaces in the topic areas below. The resulting tests will be run shortly, giving ASK staff valuable diagnostic insight into the nature of students' difficulties and how to prioritise the help that is offered on an individual basis. A whole-cohort view will also inform taught provision, for example in specifying the 'topic of the week' class by ASK and also in Study Skills sessions for our Foundations of Computing and Mathematics. Depending on the test results, these classes will almost certainly include basics such as interpreting charts and graphs, percentage changes in a finance context and will almost certainly include the abstraction (or modelling) of the word problems in mathematics. Thus, although the topics are mathematical, they will appeal to a very wide audience, including STEM and Social Sciences students alike. Question design therefore focusses on the idea of 'graduate skills', so that the content is based on the desired numeracy skills of any graduate and does not require specialist knowledge (such as the proportionality questions earlier designed for nurses where the specific context would put off engineering students, for example).

In general, proper assessment of even simple mathematical content defeats many systems and the native capabilities of VLEs on both pedagogic and technical grounds, see Sangwin (2013). A number of powerful CAA systems do much to exploit the possibilities offered by computers

(STACK, Numbas, Dewis, commercial systems like Maple TA and publisher systems such as Wiley Plus and MyMathLab) and certainly all these go well-beyond paper-based testing and the (very limited) commercial online tests. Our maths e.g. system also provides a flexible environment that includes over 3000 question spaces. Hosted at MathCentre, maths e.g. has maintained its popularity, probably attributable to the very full feedback making each question a learning resource in its own right. In addition, the teacher interface has almost 600 registered users worldwide who are able to 'pick and mix' questions from the entire database to form their own assessments which can be formative or summative. An overview of the thinking behind question design and our experience with it over many years is presented by Greenhow (2015).

Questions are coded in Javascript with MathML for equations and SVG for the graphics. Each of the questions incorporates random parameters so that each produces thousands or millions of realisations seen by the students at runtime. The primary features of these realisations are very full general feedback (model solution and links to related web material), intelligent interpretation of the student's answers so that specific feedback can be given and built-in accessibility features so that font size and colours are under the student's control. This accessibility feature is carried through to any equations and diagrams (not just text) so that partially-sighted or dyslexic students are not excluded from using the CAA. An unexpected, but very encouraging, revelation made in a presentation at the MSOR-CETL 2015 conference by Abi James and Clare Trott is that maths e.g. also 'works' with STEMReader i.e. this software can already interpret and use the MathML coded in the questions (James and Trott, 2015). We will need to explore the efficacy of using STEMReader in helping students achieve well on our tests.

The second half of this paper presents questions designed to support mathematics and computer science students taking a second year Algorithms module. Previously, we successfully introduced a suite of computer-aided assessments for revision of the coding language used (Java) and some of the underlying mathematics (mainly algebra and functions). Next year we plan to complement this with the 60 questions we have developed to assess students' knowledge of algorithms more broadly and in a language-free context. This has required the development of new question types, described below.

Employability aptitude testing of numeracy

Fig. 1 shows a question on currency conversion. In order to arrive at an answer students have to apply both the direct problem (Sterling to South African rand) and the 'inverse' problem which requires more thought: they will have to work out that they need to divide by the conversion factor in this case and this may not be obvious, especially to maths-phobic students.

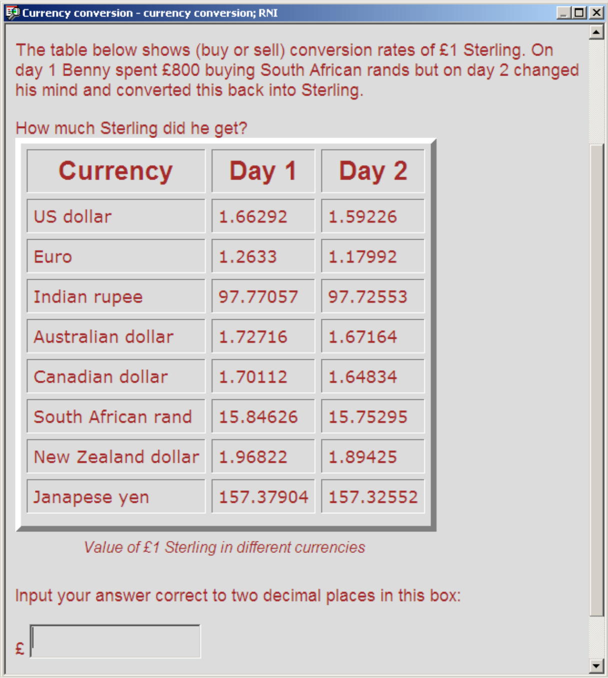


Figure 1: Currency conversion question involving direct and inverse problems.

Although apparently trivial, an intuitive understanding of the concept of an inverse function is required, as well as more calculation than that for the direct problem. Greenhow (2015) speculates on how one might measure this increased difficulty using a combination of the number of concepts and the number of ways a student can err. The latter gives rise to a count of the number of accessible states (or entropy) for the answer by applying structured but incorrect calculations (mal-rules). These mal-rules are often encoded 'behind the scenes' in responsive numerical input so that inferences can be made from students' answers and bespoke feedback given, altering them to the likely cause(s) of the error(s) made. The realism of the question is ensured by having small random changes to realistic conversion rates (at the time of writing they are roughly in line with online calculators that also specify 5 decimal places) and the amount of money to be converted. The chosen currency is randomised as is the name (Benny in this case) and the rather garish colour scheme is under the user's control by writing their preferences to a cookie. Interestingly, many students like this sort of 'inverse video' effect which may reduce screen glare. Further realism could easily be added by charging flat-rate or percentage commission charges on each currency exchange.

Fig. 2 also shows feedback for a multi-step question with an element of modelling and quite a lot of arithmetic, again on (somewhat) realistic salary data. The relevant cells are not highlighted in the question but are in the feedback to focus the student's attention. It would be possible to drop this data in the table into a spreadsheet automatically and have students do their work there, as done for many of the elementary statistics questions which would otherwise require excessive calculator use. Here, however, the point of the question is the accurate reading of the table and subsequent accuracy in their calculations. These comments demonstrate that the question author needs to identify the skill(s) intended to be tested by any question in the design process; identifying assumed skills informs the structure of the feedback (percentages) although the other assumed skills of calculator use to do addition and subtraction are taken as read (this may in itself be risky!).

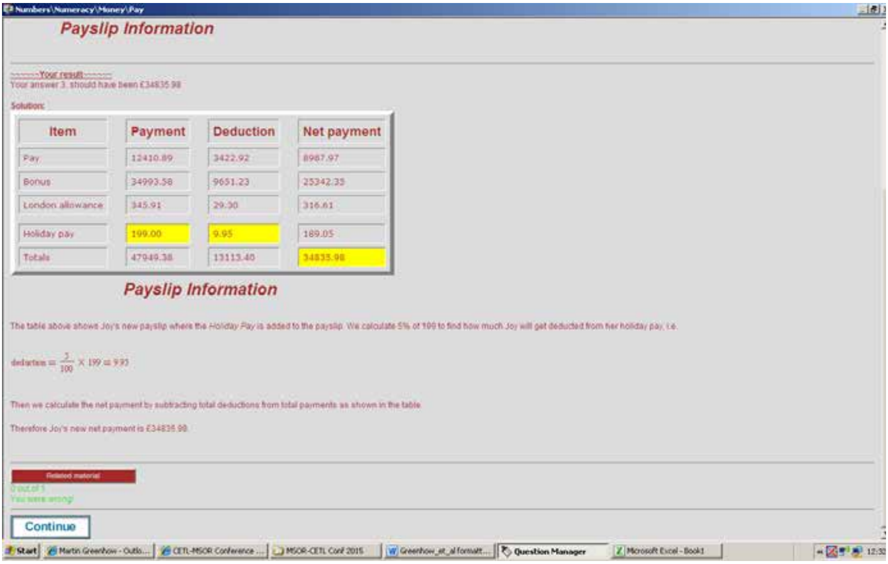


Figure 2: Feedback on a question testing reading and calculating with a table of data.

Fig. 3 shows feedback on a question that gives a holiday expenditure table and asks for the angles (whole degrees) on the bordered sectors in a pie chart. Given the randomisation and required rounding, it is not guaranteed that the angles will sum to 360 degrees (although this does happen here); this could be reverse-engineered so that it always happens but it is more realistic to warn students that rounding can have this effect.

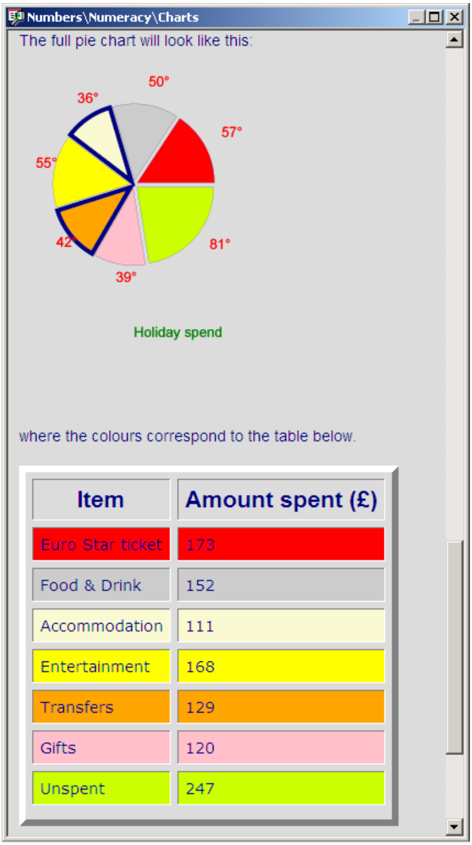
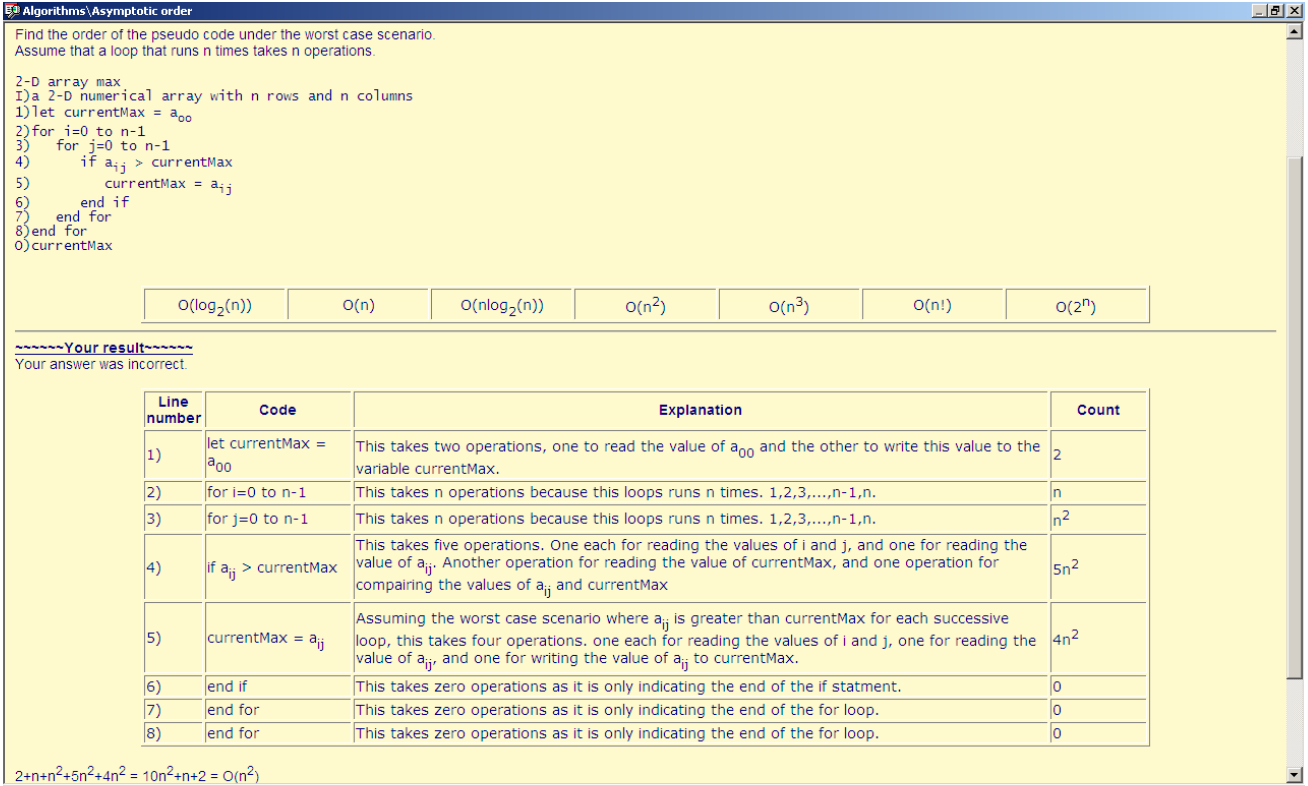


Figure 3: Feedback on a question that gives a holiday expenditure table and asks for the angles (whole degrees) on the bordered sectors in a pie chart.

Questions on algorithms

In consultation with the module lecturer, the following topics were identified and questions coded to span operation count and asymptotic order, fitness functions, heuristic and algorithmic searches, sorting and the travelling salesman problem. The resulting questions were very unlike those above, being required to test understanding more than calculation abilities, and this required developing new question functionality. Thus Fig. 4 shows a question on algorithms where the user has to select the relevant order (a cloned question asks for the operation count given a random value for n). Other questions ask students to order given lines of pseudocode to form randomly-chosen algorithms, with the added feature that not all the lines provided are needed.



Algorithms\Asymptotic order

Find the order of the pseudo code under the worst case scenario.
Assume that a loop that runs n times takes n operations.

```
2-D array max
I)a 2-D numerical array with n rows and n columns
1)let currentMax = a_oo
2)for i=0 to n-1
3)   for j=0 to n-1
4)      if a_ij > currentMax
5)         currentMax = a_ij
6)      end if
7)   end for
8)end for
O)currentMax
```

$O(log_2(n))$	$O(n)$	$O(nlog_2(n))$	$O(n^2)$	$O(n^3)$	$O(n!)$	$O(2^n)$

~~~~~~Your result~~~~~~
Your answer was incorrect.

Line number	Code	Explanation	Count
1)	let currentMax = a_{00}	This takes two operations, one to read the value of a_{00} and the other to write this value to the variable currentMax.	2
2)	for i=0 to n-1	This takes n operations because this loops runs n times. 1,2,3,...,n-1,n.	n
3)	for j=0 to n-1	This takes n operations because this loops runs n times. 1,2,3,...,n-1,n.	n^2
4)	if a_{ij} > currentMax	This takes five operations. One each for reading the values of i and j, and one for reading the value of a_{ij}. Another operation for reading the value of currentMax, and one operation for compairing the values of a_{ij} and currentMax	$5n^2$
5)	currentMax = a_{ij}	Assuming the worst case scenario where a_{ij} is greater than currentMax for each successive loop, this takes four operations. one each for reading the values of i and j, one for reading the value of a_{ij}, and one for writing the value of a_{ij} to currentMax.	$4n^2$
6)	end if	This takes zero operations as it is only indicating the end of the if statment.	0
7)	end for	This takes zero operations as it is only indicating the end of the for loop.	0
8)	end for	This takes zero operations as it is only indicating the end of the for loop.	0

$2+n+n^2+5n^2+4n^2 = 10n^2+n+2 = O(n^2)$

Figure 4: A question on the order of a randomly-selected algorithm's pseudocode and feedback.

Finally, Fig. 5 shows a multi-selection question testing students' knowledge of a set of commonly-taught algorithms. Here the boxes to be filled in change with the algorithm, although the options do not. This deliberately tests whether or not students can identify key words with the correct algorithm. Around 60 different questions, all randomised as fully as is feasible, were created. Given the specialist nature of these questions, they will be reported elsewhere after suitable trialling that will also study their effect on subsequent exam performance using the methodologies described in Greenhow (2015).

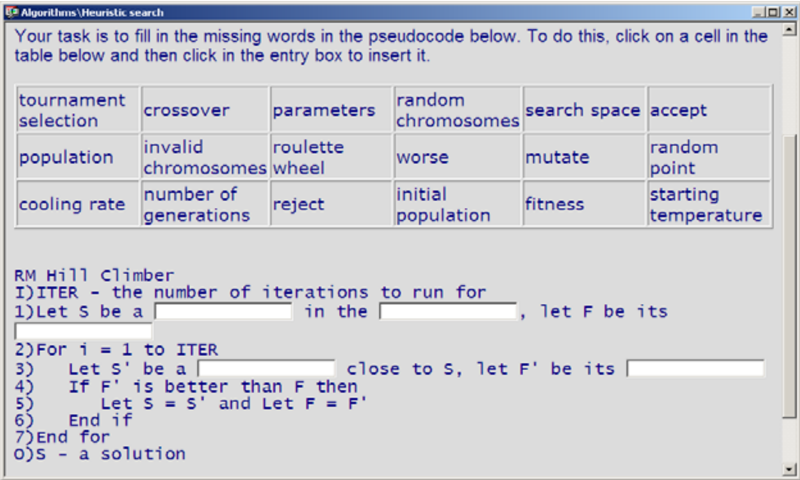


Figure 5: A multi-selection question testing students' knowledge of a set of commonly-taught algorithms.

References

Dewis: University of the West of England http://www.cems.uwe.ac.uk/caa/welcome/index.html (accessed 10/9/15)

Greenhow M. (2015) Effective computer-aided assessment of mathematics; principles, practice and results. To appear in Teaching Mathematics and Its Applications doi:10.1093/teamat/hrv012

James A. and Trott C. (2015) Developing maths text to speech to support learners with print impairments. MSOR-CETL Conference, Greenwich.

Maple TA: MapleSoft http://www.maplesoft.com/products/mapleta/ (accessed 10/9/15)

maths e.g. Brunel University http://www.mathcentre.ac.uk:8081/mathseg/ and http://www.mathcentre.ac.uk:8081/mathsegteacher/ (accessed 10/9/15)

MyMathLab: Pearson Education http://www.mymathlab.com/ (accessed 10/9/15)

Numbas: Newcastle University http://www.ncl.ac.uk/maths/numbas/ (accessed 10/9/15)

Sangwin, C. (2013) Computer Aided Assessment of Mathematics. 1st edn. Oxford: Oxford University Press.

STACK: Birmingham University http://www.stack.bham.ac.uk/ (accessed 10/9/15)

Wiley Plus: Wiley https://www.wileyplus.com/WileyCDA/ (accessed 10/9/15)

The educational uses of pencasts in mathematics education

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Abstract

A pencast solution is an interactive document containing a digital version of a handwritten solution to a problem that is synchronised with audio recorded in that moment in time. Using a Livescribe smartpen, an earlier project used a limited number of pencasts to provide revision support to first year students on an Engineering Mathematics module at Ulster University. The students that used the pencasts found them extremely helpful. More extensive work and over 100 pencasts later, several educational benefits of pencasts have been identified and are outlined in this paper. Students' educational usage of the pencasts is discussed in the context of first year engineering mathematics and mathematical methods modules. The equipment and workflow used, their benefits and limitations are also described. This paper will discuss the findings from a survey conducted as part of this project, and report on the feedback received from the students who used the pencasts.

Background

At Ulster University mathematics and engineering students are required to take foundation mathematical methods or engineering mathematics modules in the first year of their studies. Both modules assume prerequisite A-level mathematics or equivalent and the module aims to revise and extend the mathematical knowledge required for successful further study. Both modules are 'long-thin' modules with one weekly two-hour lecture followed by a one-hour tutorial class. However, there is a diverse student intake with regard to their prior mathematical knowledge, educational experiences, and time since they last studied mathematics. Such student variability presents a number of challenges to the lecturer that affect the pace and delivery of the module, and can affect students' confidence in their ability to pass the module.

In an attempt to overcome these problems, the lecturer explored a number of technological approaches. Some lecturers in higher education were creating instructional screencasts – a video recording that captures activity on a computer screen with the option to capture real-time audio-commentary. Studies conducted to date have identified that there are definite benefits in sharing screencasts with students (e.g., Galligan et al. 2012; Loch and Mcloughlin, 2011; Mullamphy et al., 2010). The lecturer was therefore keen to experiment with an alternative more affordable learning technology, which might prove easier for lecturers to use and require less time and effort to develop.

In this paper an alternative to screencasting was explored, namely to create a mathematical pencast resource. A pencast is an interactive PDF document containing a digital version of handwritten notes that are synchronised with audio. Pencasts are recorded using a LivescribeTM smartpen and special 'dot-paper'. A key benefit of this approach is that the pencast equipment is used in the same way as traditional pen and paper. The equipment is portable, quick to set up and easy to use.

Methodology

The creation of a pencast resource

The creation of the pencast resource underpinning this educational study spans several years. Initially, in May 2013, pencast solutions were created for several university examination questions taken from past paper. Due to the short timeframe in which the pencasts could be created, the questions were carefully selected from topics that would help students 'pass' the examination. In the following academic year, 2013-2014, the lecturer became involved in a technology facilitated learning (TFL) project, named CLARITI (Herron and O'Donnell, 2014), which aimed to enrich student feedback and promote self-reflection. Part of the CLARITI project required that students self-mark their work and create meaningful action plans that would help them improve their learning. As a result most of the pencasts created that year were pencast solutions for coursework problems with mark schemes. In the last academic year, 2014-2015, the CLARITI project continued and hence many new pencasts were produced. Increased effort was put into improving the quality of the pencasts. One example is a pencast solution for a mathematical problem which finds the integral of a function by using the method of substitution (see Integration by substitution, 2015). The same pencast solution with added marking scheme is also available (see Integration by substitution with mark scheme, 2015).

Most of the time and effort required to create reusable pencasts was spent in the pre-production stage. At this stage, storyboard solutions and scripts for the 'talk-aloud' were created. These went through the stages akin to a movie production scenario: "create - rehearse - revise - rehearse - revise - " etc. The production stage usually required only one take. Since pencasts cannot be edited there was no postproduction stage. The pencast solutions were uploaded to the University's Virtual Learning Environment (VLE) and shared with the students.

The study

The research reported in this paper, was conducted during the 2014-2015 academic year at Ulster University. A cohort of 55 first-year, full-time and part-time, undergraduate students (30 students registered on the mathematical methods module and 25 students registered on the engineering mathematics module) participated in the study. Approximately 100 pencasts were shared with the students; 50% created in the previous academic years were reused and 50% were created in the academic year of this study. The playback times varied between 5 and 30 minutes, with an average file size of 4MB.

After the university examination period, an anonymous electronic student survey was sent to all students. The main aim of the survey was to collect student reflections on their use or non-use of the pencasts and how the resource could be improved. The survey comprised of 17 questions, including multiple-choice questions, multiple-response questions and open-ended questions. Subjective data was collected on how students interacted with the pencasts, how helpful the pencasts were for specific educational uses and how the pencast resource could be improved. Open-ended questions were also asked to gain a further understanding of student perceptions of the pencasts. The questionnaire responses were analysed and open-ended responses were analysed thematically.

Results

Out of the 55 students taking part in the study 28 students responded to the end-of-year survey. This represented 51% of the students registered across both modules. All respondents had watched at least one pencast.

Results of closed questions

The responses to the question “If you did use the pencasts, how helpful did you find them for: (specific educational uses)” are summarised in Figure 1.

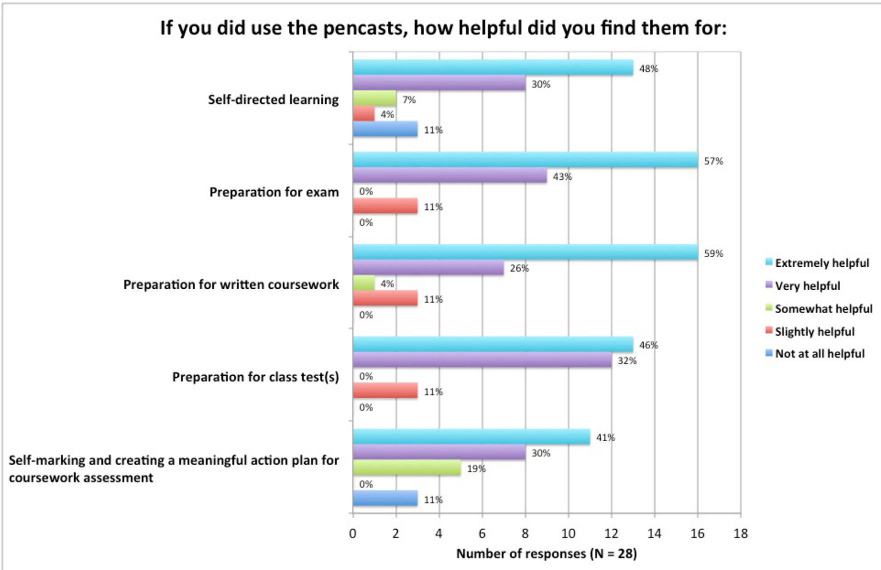

Figure 1: Perception of pencasts for various educational uses (N = 28).

The responses indicate that 41% to 59% of the students find the pencasts “extremely helpful” for each of the educational uses. Students found the pencast solutions most helpful for the preparation for examination, coursework and class tests, with 85% to 98% of students indicating that the pencasts were either “very helpful” or “extremely helpful”. Students found the pencast solutions least helpful for “self-marking and creating meaningful action plans for coursework”. However, even for this educational use, 71% of students indicated that the pencasts were either “very helpful” or “extremely helpful”. 48% of the students indicated that the pencasts were “extremely helpful” for self-directed learning.

The responses to the question “How did you use the pencasts over the last academic year?” are summarised in Table 1. The results indicate that all students accessed the pencasts at least once. Whilst only 36% of the respondents usually watch and listen to a complete pencast, 79% of students used the fast-forward and rewind features to concentrate on parts of the pencast solutions they found most helpful, and 57% of the students would come back to view a pencast again.

How did you use the pencasts over the last academic year?	Response
I fast-forward and rewind to concentrate on sections that are most helpful.	79%
I usually watch and listen to a complete pencast.	36%
I would come back to view a pencast again.	57%
I use pencasts regularly.	36%
I have watched a few.	36%
I have watched and listened to a pencast once.	4%
I have never watched and listened to a pencast.	0%

Table 1: How students interact with pencasts (N = 28).

It is important to collect feedback on the resource that is being created. The responses to the question "How can the pencasts be improved?" are summarised in Table 2. Overall, the students were satisfied with the quality of the pencasts and would like to see and listen to more.

	About right	Increase	Reduce
The number of pencast examples.	41%	59%	0%
The length of a pencast.	82%	0%	18%
The detail and number of steps in a pencast.	82%	14%	4%
The legibility of handwriting.	75%	14%	4%
The presentation of a pencast solution.	95%	5%	0%

Table 2: How pencasts can be improved (N = 28).

Student comments

The success and impact of pencasts can be discussed in relation to their relevance, how they support diversity and their accessibility. Some of the reasons why students rated pencasts helpful were because they: considered them directly relevant to the subjects covered in the class; helped them revise and prepare for class tests, coursework and exams; found the pencasts supplied all the steps for a solution; made mathematics easier to pick up and learn; helped with self-marking of the student's work and for self-directed learning.

Providing students with relevant and interactive pencasts is important for meaningful learning. One student commented that:

> *"I found the pencasts to be a very good source of learning because it went through each step in detail, making it very easy to follow."*

Another commented:

> "The pencasts helped me during both the completion of my assignments and revision. I feel that I am much more confident in this module because the pencasts allowed me to continue with my learning at home. The pencasts were extremely clear and easy to follow and greatly assisted me with my learning. "

Pencasts can be used within an effective teaching and learning strategy that helps reduce the problems inherent in teaching to a diverse intake of students. A few comments collected from the open-response questions are given below:

> "Everyone has different levels of understanding. I myself can get some elements of the module right away, but there are parts I can't. With the pencasts I can play it over and over until I get it."

> "Being away from education for a while, I find the pencasts a total necessity as a study aid, without them I don't think I would have ever caught up."

An important feature of pencasts is that they allow students to control the pace of delivery and access to the material anytime and anywhere. Some feedback from students suggests they like how pencasts provide extra teaching outside of the classroom. One student commented that:

> "It's just like having your tutor at home guiding you through a problem."

Another commented that,

> "They're basically a lecture that's available at all times and doesn't hold up the class for you to re-watch."

Discussion and conclusion

This study has shown that pencasts have many educational uses and those that have been created and shared have been extremely helpful to a diverse intake of students. An important feature of a pencast is that a student can interact with the pencast in many ways: they can control the pace of delivery; zoom in and out of the pencast document; they can easily skip to any part of the document by simply tapping on the page. They can also print the pencast document as a standard PDF.

As with any instructional media there are benefits and limitations. From this lecturer's perspective the main benefit of creating educational pencasts are that they are plain and simple to create, and quick and easy to share. With a LivescribeTM Smartpen 3, wireless streaming to a data projector in a classroom is possible allowing pencasts to be electronically projected as they are being created. The main drawback with pencasts is that mistakes made with the pen or audio cannot be edited. However, with careful planning these can be minimised or eliminated. Lack of editing ability can be viewed as a benefit since with careful planning it usually requires only one 'take' to create a pencast and therefore entails no post-production stage, as would be the case if creating high-quality screencasts. A minor drawback is that digital ink is limited to one colour. Again, careful planning of visual cues is important.

Future research directions

Now that a pencast resource has proved valuable, the lecturer is seeking to share, collaborate and improve upon an instructional design model that is effective in an online learning environment. The lecturer would like to create a model that would allow other lecturers to contribute to an open educational resource (under Creative Commons license) as this has the potential to be more useful for all students, including non-mathematical students.

It is also necessary to develop a framework that encourages student engagement with the resource. In the near future, the lecturer plans to build on this project and design active learning activities that encourage use of this resource. It is envisaged that the pencast resource will be used along side other instructional media to provide active learning opportunities that enrich and extend the classroom experience.

References

Galligan, L., Hobohm, C. and Loch, B. (2012). Tablet technology to facilitate improved interaction and communication with students studying mathematics at a distance. Journal of Computers in Mathematics and Science Teaching, 31(4), 363-385.

Herron, M. G. and O'Donnell, C. (2014). "Technology-enhanced learning and teaching in mathematics; enhancing feedback and promoting self reflection (CLARITI)". Accessed via http://www.sigma-network.ac.uk/wp-content/uploads/2014/09/Herron_M_CETLMSOR_2014Presentation-CLARITI.pdf (25 November 2015)

Integration by substitution. (2015). Pencasts. http://addl.ulster.ac.uk/images/uploads/integration_by_substitution.pdf

Integration by substitution with mark scheme. (2015). Pencasts. http://addl.ulster.ac.uk/docs/integration_by_substitutionMS.pdf

Loch, B. and McLoughlin, C. (2011). An instructional design model for screencasting: Engaging students in self-regulated learning. Changing Demands, Changing Directions. Proceedings ascilite Hobart, 816-821.

Mullamphy, D. F., Higgins, P. J., Belward, S. R. and Ward, L. M. (2010). To screencast or not to screencast. Anziam Journal, 51, C446-C460.

When, what and how are changes being made in 14-19 mathematics education – a view from a curriculum development body

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Mathematics in Education and Industry

Abstract

This paper outlines some of the ongoing reforms to pre-16 and post-16 mathematics qualifications and their possible impact for Higher Education over the coming years. It is an update of the Higher Education Academy commissioned, MEI-written, 'Understanding the UK Mathematics Curriculum Pre-Higher Education' 2010 report and the subsequent article 'Where are we now?' in the MSOR Connections journal in 2014.

A background of hugely positive entry statistics for mathematics qualifications is presented from over the last decade, along with changes that will happen in pre and post-16 mathematics education from September 2015 onwards. This includes a new GCSE Mathematics curriculum from 2015 and a completely revised A level structure and curriculum, for mathematics A levels, from 2017.

The intention is that students should enter Higher Education better prepared mathematically after having studied the new GCSE and A levels, but such widespread change across the whole education landscape, particularly in respect of funding, could mean there is a risk of fewer such students taking the qualifications.

Background

Mathematics in Education and Industry (MEI), through its charitable status, is committed to improving mathematics education and in doing so works in 14-19 curriculum development; provides professional development and resources for teachers; provides tuition and enrichment for students, as well as seeking to have a positive influence on national mathematics education policy. This includes MEI managing the national Further Mathematics Support Programme.

Due to its expertise, MEI was commissioned by the Higher Education Academy (HEA) to write 'a guide for academics' in respect of pre-university mathematics qualifications, see Lee et al (2010). An update on changes between 2010 and 2014 was given in an article for the HEA's journal, see Lee and Dudzic (2014).

The world of mathematics education has not stood still and changes continue at a rapid pace. This article therefore details the current and planned changes in 14-19 mathematics education, which will ultimately affect the students that arrive in Higher Education (HE).

14-16 mathematics education

Over the last decade a culture emerged of early (and multiple) entries to GCSE, see Ofsted (2013). However, rule changes in September 2013, which meant only the first 'sitting' of an exam counted towards school performance measures, resulted in a significant decrease in early entries in 2014 and 2015 (a reduction by over 80% in Mathematics in 2014, compared to 2013).

From September 2015 a reformed GCSE Mathematics curriculum is being taught in schools in England. The new qualification has a linear structure, with examinations taken only at the end of the course. Thus summer 2017 will see the first examinations of this content being sat by students. There will be more content than the previous curriculum and it will have greater emphasis on problem solving. The intention is that the new GCSE mathematics course will be more demanding and 'as such' more time should be set aside for teaching mathematics in schools. Early Department for Education figures suggest that only 25% of schools may be giving extra time.

The grading system will change to become numerical – grades A* to G will be replaced by grades 9 to 1. At present the guidance, see DfE (2014), is that Grades G to D will be aligned to '1 to 3', C to B aligned to '4 to 6' and A to A* to '7 to 9'.

The new mathematics GCSE will be tiered, with grades 4 and 5 available through both tiers. For each examination, the top 20 per cent of those who get grade 7 or above will get a grade 9, i.e. the very highest performers. Grade 5 will be positioned in the top third of the marks for a current Grade C and bottom third of the marks for a current Grade B. This will mean it will be of greater demand than the present grade C. It is grade 5 that in the future will be taken as the 'benchmark' for performance tables (which grade C is in the present system). A chart showing how the distribution could compare is shown below:

<table>
<tr><td rowspan="2">Grade comparison</td><td colspan="2">A*</td><td colspan="2">A</td><td colspan="2">B</td><td colspan="2">C</td></tr>
<tr><td>9</td><td colspan="2">8</td><td>7</td><td>6</td><td colspan="2">5</td><td>4</td></tr>
</table>

For HE it will be applications in autumn 2019 that will have studied the new mathematics GCSE. Note that English GCSE is also being reformed for first teaching in September 2015, but other subjects will be reformed later.

Post-16 mathematics education

There are three distinct pathways emerging for studying post-16 mathematics: AS/A levels in mathematics and further mathematics; new Core Mathematics qualifications; and working towards GCSE resit for those students who do not achieve grade C at GCSE. These will be considered in turn.

GCSE Resit

In late 2014 the DfE offered the following guidance on the condition of 16-19 funding in English and mathematics (see: www.gov.uk/guidance/16-to-19-funding-maths-and-english-condition-of-funding)

"For the academic year starting August 2015, all full time students starting their study programme who have a grade D GCSE or equivalent in mathematics and/or English must be enrolled on a GCSE or approved IGCSE qualification in mathematics and/ or English, rather than an approved stepping stone qualification. Full time students are those on a study programme of at least 540 planned hours if age 16 to 17 or at least 450 hours if age 18."

The outcome of this will be many more students needing to resit GCSE mathematics as part of their post-16 programme of study. This is highlighted as it will require many more teachers of mathematics – an extra pressure on schools and colleges.

Core Mathematics

New Core Mathematics qualifications have been developed and are available nationally from September 2015, with first examination in 2017 (though note an 'early adopters' scheme is running – schools and colleges which began teaching from September 2014 and will have a first exam in 2016). The qualifications are the same 'size' as an AS level, but are intended to be taught over two years, in addition to other academic or vocational qualifications. They are aimed at students who achieve a grade C or better in GCSE, but who do not wish to follow an AS Mathematics course. They do have some 'currency' in HE as they carry UCAS points (A=60, B=50, C=40, D=30, E=20).

Six core mathematics qualifications are available from the awarding bodies and their titles give indication of their focus, i.e. Level 3 certificate: in using and applying mathematics, in quantitative problem solving, in quantitative reasoning, in mathematics in context, in mathematical studies and in mathematics for work and life.

Core Mathematics qualifications should consolidate and build on students' mathematical understanding and develop further mathematical understanding and skills in the application of mathematics to authentic problems, thereby offering progression from GCSE mathematics. At least 20% of their content must be beyond higher tier GCSE Mathematics and they should provide a sound basis for the mathematical demands that students will face at university and within employment across a broad range of academic, professional and technical fields.

A levels

The number of entries for AS/A level Mathematics and Further Mathematics has been rising considerably over the last decade. Figures for UK entries from the Joint Council for Qualifications can be seen below:

	2003	2005	2007	2009	2011	2013	2015
AS level Maths	63841	68178	77387	103335	141392	150787	165311
A level Maths	50602	52897	60093	72475	82995	88060	92711
AS level Further Maths	3371	5054	7426	13165	18555	22601	27034
A level Further Maths	5315	5933	7872	10473	12287	13821	14993

Note. Only 'odd' years have been included due to space limitations and also note that AS entries are large due to the technical requirement to 're-certificate'.

Very large increases in AS/A level Mathematics between 2003 and 2015 were seen, but in percentage terms the changes in AS/A level Further Mathematics are even more impressive. In 2014 the milestone that Mathematics overtook English as the subject with most A level student entries occurred and remained the same for 2015.

A wholesale reform of AS/A levels is currently being implemented, this involves a transforming the qualifications from being modular (as they have been since 2000) to being linear. Some subjects, like English and the sciences are available for first teaching from September 2015, but others, including Mathematics and Further Mathematics, will be first taught from September 2017. Therefore, students entering HE in Autumn 2019 will be the first through the new mathematics A levels (and will also be the same students who went through the new GCSE mathematics curriculum).

The subjects will be graded the same (A-E for AS level, A*-E for A level). However, not least due to the requirement of being a linear course, the AS level will be 'de-coupled' from the A level. This has particular ramifications for Mathematics and Further Mathematics, which used to allow great flexibility in the use of numerous modules that made up the qualifications.

The content has been chosen by The A level Content Advisory Board (ALCAB) and is fixed for A levels in Mathematics. It contains some pure, some mechanics and some statistics, but no decision mathematics. Students have no choice within the qualification. This does mean that HE will now be able to have a firm understanding of just what a student entering with the qualification will have studied; up to now only two-thirds of the content has been common to all A levels in mathematics.

In respect of Further Mathematics – 50% of the course has fixed pure content. For the remaining 50% exam boards may offer a range of optional components; these could be more pure, more mechanics and/or statistics, or other applications.

There is an increased emphasis on problem solving, modelling, reasoning and proof, and the use of technology is encouraged. There is also a new approach to statistics in A level mathematics with a large data set to be explored during the course, using technology. The emphasis is on interpreting data rather than on performing calculations or drawing diagrams and the Normal distribution and some hypothesis tests are included in A level mathematics. However, unlike the GCSE mathematics curriculum change, the changes to A level mathematics are not meant to make the qualification harder.

At this time it is not possible to say what the MEI A level specification, administered by OCR, will contain. However, throughout its history, MEI has demonstrated a firm belief in the importance of technology in mathematics education, both for increasing students' understanding of mathematics and to prepare them for a world in which technology is used extensively for mathematical processing. Hence MEI want to provide suitable A levels for progression to HE in the 21st century, so will continue to offer an innovative curriculum. To support this there have been specific working groups on the different strands, which includes teachers, academics and those based in industry, working towards producing the new curriculum.

Impact of all the changes

In the coming years, predominately from 2019, students will be entering HE having studied a more challenging GCSE in mathematics and new AS/A levels in mathematics. The intention is that these students should be better equipped to deal with the mathematical requirements of the numerous STEM and STEM-related HE courses. However, there are several issues that cause concern, which could potentially affect the number of students entering HE with such qualifications, these include:

- Where will the additional mathematics teachers come from for GCSE resit and Core Mathematics?
- To what extent will CPD be needed for teachers as mechanics is now compulsory and there is a new approach to statistics?

- The effect of linear qualifications, with AS levels decoupled – mathematics has flourished under the 'try a bit, succeed at it, now try some more' approach possible with a modular system. Committing to a 2 year course in A level Further Mathematics when you are 16 could be seen as risky.
- Students, particularly with grade B/C at GCSE, might be encouraged to take Core Mathematics, and struggling A level students might be encouraged to change to Core Mathematics, thus reducing AS/A level numbers.
- There will be considerable upheaval in the school system for several years, including in respect of funding – UCAS (2015) has already signalled concern that fewer students may study A levels.

If there is a good take-up of Core Mathematics qualifications, supported by HE including it in their entry requirements, then students should be better prepared for the quantitative demands of a range of HE courses. Similarly, a demand for Further Mathematics will continue if HE STEM departments include supportive comments, such as those seen at: **www.furthermaths.org.uk/maths_entry**

In summary, the education landscape doesn't stand still. Neither should it. The continual striving to produce enthusing, relevant, appropriate curricula is on-going. With the new qualifications students should be better prepared for future study and work; it must be hoped that the numbers studying the qualification remain buoyant through this period of substantial change.

References

DfE (2014) "Setting standards for new GCSEs in 2017". Accessed via http://www.gov.uk/government/news/setting-standards-for-new-gcses-in-2017 (10 September 2015)

Lee, Stephen, Browne, Richard, Dudzic, Stella and Stripp, Charlie (2010) "Understanding the UK mathematics curriculum pre-higher education - a guide for academic members of staff". Accessed via www.mei.org.uk/files/pdf/Pre_Uni_Maths_Guide.pdf (10 September 2015)

Lee, S & Dudzic, S (2014) Understanding the UK Mathematics Curriculum Pre-Higher Education – Where Are We Now?. MSOR Connections. DOI: 10.11120/msor.2014.00020

Ofsted (2013) Schools' use of early entry to GCSE examinations, Ofsted Report: 120198

UCAS (2015) "Unpacking Qualification Reform". Accessed via www.ucas.com/sites/default/files/ucas-unpacking-qualification-reform-jan-15.pdf (10 September 2015)

Engaging with Mathematics: How mathematical art, robotics and other activities are used to engage students with university mathematics and promote employability skills

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Abstract

There has been much discussion about what exactly employability skills are for mathematics students and how they can be embedded, promoted and developed in mathematics curricula. Mathematics graduates are highly employable and are valued for their reasoning skills, analytical and logical approaches to problem solving, and their abstract thinking. It is the more general employability skills that are more difficult to promote in a mathematics specific context within programmes.

When designing the BSc and MMath Mathematics programmes at Middlesex University the team considered how to develop and enhance employability skills whilst promoting and engaging students with all aspects of mathematics.

In this paper we will discuss the types of skills developed, the activities used to promote them, and reflect on the successes and challenges of the venture. Additionally we will discuss plans for future development and enhancement of the initiative.

Introduction

In 2013 Middlesex University identified a number of growth subject areas for programme development, mathematics was one of them. The mathematics team were given the opportunity to reintroduce specialist mathematics degrees including a BSc and MMath Mathematics.

It was felt that developing employability skills in the curriculum, as well as the theoretical and rigorous content of the programmes, was fundamentally important; and the team felt that these two should not be separate strands but rather intertwined in the learning and teaching strategy. A number of questions prompted the design:

- Will this degree promote development of the skills valued by employers?
- What makes mathematicians employable?
- How do students encounter mathematics and mathematical skills?
- How can we promote engagement with mathematics?

A number of successful approaches used to develop graduate skills in mathematics degrees are detailed in Waldock (2011a and 2011b) and Rowlett (2012) where a number of case studies are discussed that employ different techniques to develop particular skills. In Waldock (2011b) the range of activities was quite broad, but the perception by students of the importance of engaging in the activities was vital.

Whereas many specialist skills are developed by mathematics students as a natural consequence of their progress on their programmes, other more generic skills require embedding. Hibberd and Grove (2009) state that “employers have repeatedly said that they not only value graduates’ specialist skills but would also look for development of a range of generic skills, what might be called employability skills including amongst others written and oral communication, team working, and IT skills”. This embedding of skills is also encouraged in the mathematics, statistics and operational research subject benchmark, QAA (2007).

With this in mind the team felt that engagement with the discipline was vital. The skills should be developed and linked, where possible, to mathematics.

The approach to skills

The mathematics team at Middlesex University took a holistic approach, developing skills both within modules and within a series of programme seminars, activities and workshops called Engaging with Mathematics. This reflects the suggested questions and ideas for developers in Challis, Robinson, and Thomlinson (2009: p41), whether or not skills should be integrated in the mathematical content of the programmes, in a separate “skills module”, or as a combination of the two approaches.

The team felt that the aim was to get students to engage with all aspects of mathematics, going beyond mathematical tasks and techniques, to develop a range of skills valued by students and employers. Activities were designed and embedded within the specialist mathematics programmes that enable students to explore and experience mathematics in different forms as well as promoting the development of knowledge and skills. Some activities were embedded within modules promoting skill development alongside module content and some activities formed part of a broader programme-wide initiative.

The broader approach was the Engaging with Mathematics series. This included, amongst other events, a weekly timetabled workshop on mathematical problem solving, communication, engagement activities, and progress review and reflection activities. Further sessions included constructing a mathematical sculpture with students from outside the department and across the breadth of the student population, the mathematics and robots workshops, undergraduate seminars, problem solving sessions, communication sessions, and outreach activities.

In order to ensure the skills were developed in a mathematical context we asked ourselves what it meant to learn mathematics successfully. The discussion concerning the nature of mathematical learning and the structure of good mathematical problems by Borovik and Gardiner (2006) reflects this design in recognising that mathematics is cumulative and systematically learnt; it builds and integrates as it progresses. Furthermore, mathematics must be motivated; students need an emotional involvement with it in order to fully develop their ability. Understanding material is key and linking to real life is important. To keep students engaged, problems and activities must be challenging, accessible, developmental, revealing and extendable. These principles would influence the teaching philosophy of the programme and all activities in the Engaging with Mathematics initiative.

Identification of employability skills was an important aspect of the design and how these could be developed through activities. These included understanding patterns, being rigorous and logical, abstracting from real-world situations, clarity of thought and reasoning, problem solving, communicating results (in particular conveying to others one’s own mathematical thinking), demonstrating a critical approach (in particular criticising other people’s arguments), working as a team to solve a problem, and using computers effectively. This is not exhaustive but contains those activities linking to the general employability skills. Activities that promoted and developed these skills are discussed below.

Mathematical sculpture – Sword Dancing

The team secured funding for a research professor and mathematical sculptor, George Hart, to come to Middlesex for one week to work with staff and students. The Sword Dancing sculpture was one of the team's more ambitious activities. It brought together staff and students from across the University in a joint mathematical construction activity over two days. Together staff and students from a variety of disciplines built a sculpture comprising of two pieces that mirror each other, designed by George Hart, entitled Sword Dancing. Mathematics students worked with students from architecture, dance, education, engineering, drama, design, and music.

The construction workshop ran as if it was a large puzzle to be solved. Students from different disciplines worked in small teams initially to look at how three different component parts of the sculpture could be fitted together. They needed to work as a team to manipulate the components but also communicate why they felt that one particular orientation of components would successfully work and combine to form a larger component of the sculpture which had repeating elements within it.

The construction of the large mirrored elements of the sculpture took approximately eight hours spread over two days and students and staff felt a strong sense of achievement at the end of the activity. This was a very successful activity and it was noted by tutors that the level of engagement and confidence of students had increased.

Students were required to reflect on the success of the activity as part of the first year portfolio. One student commented that 'working with other students gave me an insight into how they tackle problems, where I tried to find the most logical answer the students working with me looked at how the pieces would go to together in a more artistic form. We combined these approaches to solve the problem'. Another commented that 'it broadened my horizons.' 'I chatted to people from other areas which led me to do additional reading which I really enjoyed and broadened my knowledge'

Zometool workshop – constructing 120-cell

Mathematics students and staff worked together to construct polyhedra and a three dimensional projection of the 120 Cell during a Zometool construction kit workshop facilitated by George Hart (see http://www.zometool.com). This developed confidence, communication skills and problem solving skills. This was the first building mathematics themed workshop undertaken by staff and students jointly and was more difficult than the team had originally thought. The students found it a challenge to view staff as peers in the activity and the staff found it challenging not to lead individual team activities.

A variant of this activity was undertaken with the new BSc Mathematics cohort who joined in October 2015. This required staff and students to build components for a canopy. The students commented on this in their week 4 reflective programme activity positively remarking that the most interesting learning experience so far was 'building the shapes to put together to make a canopy. I found the shapes really interesting. Mathematics is awesome!', and 'helping build the structures. It was interesting how it would all fit together.'

Robots and Mathematics

Sessions for motivation and engagement were key. Sessions like the mathematics and robots session extended material seen in the students' first year material on vectors and matrices. These required students to build on their existing knowledge and extend concepts and ideas. It developed understanding and application of theory and problem solving skills.

Problem solving

Almost all sessions in Engaging with Mathematics included a problem solving element. Sessions included mathematical puzzling, logic in the real world, and outreach mathematics. These were all in addition to the sessions already detailed. All had a problem solving approach and required students to work together on a variety of tasks and communicate their solutions and reasoning to others.

Communication

The communication strand involved some practical sessions on writing mathematics, developing mathematical arguments, typesetting mathematics in Word and PowerPoint, motivating mathematics, and a session on how to give technical presentations. These complemented activities such as discussions on Mathematics in the media and the seminar series.

Another very simple activity that was successful was the `fact of the week', a way for students to get to know each other and build confidence ready for in class presentations. All students were required to stand up in class, introduce themselves and then tell the others a fact for that week. Initially facts were about themselves and their backgrounds, but further into term students are required to identify something of a mathematical nature.

Students commented in their reflective activities that one of the most interesting learning experiences they had had so far was 'engaging with Mathematics, building structures and learning how to write Mathematics', and 'the facts about class mates in Data and Information'.

Outreach

We were keen to involve students in outreach to promote communication, team working and problem solving skills. Students took part in SmashFest2015, going out to schools and taking part in on-campus school visits.

Reflections on the first year of the initiative and conclusions

The initiatives have only run for one year but the feedback we have received has been very positive. The motivation and engagement of students has increased and the first cohort of the programme set up a Mathematics society. In its first year the society ran a giant Soma cube activity supported by the Mathematics team. This year the society has recruited 150 new members and they are running their own events independently.

Students are more confident in class and in their approach to mathematical activities. There was a notable change in student engagement after the Sword Dancing construction activity. All staff noted the difference in student engagement and skill level in sessions after this activity was completed.

After discussions with the students it was noted that the timing of the scheduled sessions was not helpful and this will be improved for the next run of the initiative. All students recognised that their skills had progressed in their portfolio assignment but felt that the way this was recorded and reflected upon should have been more systematic. This will also be improved in the next phase.

The team now face new challenges for the second run of the initiative:

- Should year 1 and year 2 students integrate on all activities or should there be dedicated sessions for both individual cohorts and a combination of both?
- How can the team ensure that students have a strong enough voice in the design of activities?

One challenge is to ensure that all activities have a sufficiently strong mathematical focus so that the connection between learning mathematics and the employability skill is maintained.

A targeted series of Mathematics careers and employment workshops at higher levels is clearly needed and it is vital that students are exposed to a variety of career mathematicians who will inspire and potentially mentor students in the job hunting process.

The team feel that the initiate has been beneficial to students and plan to evaluate the scheme more comprehensively at the end of its second year.

References

Borovik, A.V. and Gardiner, T. (2006) ‘Mathematical Abilities and Mathematical Skills’. Accessed via http://www.Mathematics.manchester.ac.uk/~avb/pdf/abilities2007.pdf (July 2006)

Challis, N., Robinson, M. and Thomlinson M. (2009) “‘Employability’ skills in mathematical courses”. MSOR Connections, Vol 9 (No. 3): 38-41

Hibberd, S. and Grove, M. (2009) ‘Developing graduate and employability skills within a mathematical sciences programme’. MSOR Connections, Vol 9 (No. 2): 33-39

Quality Assurance Agency for Higher Education (QAA). (2007) Subject benchmark statement: Mathematics, Statistics and Operational Research.

Rowlett, P. (2012) ‘Further Work Developing Graduate Skills in HE Mathematics Programmes’. Accessed via http://www.mathcentre.ac.uk/resources/uploaded/furthergradskills.pdf (June 2012)

Waldock, J. (2011a) ‘Developing Graduate Skills in HE Mathematics Programmes’. MSOR Connections, Vol 11 (No. 3): 16-19

Waldock, J. (2011b) ‘Developing Graduate Skills in HE Mathematics Programmes – Case studies of Successful Practice’. Accessed via http://www.mathcentre.ac.uk/resources/uploaded/gradskills.pdf (March 2011)

Re-pacing mathematics support to transcend the propensity for "cramming"

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Abstract

Mathematics support tends to be characterised as being a remedial measure, designed to address deficiencies in the mathematical knowledge required for degree courses across various disciplines, and often when coursework deadlines and examinations are imminent. Yet student feedback consistently manifests an enthusiasm for and interest in ameliorating mathematical competence, and a regret that such provision all too often becomes a matter of "cramming".

Whilst it is easy to blame students for neglecting mathematics, it is important that institutions take responsibility for positioning mathematics support more prominently in student life. Staff experience and student feedback all lend credence to the suggestion that mathematics support needs to be redistributed throughout the academic year.

A difficult dilemma is how to strike a balance between encouraging students to cultivate independent study skills and guiding students more closely. To address this, and to ensure that students ultimately grow some level of fluency in maths, careful consideration needs to be given to teaching methods, resources, and the structure of contact hours.

We will consider some of the various types of interaction between students and maths tutors at the University of East London. Drawing on our practical experience following a major expansion of the mathematics support provision at the University of East London in 2015, we reflect on the current state of affairs and what could be done to turn mathematics support from a reactive stop-gap to a more regular, proactive, and intellectually enriching journey that spans the entire academic year.

Background

In most walks of life, it is a common trend for people to delay the completion of tasks until shortly before a deadline. In student life, such procrastination can be manifested in hastily completed coursework submissions, but also in students concentrating their study and revision very close to the period in which terminal assessment takes place. It is possible for intensive revision close to the examination to be an effective means of reinforcing familiar skills and addressing known weaknesses; yet, too often, students discover that they have not got enough time to attain a level of mastery over the topics under assessment. It is in this sense of being ill prepared that this paper refers to the term "cramming".

When discussing "cramming" in the context of maths support, the period under consideration can seem quite lengthy. The reason for this is that a certain level of mathematical competence is often a prerequisite for many degree courses, and failure to address this early in the academic year renders it much harder to keep up with the academic demands specific to their discipline. This situation is exacerbated by the propensity of some students to be either unaware of their weaknesses or slow to confront them. In other words, a student is "cramming" as soon as the time remaining to acquire the full set of both the prerequisite mathematical skills and the understanding of course-specific material becomes insufficient.

In considering how to structure support, it is very important to determine how to better use available resources, both in the form of the time and capacity of the available tutors and material resources. Research has shown that simply throwing a lot of resources at students indiscriminately can sometimes even be detrimental: for example, academics at one New Zealand institution discovered that making recordings of lectures available in the library not only resulted in lower lecture attendance, but also failed to elicit high takeup (in a cohort of 746 students, only 94 signed up to access the recorded lectures, and no more than 13 of them ended up actually accessing them) — the researchers described this as the 'local traveller' syndrome, or the idea that, since the material is readily available, students put off actually accessing it, and in many cases never get round to it (Bell et al. 2001, pp.120–121). A similar problem was also observed in a UK institution by Inglis et al. 2011, which found that, when presented with a variety of learning styles, over a third of students (185 out of 534) failed to make substantial use of any of them, and the rest tended to specialise, with each learning style attracting a 'cluster' of prolific users who tended to make far less use of other styles, a phenomenon which led them to conclude that 'blended teaching' is a more apposite term than 'blended learning'.

Our experience at the University of East London (UEL)

During 2015, the University of East London (UEL) embarked on a major expansion of its academic support provision: since February 2015, there have been four part-time maths tutors across two campuses.

Our front-line role as tutors is to offer mathematical support to undergraduates and postgraduates through weekly drop-in sessions, one-to-one appointments, small-group sessions, and workshops. Alongside academic writing support, our team operates under the auspices of the Skillzone (part of the Library and Learning Services), which students from all Schools of the University are eligible to access. We have seen students individually and in groups on topics ranging from basic functional skills to advanced statistical methods.

Sometimes, the purpose is to assist students in understanding a sophisticated facet of their academic studies that relies on mathematical modelling or calculation; at other times, the purpose becomes more instrumental, pertaining to examination preparation. Our capacity to improve student performance was frequently constrained by a lack of time between appointments and the pertinent examinations. Below, we present evidence of the extent to which students at UEL deployed "cramming" as manifested in the timing of appointments.

Data analysis of appointments across the schools

For the purposes of our data analysis, both drop-in visits and appointments booked in advance are hereinafter described as 'appointments'. Our data cover appointments in the 2014–2015 academic year. Until 20/01/2015, there was only one maths support tutor. Thereafter, appointments could be made with any of the four tutors during term-time, and for most of the period between the end of term and resits (June to August, hereafter known as the 'resit period'), at least one tutor was available.

Our data, compiled manually after each appointment, show that 45% of all the appointments took place between March and May, and another 22% during the resit period. Figure 1 brings this concentration into stark relief: for example, in the period 16-31/03/2015, there were three times as many appointments as there were in the period 1-15/02/2015 Determining which periods may be defined as "cramming" may be a somewhat subjective exercise, although it is arguable that a concentration of 67% of appointments in the period from March (most examinations take place in May, and resits in August) manifests extensive "cramming".

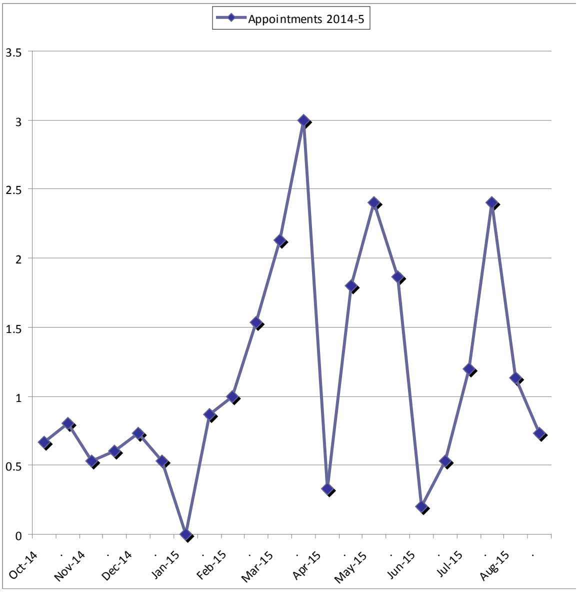

Figure 1: Appointments Oct 2014 to Aug 2015 (1 unit = appointments in February 2015).

Having said that, there is potential for severe bias on account of the increase in human resources and publicity which started to take effect from late-January 2015. Nevertheless, when looking at individual modules where the support service had the same degree of intervention throughout the year, the same intensity of cramming is observed. Specifically, we scrutinised the data of two engineering modules: in module A, 11 students made 32 appointments; and in module B, 19 students made 52 appointments.

For module A (see Figure 2), diagnostic testing had taken place at the start of term, and 64% of the 11 students who used the service had made their first appointment at the start of term, compared with 16% of the 19 students on module B (see Figure 3), in which diagnostic testing had not taken place. However, module A was not without “cramming” across the board: only 31% of the 32 total appointments occurred at the start of term, suggesting that “cramming” was not limited to the 36% of students who used the service, but had waited until after the start of term to make their first appointment. For module B), meanwhile, the 52 appointments were even more concentrated towards the end of the academic year, with 52% of them in the resit period, compared with only 9% in the same period for module A.

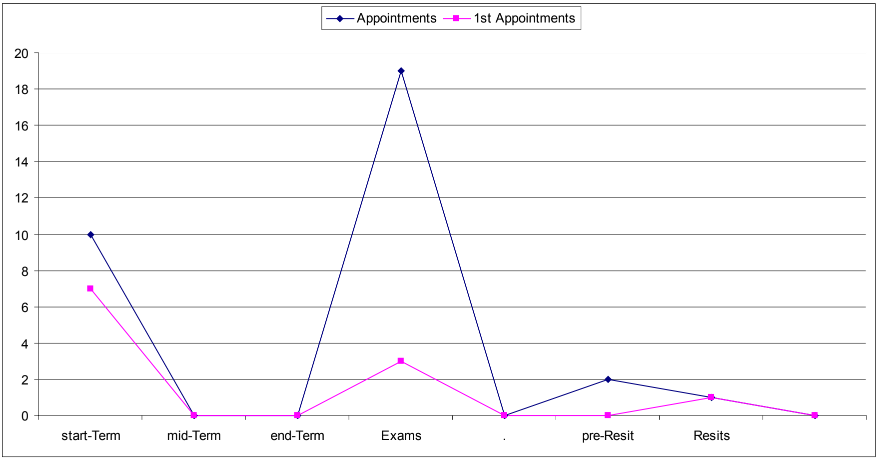

Figure 2: Total appointments and first appointments made by students studying Module A.

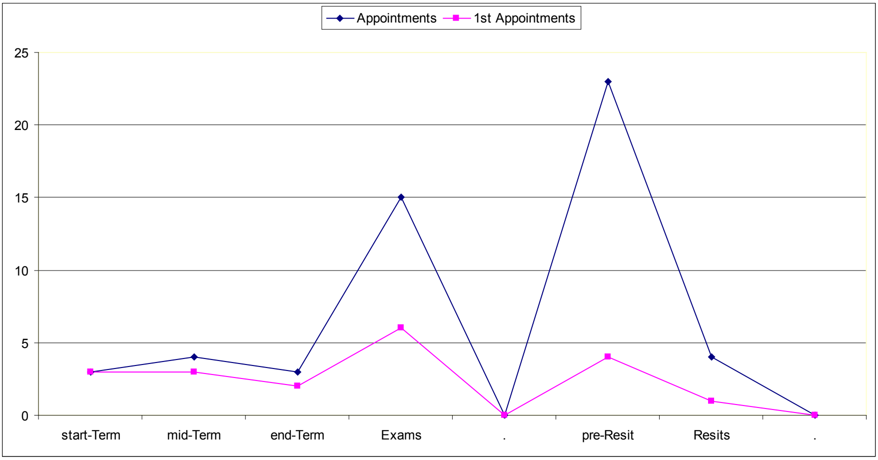

Figure 3: Total appointments and first appointments made by students studying Module B.

This comparison manifests the value of diagnostic testing in helping students take maths seriously from the outset. However, it is limited to those students who have actually attended one or more appointments, and does not consider the 'silent majority' of students who are still not being reached.

Reaching more students by embedding workshops

In some institutions, the calibre of students may be such that this 'silent majority' would not be a concern; however, at UEL, it is evident that a great many students manifestly lack adequate mathematical competence. For example, in one particular examination which formed part of a Basic ICT and Maths module for Foundation degree students, almost half of the cohort (61 out of 123) who sat the examination were required to resit.

More alarmingly, as shown in Table 1, of the 61 students required to resit, only 19 eventually passed, 16 failed again, and 26 did not attend for the resit.

In preparation for the resits, over the period of a month, 7 students attended 23 appointments, and 5 of them passed. In contrast, of the 29 students who attended for the resit but did not attend any appointments, only 14 passed.

	Pass	Fail	Absent	**TOTAL**
One or more Skillzone (maths) appointment(s) attended	5	1	1	**7**
No appointments(s) made/attended	14	15	25	**54**
TOTAL	**19**	**16**	**26**	**61**

Table 1: Post-resit outcomes for 61 students required to resit one or both of the mathematics examinations in a Basic ICT and Maths module.

The connection between attending one or more Skillzone appointments and resit performance is supported by a chi-squared test at 95% significance (n=2, c2=6.039, critical value at p=0.05 is 5.991).

Moreover, a statistical analysis of the scores obtained in the resit shows that appointments with maths support staff not only helped people ‘get over the line’, but also had a bearing on how high a pass was achieved. Although resit students have their scores capped, it is pertinent to note this, since it may elucidate how to help students do well the first time. When considering exclusively the 19 students who passed the resit, we found that the mean score achieved by the five students who attended one or more Skillzone appointments was 12.49 percentage points higher than the 14 students who did not (see Table 2). A one-tailed t-test at 99% significance (n=17, t=2.626, critical value at p=0.01 is 2.567) supports the view that this is statistically significant.

	N	Mean	Standard deviation
One or more Skillzone (maths) appointment(s) attended	5	57.20	8.52
No appointments(s) made/attended	14	44.71	10.65

Table 2: Comparing the performance of: students who passed and attended one or more Skillzone (maths); and students who passed but did not make/attend any Skillzone (maths) appointments.

This suggests drop-in support alone to be insufficient in reaching students, so the Skillzone also runs a series of workshops at both campuses on a weekly basis, on topics advertised in advance on the University website. For these, we prepare a presentation with worked examples and handouts, whilst leaving scope to deviate from the script, in order to address questions from the students.

Over the two terms we have been delivering these workshops, attendance has tended to be very low (despite various initiatives to publicise what we offer), yet student feedback has been uniformly positive. In fact, a common theme from this feedback has been a desire for more workshops and more opportunities to practise mathematics questions during contact-hours. One reason for the poor attendance may be that the workshops are under the auspices of the Skillzone, as opposed to a particular academic department or course, the result being that, even if highly useful and relevant for those who do attend, they are perceived to be essentially extra-curricular.

This conjecture is supported by our contrasting experience of running compulsory Numerical Reasoning workshops for a second-year undergraduate Employability module in the School of Health, Sport, and Biosciences. We saw a total of 111 students (split across four groups) for a series of timetabled sessions which pertained directly to a particular outcome common to all of them, an end-of-year Numerical reasoning test designed to resemble the sort of induction testing they may encounter in applications for types of NHS jobs relevant to their studies. Despite the differences between this module and the Skillzone workshops, the student feedback was remarkably similar: again, there seemed to be a desire for more sessions, and more time to practise questions.

Of course, we should exercise some circumspection when analysing student feedback, since augmenting contact time is not necessarily a ‘silver bullet’. However, we cannot use this as a blanket excuse for ignoring such feedback, especially when it is evident that many students would benefit from more guidance to help them bring their mathematical skills to a level commensurate with the requirements of their courses. Although the performance data for the Employability module comprise an aggregate of Numerical and Verbal reasoning tests, the context is instructive: the sessions were arranged as a result of a mid-year mock examination, which the majority had failed. In the real assessment, three months later, almost three-quarters of students passed, and the mean overall mark increased by 15 percentage-points (see Table 3).

	Number of students who passed	Mean overall mark
Mid-year mock assessment	32 (28.9% of cohort)	26%
End-of-year real assessment	81 (73.0% of cohort)	41%

Table 3: Comparing performance in an Employability module in a mid-year mock assessment and an end-of-year real assessment

Conclusions

A common theme from the case studies we have discussed is the importance of diagnostic testing as a tool to monitor student progress. Research from a number of sources has shown that diagnostic tests encourage students to confront issues early (Mireles et al. 2011, p. 40), and furnish staff with a formal infrastructure for identifying so-called ‘at-risk’ students (Matthews et al. 2012, p.19), instead of relying upon self-referrals. Moreover, in the case study conducted by Inglis et al., standardised diagnostic test scores were found to be, after lecture attendance, the most reliable indicator of future examination performance, with a p-value under 0.001 (Inglis et al. 2011, p. 497). Tempting though it may be to place the onus wholly on students, we should not lose sight of the fact that learning how to study effectively lies at the crux of Higher Education; indeed, as has been pointed out by Inglis et al., we have a responsibility to instil and develop students’ “general study skills”, a view reiterated by the Quality Assurance Agency (Inglis et al. 2011, p. 500).

One means is through the course structure: Goldschmid and Goldschmid 1974, suggesting that grades were one of the most powerful incentives for undergraduates, advocated for spreading assessments and coursework deadlines across the year, so that students can clearly see the connection between individual assignments and the final grade, something sufficiently important as to take precedence over their concerns that “Such deadlines unfortunately set limits to the self-pacing of the individual students” (Goldschmid and Goldschmid 1974, p.12). However, as a support service, it is not within our scope to rewrite course syllabi, so our priority is to have a systematic means of monitoring progress, something which can be achieved through regular scheduled tests — starting with a diagnostic test at the beginning of the academic year — that do not have a bearing on official assessment.

Indeed, for a small group of our mature students enrolling this academic year, we ran, in collaboration with the Information, Advice and Guidance Centre, a short course in July to refresh their mathematical skills in advance of enrolment. Although it is too early to tell what impact this will have on retention and academic performance, the course was positively received —Mireles and Ward have suggested that, whilst such courses do not guarantee a permanent improvement in results, they are effective in improving preparedness for the demands of undergraduate study (Mireles and Ward 2011, p.19).

Beyond formal staff support, we have also sought to facilitate informal peer support, through the opening, in March 2015, of Maths Space, an open-plan physical location in the library of the Docklands Campus where students can work individually or collaboratively on mathematical content, in close proximity to the Docklands-based tutors — we hope that this ‘arms-length’ provision, which has proven effective in other institutions, will increase the motivation of students to cultivate independent study skills (Croft et al. 2008, pp.13–16). Meanwhile, the library of the Stratford campus offers a quieter environment with greater privacy for the weekly drop-in sessions in a designated room in the library. This is important because anecdotal evidence suggests that there remains a stigma surrounding the accessing of support amongst some undergraduates.

Whilst drop-in appointments are undoubtedly valuable to the students who avail themselves of them, we should not drift towards allowing a drop-in service to become a substitute for a comprehensive programme of timetabled lectures and class tutorials which can provide early engagement and thereby, to some extent, reduce dependence on cramming with all its pitfalls.

In the coming year, we will have the opportunity to evaluate the impact of integrating provision directly into courses. We will be implementing diagnostic tests as part of the induction programme, followed by pro-active work with students whose scores suggest that they are in need of support. Meanwhile, plans are also underway to integrate mathematics support into the official teaching schedule for several undergraduate modules in the School of Health, Sport, and Biosciences.

Ultimately, it is important that we, in conjunction with academic departments, respond to the tendency for “cramming” and tackle it with a more holistic approach, distributing maths support throughout the year, carefully deploying different forms of intervention as the situation demands.

References

Bell, T., Cockburn, A., McKenzie, B., and Vargo, J. (2001) “Flexible delivery damaging to learning? Lesson from the Canterbury Digital Lectures Project”. In ED–MEDIA 2001: World Conference on Educational Multimedia, Hypermedia and Telecommunications. pp 117–122.

Croft, T., Grove, M., and Bright, D. (2008) “A resource and activity centre for mathematics students beyond their transition to higher education”. MSOR Connections, Vol. 8 (№1):11–16.

Goldschmid, B., and Goldschmid, M.L. (1974) “Individualizing Instruction in Higher Education: A Review”. Higher Education, Vol. 3 (№1):1–24.

Inglis, M., Palipana, A., Trenholm, S., and Ward, J. (2011) “Individual differences in students’ use of optional learning resources”. Journal of Computer Assisted Learning, Vol. 27 (№6): 490–502.

Matthews, J., Croft, T., Lawson, D., and Waller, D. (2012) Evaluation of mathematics support centres: a review of the literature. The National HE Stem Programme.

Mireles, S.V., Offer, J., Ward, D.P., and Dochen, C.W. (2011) “Incorporating Study Strategies in Developmental Mathematics/College Algebra”. Journal of Developmental Education, Vol. 34 (№3):12–19; 40–41.

Identifying problematic mathematical topics and concepts for first year students

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Abstract

There is ample evidence to support the fact that students transitioning from post-primary to mathematics in higher education struggle with the requirement for an increased level of independent thinking and a move away from rote learning. As a result we are undertaking a large-scale project focussed on the development of interactive formative assessment techniques that aim to improve the teaching and learning experience of first year undergraduate mathematics modules.

As a first step, in order to identify the mathematical topics and concepts that are problematic for first year undergraduate students two surveys were developed, distributed and analysed: one aimed at students and another at lecturers.

Overall, students reported little difficulty with many of the mathematical topics and concepts presented in the survey. Further analysis revealed that students who completed Ordinary Level Mathematics in their final year at post-primary perceived that they had greater difficulty than those of their peers who took the Higher Level course. There was a marked contrast between the concepts identified by the lecturers and the students. Lecturers reported that many students struggle with basic arithmetic and algebra whereas students identify calculus as the main problem.

Background

It has been recognised that the transition from post-primary to higher education mathematics is problematic for many students. Evidence has shown that students grapple with first year mathematics, in particular the transition from rote learning to independent thinking. Gill and O'Donoghue (2007) investigated this well-known 'Mathematics problem' in an Irish context and it has been well documented in the UK and elsewhere (Lawson et al., 2012; OECD, 2004).

The National Forum for the Enhancement of Teaching and Learning in Higher Education in Ireland selected 'Teaching for Transitions' as their first enhancement theme. They identified the 'need to integrate approaches to building digital capacity across the sector' as one of the principles of their roadmap for enhancement in a digital world. (National Forum, 2015). In line with these policies they funded this project as one of their Teaching and Learning Enhancement Projects and it concerns the development of digital formative assessment techniques to improve the teaching and learning experience of first year undergraduate mathematics modules.

Black and William (1998) defined formative assessment as 'encompassing all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged' (p7-8).

This formative assessment steers students to learn, enables teachers to make informed teaching strategies and motivates students. ‘This is assessment for learning.’ (Bloxham, 2008 p. 14). Schoenfield (2015) defines formative assessments as ‘examinations or performance opportunities the primary purpose of which is to provide student and teachers feedback about the student’s current state, while there are still opportunities for student improvement’. In this project we aim to identify mathematical topics and concepts that are problematic for first year undergraduate students in Higher Education Institutes (HEIs) in Ireland, and to use this information in the development of formative assessment techniques and resources consisting of online activities and interactive tasks to improve student understanding of the topics identified. We will evaluate the effectiveness of these resources before developing a shared digital platform for all the HEIs in Ireland.

This paper reports on the process of identifying the problematic mathematical topics and concepts identified by students and lecturers.

Methodology

There are five HEIs in Ireland involved in this project; Athlone Institute of Technology (AIT), Dublin City University (DCU), Dundalk Institute of Technology (DKIT); Maynooth University (MU) and St. Patrick’s College Drumcondra (SPD).

In order to identify the problematic concepts, two surveys were developed: one aimed at students and another at lecturers. A total of 460 students, attending mathematics modules in four of the HEIs involved in the project, completed the student survey in the spring of 2015. Most of the students were just finishing their first year in higher education. A small number (circa 20) were at the end of their second year.

Data was gathered using 23 Likert item questions followed by 7 open-ended questions (n= 460). The Likert items concerned mathematical topics from the typical first year undergraduate curriculum such as using the laws of logarithms to simplify expressions (Question 5) and finding and graphing the tangent to a curve (Question 15). An example sheet with worked examples of each type of question was given to the students to remind them of the ideas and skills involved in each question. Students were asked to rate their ability to (a) understand the ideas involved and (b) do the questions, using a 5-point Likert scale; strongly agree, agree, neutral, disagree, and strongly disagree. The open questions asked which topics caused the students most difficulty, what types of resources they currently use and what new resources they would like to be made available. There were 5 questions at the beginning of the survey asking students about their background; institute, course, gender, mature student and Leaving Certificate mathematics level taken. Appendix A contains a copy of the Likert item questions contained in the survey handed out to students.

All of the Likert survey data was entered into Excel and analysis of this data was performed using charts and chi-squared tests. The responses to the open-ended questions were imported to Nvivo where coding was completed.

The second survey was carried out to ascertain the main concepts, procedures and tasks that mathematics lecturers identify as being problematic, the types of resources that are already in use in relation to these topics and how they are disseminated. Data was gathered using a Google form that was shared amongst the HEIs in Ireland. 33 responses were received from mathematics lecturers in 15, out of a total of 21, HEIs in Ireland (n=33). All data was input into Nvivo for coding. Appendix B contains a copy of the questions asked.

These questions were selected and discussed by members of the project group who teach first year undergraduate mathematics.

Student Survey Results

Table 1 shows the breakdown of the students' backgrounds captured as part of the surveys.

Category	Gender	Mature	Leaving Cert Mathematics
Males	293 (65%)		
Females	160 (35%)		
Non Mature		368 (84%)	
Mature		69 (16%)	
Higher			282 (64%)
Ordinary			142 (32%)
Foundation			5 (1%)
Did not take			15 (3%)
Total number of responses	**453**	**437**	**444**

Table 1: Student background data.

The category of most interest is the mathematics level completed by students in their Leaving Certificate. This is the terminal post-primary state examination in Ireland. Students can opt for three different levels in this examination; Higher, Ordinary and Foundation Level. Entry requirements in mathematics for higher education depend both on the institute and the student's course of choice. In this paper we will examine any difference between responses from students who had completed Higher Level mathematics and those who completed Ordinary Level mathematics.

When we considered the responses to the Likert scale questions we noticed that the majority of students' answers were in the strongly agree (44%) and agree (33%) categories, with 15% of responses being neutral, and only 7% in the disagree category and 1% in the strongly disagree category. It seems that the vast majority of students do not encounter problems with this material or do not perceive that they have problems with the mathematics question types presented in the survey or perhaps are unwilling to rate their own ability poorly.

Figures 1 and 2 show the percentage of student responses, per Likert scale, for each of the questions. Figure 1 shows responses from students who took Ordinary Level mathematics, while Figure 2 shows Higher Level.

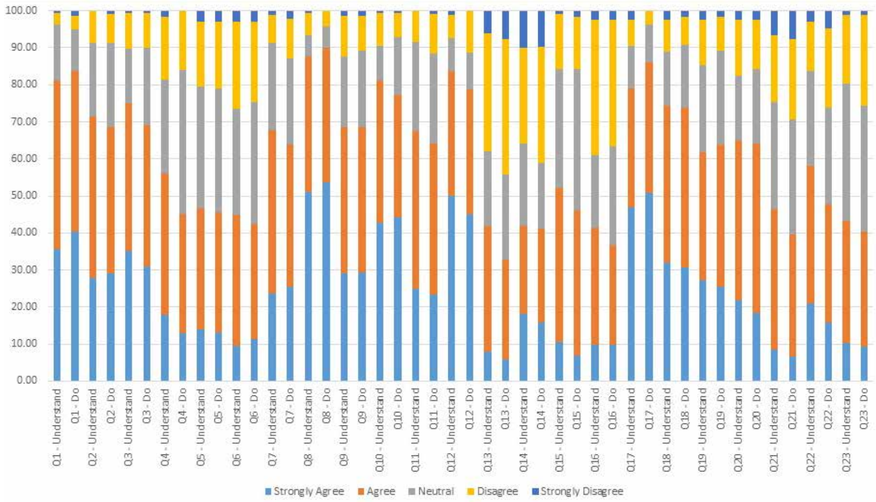

Figure 1: Survey Responses for students who took Ordinary Level Mathematics at Leaving Certificate. The % of student responses, per Likert scale, is shown for each of the 23 question types. The % for Understand and Do, for each question, are displayed in separate columns.

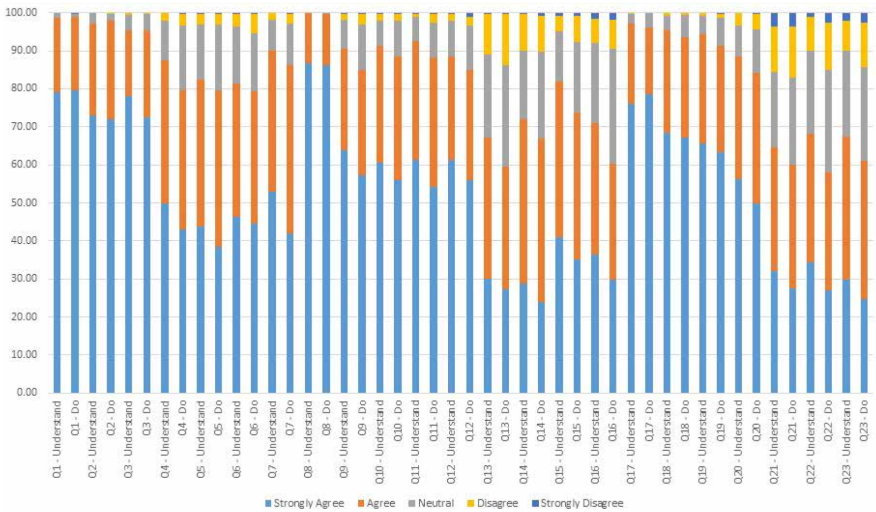

Figure 2: Survey Responses for students who took Higher Level Mathematics at Leaving Certificate The % of student responses, per Likert scale, is shown for each of the 23 question types. The % for Understand and Do, for each question, are displayed in separate columns.

Looking at the data in Figure 1, the question types that Ordinary Level students may perceive they have difficulties with are:

- Q4: Powers – using laws of indices
- Q5: Logs – using the laws of logarithms to simplify expressions
- Q6: Using the connections between logs and exponents
- Q14: Finding limits of functions using rules of limits
- Q16: Deciding whether a function is continuous or not
- Q21: Finding stationary points
- Q22: Optimisation (max/min) problem
- Q23: Graph sketching using derivatives

For each of the above question almost 20% or more of Ordinary Level students who responded to the question either disagreed or strongly disagreed that they could (a) understand and (b) do the question types. There were no question types where more than 20% of students who had taken Higher Level Mathematics responded in this way.

A chi-squared test, comparing Higher Level and Ordinary Level overall response rates per scale, showed a statistically significant difference between the responses from students who took Higher Level and those who took Ordinary Level ($p=0.004$). Note that the 5-point scale was reduced to 3 (agreement, neutral, disagreement) to ensure no item had less than 5 responses for this test. Thus students who had taken Ordinary Level mathematics at post-primary are more likely to perceive that they have difficulty with powers, logs, limits, functions and calculus than those who took Higher Level.

There were 414 student responses to the open-ended question asking students about the topics that caused most difficulty. Clearly students recognise that they have some difficulties, but as indicated above may not be willing to admit this. The responses to the open questions were coded according to the most reported topics and are shown in Figure 3 below.

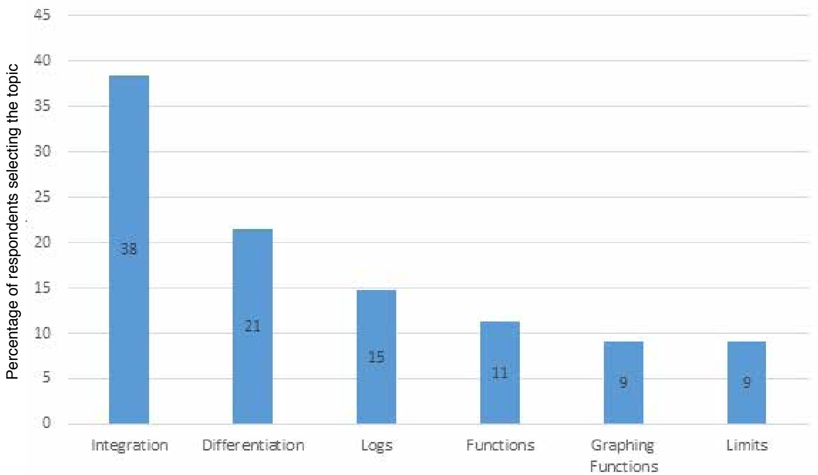

Figure 3: Percentage of responding students identifying these topics (students may have mentioned more than one topic). The % of responding students who identified the problem topics of integration, differentiation, logs, functions, graphing functions and limits in response to the open question on topics causing difficulty.

These topics are displayed in decreasing order of frequency reported; 159 students reported problems with integration, 89 with differentiation, 61 with logs, 47 with functions, 38 with graphing functions, 37 with limits. These are shown as a percentage of the overall number of students responding to the particular question (414). Some students mentioned more than one topic in their response to this question.

In the comments section many of the students referred to problems with topics they had not covered prior to attending higher level education:

'Optimization and graphing functions. It was one of the topics that was least covered in secondary school, therefore coming into university, studying maths at a higher level was a bit difficult to grasp. The formulas and when to use the right ones was the difficulty.' (Student 31)

The idea of selecting the right formula/method came up a few times:

'Graphing functions and interpreting data from graphs; unsure of what methods to use. Any topics not covered in leaving cert maths' (Student 135)

Lecturer survey results

Figure 4 shows the results of the coding.

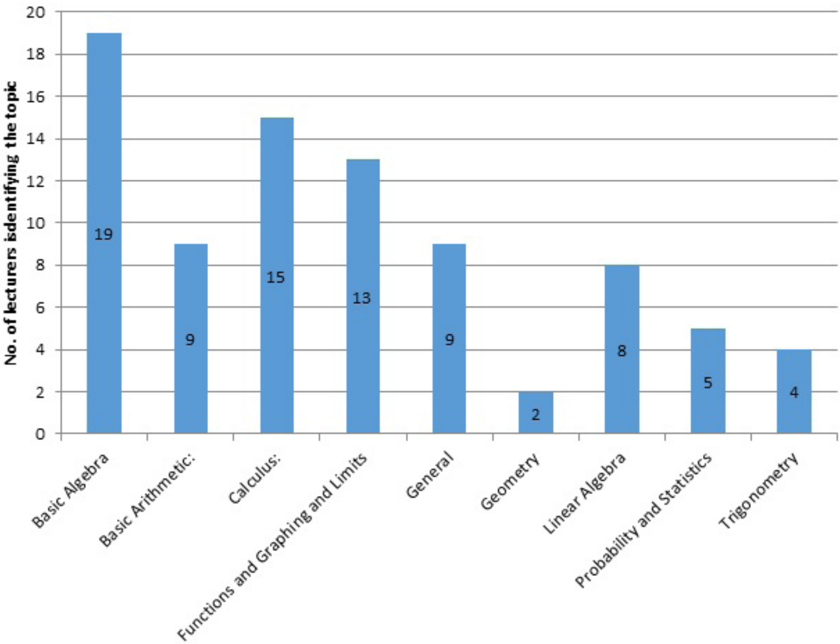

Figure 4: The number of lecturers who identified the displayed categories as problematic. Lecturers mentioned more than one topic.

19 lecturers reported that students have problems in basic algebra; this is the biggest concern for lecturers. This is in contrast to the reporting from students where Calculus is the most reported problem (see Figure 1 and 3).

In order to compare the lecturer and student open-ended data, the student data was recoded in Nvivo using the lecturers' codes. For example, of the 19 lecturers who reported problems in basic algebra, 13 (42%) specifically mentioned logs, indices, exponents or powers in their response. In stark contrast, only 74 from the 414 (18%) of students responding to the corresponding open question contained referred to either logs, indices, exponents or powers.

In relation to logs, one of the lecturers reported:

'Logarithms - general understanding and how to use rules to solve equations; application to experimental laws' (lecturer 8)

And a student who recognised the importance of understanding indices:

'Mostly ideas of topic confuse me most. Most difficult was algebraic manipulation of rules of indices. Without knowing these it was hard to do a lot of the maths' (Student 30)

Conclusions and way forward

In our survey, most students highly rated their ability to understand and do a variety of Firstt year undergraduate mathematics question types. There was a significant difference between the ratings provided by students who took Ordinary Level mathematics at Leaving Certificate and those who completed the Higher Level. 20% of students who completed Ordinary Level rate themselves poorly in powers, logs, functions and some aspects of calculus. This is in line with Breen et al. (2009), who noted that students who take Ordinary Level mathematics display lower levels of confidence than those who take Higher Level. In addition, Faulkner et al. (2014) have shown that students entering higher education with Ordinary Level mathematics perform less well than Higher Level students in the mathematics diagnostic tests. In Australia, Rylands et al. (2009) found that a student's mathematical level in secondary school is a good indicator of preparedness for third level mathematics.

We were surprised that the students did not report having problems with many of the topics listed in the Likert questions, however the lecturer data shows that lecturers across the country are seeing students struggle with basic mathematical skills as well as higher order concepts.

It may be that students having problems with differentiation etc. are actually having problems with the basic concepts, such as rearranging a formula, rather than differentiation itself.

Students and lecturers were also asked about resources they find useful and how they would like to see them delivered. The results of this data are not reported here but have been used to help shape the proposed delivery of the resources.

Now that we have identified the main concepts and topics and the preferred delivery mechanism we plan to develop online activities and tasks to promote understanding of these concepts, and evaluate the effectiveness of these resources.

References

Black, P., and William, D. (1998b) Inside the black box: Raising standards through classroom assessment. Granada Learning

Bloxham, S. (2008) Assessment in teacher education: stakeholder conflict and its resolution. Practitioner Research in Higher Education, Vol. 2 (No. 1):13 -21.

Breen, S., Cleary, J. and O'Shea, A. (2009) An investigation of the mathematical literacy of first year third-level students in the Republic of Ireland. International Journal of Mathematical Education in Science and Technology, Vol. 40 (No. 2):229-246.

Faulkner, F., Hannigan, A. and Fitzmaurice, O. (2014) The role of prior mathematical experience in predicting mathematics performance in higher education. International Journal of Mathematical Education in Science and Technology, Vol. 45 (No. 5):648-667.

Gill, O. and O'Donoghue, J. (2007) "Justifying the existence of Mathematics learning support: Measuring the effectiveness of a mathematics learning centre." In J. O'Donoghue and T. Maguire, eds. The Changing Face of Adults Mathematics Education: Learning from the Past, Planning for the Future. Proceedings of the Adults Learning Mathematics (ALM) 14th annual international conference (pp 146-153).

Lawson D., Croft, T. and Waller, D. (2012) "Mathematics support past, present and future." Innovation, Practice and Research in Engineering Education. Accessed via http://www.academia.edu/2715773/Mathematics_support_past_present_and_future (01 September 2015)

National Forum for the Enhancement of Teaching & Learning in Higher Education (2015). A ROADMAP FOR ENHANCEMENT IN A DIGITAL WORLD 2015-2017 Accessed via http://www.teachingandlearning.ie/wp-content/uploads/2015/03/Digital-Roadmap-web.pdf (01 September 2015)

Organisation for Economic Co-operation and Development (OECD) (2004). Learning for Tomorrow's World – First Results from PISA 2003. Paris, OECD

Rylands, L. and Coady, C. (2009) Performance of students with weak mathematics in first-year mathematics and science. International Journal of Mathematical Education in Science and Technology, Vol. 40 (No. 6):741-753.

Schoenfeld, A.H. (2015). Summative and formative assessments in mathematics supporting the goals of the common core standards. Theory into Practice, Vol. 54 (No 3).

Appendix A: Student survey questions

List of the 23 question types students were asked to rate

- Q1: Systems of Linear Equations 2 variables
- Q2: Systems of Linear Equations 3 variables
- Q3: Rearranging Formula
- Q4: Powers – using laws of indices
- Q5: Logs – using the laws of logarithms to simplify expressions
- Q6: Using the connections between logs and exponents
- Q7: Solving inequalities
- Q8: Solving quadratic equations
- Q9: Graphing basic functions
- Q10: Interpreting graphs of basic functions
- Q11: Algebraic fractions

- Q12: Dealing with percentage change
- Q13: Finding limits of functions using graphs
- Q14: Finding limits of functions using rules of limits
- Q15: Finding and graphing the tangent to the curve
- Q16: Deciding whether a function is continuous or not
- Q17: Basic Differentiation
- Q18: Differentiation: the product rule
- Q19: Differentiation: the quotient rule
- Q20: Differentiation: the chain rule
- Q21: Finding stationary points
- Q22: Optimisation (max/min) problems
- Q23: Graph sketching using derivatives

Question 14 format and an example of this question type

14) Finding limits of functions using rules of limits

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I understand the ideas in questions like this.					
I am able to do questions like this.					

14. Finding limits of functions using rules of limits

Example: Use the rules of limits to evaluate

$$\lim_{x \to 2} \frac{3x^2 - 4x + 9}{x + 5}.$$

Figure 5: Question example on Finding Limits and Rules of Limits

Example questions were given to the students as part of the survey to enable them identify the questions types.

Open Questions

1. What topics in first year mathematics caused you most difficulty? (Feel free to include topics that are not on the list above.) Please indicate whether it was the methods or the ideas involved that made the topic difficult for you
2. What topics in first year mathematics did you find most easy?
3. Please list any resources that you have found helpful for dealing with first year mathematics topics.

(Please give as much detail (e.g. web address) as possible.)

Books:____

Handouts: ____

Videos: ____

Websites: ____

Other (please specify): ____

If possible, please indicate why the resources listed above were useful.

4. Are there any gaps in the resources available? Please explain.

5. Have you any advice on the resources you would like us to develop?

6. How should these resources be made available?

Print-based:

Videos:

Websites:

Other (please specify):

7. Any other comments

Appendix B: Lecturer survey questions

1. Institution Name
2. Department
3. Please list the names of first-year service Mathematics modules that you teach or have taught recently and the student groups/programmes involved.
4. What concepts in the first-year curriculum do your students find most difficult to understand?
5. What procedures and tasks in the first-year curriculum cause most difficulty for your students?
6. Please list any resources that you have found helpful to aid students with the difficulties outlined above.
7. If possible, please indicate why the resources listed above were useful.
8. Are there any gaps in the resources available? Please explain.
9. Have you any advice on the resources you would like us to develop?
10. How should these resources be made available?
11. Do you agree to participate in this study?

Working with employers to enhance employment outcomes for Mathematics students

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Abstract

The employment prospects of mathematics graduates have received much attention lately as, despite the problem-solving and analytical skills which these graduates have developed, the employment outcome statistics are disappointing. We describe a successful collaboration with a recruitment consultancy which was one of the Greenwich Department of Mathematical Sciences' employability initiatives in 2014/15.

This collaboration aimed to improve students' interview skills by offering them the opportunity to experience a mock interview, on both sides of the table, with specialist recruiters from the financial sector. Students were given extensive feedback by the professionals, with a particular emphasis on making the most of their achievements. Academic staff watched, and occasionally took part, in the mock interviews. Since many academics do not have recent personal experience of the current recruitment process in the areas in which mathematics graduates are seeking employment, they gained very valuable insights which will help them better support students.

Student feedback on the initiative has been very positive and the implementation appears to have boosted the confidence of participants and enhanced their understanding of the graduate recruitment process. It was also a very useful experience for the academics who took part. However, there are a number of issues, including student engagement, which need attention for a successful implementation to realise the full benefits of the initiative. This presentation will discuss our experience and the problems encountered during the process, and outline possible actions that could help address them.

Introduction

Graduates in mathematics generally possess strong problem-solving and analytical skills which are valued by potential employers. However, the UK Higher Education Statistics Agency (HESA) survey of the Destinations of Leavers from Higher Education (DLHE) shows that the proportion of mathematics graduates in further study or "graduate-level" jobs six months after graduation is disappointing. There are many reasons for this, including the gender balance in the subject (Ball, 2015), issues in the DLHE classification which mean that some entry-level jobs for graduate mathematicians are not classed as "graduate-level", and a lack of confidence in many graduates in their problem-solving abilities (as seen in the National Student Survey questions 20 and 21) (Waldock 2011). This last point may mean that graduates do not present these skills to full advantage in job interviews.

The Department of Mathematical Sciences at the University of Greenwich, like many other departments, has increasingly put resources into the delivery of skills for employment. It has worked with employers and organisations like the Adab Trust, a charity specialising in helping students from black or minority ethnic (BME) backgrounds into graduate employment, and with individual employers, to offer students CV clinics, motivational talks, speed interview events, training for “elevator pitches” and similar opportunities. In addition the Department has developed with the Institute of Mathematics and its Applications (IMA), a subject-specific business game, designed to enhance students’ business awareness (Bradshaw, 2013).

Department staff feel that many students under-perform in interviews, failing to make the most of their skills and achievements. Training students for employment interviews during a mathematics degree is difficult. Practice is important, but mock interviews are time-consuming and labour-intensive to provide. Generic mock interviews with staff from the University’s central employability service are valuable but cannot address the special needs of mathematics students. Some academic staff at any institution, even if they had time to deliver large-scale mock interviews, inevitably lack recent successful experience of the contemporary recruitment process outside academia (and the criteria for appointment or promotion as an academic, often focusing on research publications, are rather different from those used by most other employers).

For some years Department staff have conducted demonstration interviews in class. One academic has been interviewed by another for a vacancy of the kind for which students might apply. The “candidate” deliberately performs badly, and students then discuss how they might have done better. More recently videos of staged demonstration interviews have been made available to students (Bradshaw, 2015). Sometimes volunteer students from the class are then interviewed and the results discussed by the class. Feedback from students showed that these activities have been effective and have helped them in real-life interviews. Nevertheless, however carefully students study such activities, a genuine interview presents different challenges, and students benefit from individual feedback.

The CEO of a recruitment consultancy had delivered a talk about employers’ expectations of graduates at the University in the autumn of 2014, and in discussion afterwards he indicated that some of his staff would be happy to work with the Department to help its graduates. With Department staff, an event giving students the opportunity to attend a mock interview with these professional recruiters was planned.

The planned event

It was felt that the most appropriate target students for this activity would be second year students who would already be thinking about their graduate careers (and might be applying for sandwich placements). For practical reasons it was decided to hold the event in the non-teaching week before a group modelling activity. The plan was that students would attend for the mock interviews in their modelling groups (groups of six, assigned in such a way that students chose some but not all of their group-mates) (Bradshaw, 2009).

One powerful tool in improving one’s interview performance is to take part in an interview panel as an interviewer rather than interviewee. In our experience this gives one a better understanding of what interviewers are looking for, and helps one appreciate how best to answer competency-based questions. So the original plan is that students would attend in self-chosen groups of three (from their modelling groups) and each student would experience three interviews, with one professional interviewer and the other two students forming the “interview panel”. This would maximise the number of students who could be accommodated while ensuring that there was a professional involved in every mock interview.

As a coursework assignment (Bradshaw, 2014) three suitable job adverts for positions suitable for graduating mathematicians, and the relevant person specifications, had been given to students and they had each prepared an application for one of the vacancies. Taking advantage of the work they had already done, participating students were asked to prepare for an interview for that position. The interviewers would ask questions focusing on the essential criteria in the person specification. The students were therefore able to prepare by thinking of examples to demonstrate that they possessed the competencies specified.

Students were of course aware that the process would potentially reveal personal information to other students. They understood this issue (and did not need to answer interview questions truthfully, so they could adopt a fictional persona if they wished). Students who chose to take part were aware of this ethical issue, and presumably calculated that the benefit would outweigh any privacy concerns they might have.

In order to test and fine-tune the format, a rehearsal was scheduled involving students who had wished to take part but were not available on the appointed day. (This was often because of work commitments. It is ironical that the demonstrable commitment to one's part-time work which is a key property in seeking graduate employment – see for example the research reported by Garner (2015) – often prevents students from attending the extra-curricular events offered to help them improve their employability.) The rehearsal involved staff members taking the roles of the professional interviewers.

What happened

Students were told about the plans in class (and subsequently by email and through the Virtual Learning Environment) before Christmas. There was considerable enthusiasm. As one student said, "You are offering us interview training with professional recruiters from the financial sector in which many of us are hoping to find graduate jobs. Wouldn't we be mad not to sign up?" In the event about fifty students did register to take part. Others may not have done so because they were planning to apply for teacher training or Master's programmes and believed (wrongly, in our view) that the session would not be relevant to them, or because of family or work commitments in the non-teaching period. After students had signed up, a schedule was drawn up and sent to the professional interviewers as well as the students.

During the days before the event the tutor organising it received many emails from students which (generally) showed their enthusiasm. They were asking about preparation, dress, what questions to expect, and similar topics. So staff were optimistic about the event. However the rehearsal on the day before did not go entirely well. Some students did not turn up, and others were late and casually dressed. Although the format of the interview worked well at the rehearsal, and although we hoped that students would take time-keeping and professionalism more seriously at the real thing, we were concerned that the recruiters might not be impressed by such lack of professionalism. Consequently, on the eve of the event the second author hastily sent a rather stern email to students emphasising the importance of the event, and the need to arrive in plenty of time, to dress smartly and to prepare well. This email was perhaps to prove a mistake.

On the day itself, students certainly turned up smartly-dressed and (mostly) on time (there were problems with public transport in London on the day). However less than half of those we were expecting actually turned up! Naturally, we were concerned about the impression this would make on the professional recruiters, who, however, were less surprised and disappointed than we were: apparently, no-shows are common amongst their professional clientele! We asked that they didn't pass this information on to the students.

So we made some changes to the plans for the day, but essentially followed the intended format, with academic staff joining the panels when necessary, and also observing. Immediate feedback was given to each interviewee. For us academics watching, we were impressed by how positive the feedback was: we would have been much more critical of our students and perhaps a lot less helpful to them as a result! Many of the students were extremely nervous, and we felt that some of them performed poorly as a result, but the interviewers found evidence of potential in every case and gave clear advice on how better to communicate that potential, and on how to handle their nerves.

Feedback from students and from staff was extremely positive. Students felt they had derived great benefit from the interviews and the professional advice and that they would be much more confident, and better-prepared, for real interviews. Staff felt they had gained valuable insights into the present-day recruitment process and as a result are better able to advise students. Several students commented that those who did not attend had missed an excellent opportunity.

At the end of the day we conducted video interviews with all the recruiters, and extracts from these are being made available to students through our VLE, increasing the benefit from the event.

Lessons learned

A number of lessons were learned from this experience.

The first is the willingness of employers to help. The company which conducted the interviews is a recruitment consultancy in the financial sector. They do not deal with graduate recruitment, but with placing people several years into graduate careers, so they were not doing this in order to gain immediate access to students as potential clients, yet they sent very senior staff to run this activity for a day, and were happy to have done so despite the disappointing student uptake. Companies (and individuals) like this are remarkably willing to help universities, either through their corporate social responsibility programme, or to gain experience, or just out of public-spiritedness. This presents opportunities for higher education maths departments to give students access to direct professional advice and helps address the issue that academic staff are not necessarily credible to students in advising about employability outside higher education.

A second outcome was that the tutors who took part gained much-needed first-hand experience of the graduate interview process. They also saw how recruitment professionals give feedback. As academics, we draw attention to what is done badly, which can be demoralising for students. The professional recruiters gave extremely positive feedback, and were excellent at seeing where student interviewees were not making the most of their potential. As a result, even students who we felt had not performed particularly well in the mock interview left with their confidence considerably boosted. When nervousness and lack of confidence are big factors which hamper students in interviews for graduate jobs, our impression was that this exercise, and particularly the feedback from the recruiters, will really help these students when they are interviewed in earnest.

A third point was how seriously the professionals prepared for the mock interviews. Since they had had in advance a list of candidates, they had investigated the LinkedIn and social media presence of every single signed-up student and came prepared with individual advice, especially for those whose Facebook profile is rather too public. This contrasted with the preparation by the students, who naturally focused on the job specifications rather than looking up the interviewers, and was a valuable reminder to the academics of the level of research undertaken by employers in the recruitment process.

But the biggest lesson was about the turnout. In general student engagement with employability events has sometimes been disappointing. This was the case here, and our natural inclination was to conclude that students don't attach enough importance to preparing for the recruitment process for their chosen careers, that they prioritise academic work over developing employability skills, and that they believe that it will be easy to find a graduate job so that they don't need to make efforts in that direction until after they have graduated. This event showed us that these are not the only reasons why many students do not engage with such activities.

We asked students, both those who participated and those who didn't, and student representatives, what had happened (taking care to do so in non-threatening ways). A consistent picture emerged: students wanted to take part but find such activities terrifying. We had been puzzled that even one student, who had emailed a tutor repeatedly in the run-up to the mock interviews with questions about preparation, dress and so on, and who had emailed on the evening before saying how excited he was, still did not turn up: he told us that, on the day, he was so nervous he couldn't face the event. This seems to have been typical of those who did not turn up: they really valued the opportunity, but the prospect of an interview with a real employer scared them. The second author's email before the interviews had possibly only added to this fear and perhaps even caused greater non-attendance.

While it is not easy for us to understand why this activity should be so fear-inducing, we have learned that for many students there is a great deal of fear associated with the graduate recruitment process. It is not that students are not engaging because they don't care: they care so much that it actually inhibits them. This lesson will influence our future thinking.

So overall this was a very worthwhile activity for the Department. It benefited the students who took part; it upskilled the Department's staff regarding the current recruitment environment for our graduates; and it gave us insights into students' attitudes towards employability which will help us better target our efforts in future.

References

Ball, Charlie (2015), 'What do maths graduates do?', HoDoMS Conference presentation, Accessed via http://www.hodoms.org.uk/AGM.html (28 August 2015)

Bradshaw, N., (2009), 'Tribute to triplets: a model for successful group work', Compass: The Journal of Learning and Teaching at the University of Greenwich, 1 (1), pp. 7-9.

Bradshaw, N., (2013), 'IMA Business Game', Mathematics Today, 49 (1), p. 28.

Bradshaw, N. (2014), 'Employer-endorsed employability assessment: an assignment delivered in an operational research course to second year mathematics students', HEA STEM Annual Conference, April 2015. Accessed via https://www.heacademy.ac.uk/resources/detail/stem-conference-2014/Post_event_resources/MSOR/Employer_endorsed_employability (28 August 2015)

Bradshaw, N. (2015), 'The use of video and mathscasts to engage and support the learner and promote mathematical thinking', IMA International Conference on Barriers and Enablers to Learning Maths, August 2015. To be available at http://www.ima.org.uk/conferences/conferences_calendar/barriers_and_enablers_to_learning_maths.cfm.html

Garner, Richard (2015), 'Leading employers value work experience among graduates over grades, says new research', The Independent, 31 May 2015. Accessed via http://www.independent.co.uk/news/education/education-news/leading-employers-prefer-work-experience-over-grades-says-new-research-10286829.html (28 August 2015)

Waldock, Jeff (2011), 'Introduction', in Jeff Waldock (editor), 'Developing Graduate Skills in HE Mathematics Programmes – Case Studies of Successful Practice, HE STEM, pp. 3-7. Accessed via www.mathcentre.ac.uk/resources/uploaded/gradskills.pdf (28 August 2015)

Realism and employer engagement in a work-related mathematics group project

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Abstract

A new final year module was developed in 2012 as part of the Keele undergraduate mathematics degree employability strand. This aimed to develop skills including problem-solving, group working, communication skills and reflection, which are valuable in employment but not necessarily developed by traditional mathematics teaching. This article reports on the development of the module and focuses on a group project that attempted to expose students to a realistic project task, first by giving access to a real data source, and later by involvement of industrial collaborators. The involvement of an industrial 'domain expert' was found to be useful, while having students complete an unstructured group project based on real data is thought to be a valuable learning experience, despite mixed student feedback.

Background

Mathematics graduates need transferable skills to "use their knowledge effectively" (Challis et al., 2002; p. 89) and it is "incumbent on us, as teachers, to help our students to learn and develop these skills" (p. 80). The need is there, as employers report that graduates are technically competent but lack professional skills (Lowndes and Berry, 2003), and few recent graduates believe their degrees developed those skills that were "of substantial importance in the workplace" (Inglis, Croft and Matthews, 2012; p. 27).

The final year module in the Keele employability strand is 'Professional Mathematics', a 15 credit, one semester, optional module for mathematics and joint honours students with no pre-, post- or co-requisites, created for 2012/13 by one of the authors (PR) and led since then by the other (ER). The module document explains that the module intends to develop skills which are needed in employment or when undertaking a research degree but which "may not be developed by traditional mathematics teaching". The key skills identified for the module to attempt to develop were problem-solving, group working, communication skills and reflection.

Traditional methods of teaching and assessment are "strong" for "the attainment of knowledge" but make "more limited contributions to other elements" (Hibberd, 2005; p. 6). Waldock (2011) argues for developing graduate skills using alternative methods of assessment which encourage skills development alongside mathematical content. Hibberd (2002) recommends group project work for "a more active learning of mathematics, and an appreciation and acquisition of associated key skills" (p. 159). Professional Mathematics is, therefore, based around group projects.

Chadwick et al. (2012) suggest that work-related learning requires "realism", though moderated by practical constraints, and recommend "authenticity" can be provided by "employer engagement" (p. 51). This may be because students value advice from industrial representatives over that from academics or careers staff (Chadwick, Sandiford and Percy, 2011). However, direct employer engagement is resource-intensive and not always felt to be crucial; for example, Benjamin et al. (2012) created a shared resource bank of industrially-inspired projects for use where access to employers is not available.

Three group project tasks were planned. The first is a short and low-stakes modelling task, designed to enable groups to learn about the strengths of its members and their interactions. In the second project, groups work on a specific task from a client. In the first year of operation, due to practical constraints, the client was fictional; in later years, an alumnus has posed as the client. This paper will focus on the third group project task, which attempted to inject 'realism' by being based around an open-ended investigation of real-world data, and which has undergone changes over the three years of module operation.

Alongside the group tasks, peer assessment of contribution and five pieces of individual work (maths coursework and reflective essays) were used to allow for individual marks. Marks were assigned for group operation, assessed via minutes of weekly group meetings.

The final group project in 2012/13

For the third project, the main aim was to offer students a more realistic task than the well-specified problems in projects 1 and 2. To do this, a real data source was used and students were deliberately given little direction.

To collect real data, during the 2012 Olympics and Paralympics, which took place the summer before the module started, a PHP script collected around 3 million public tweets containing the words "olympics" or "paralympics". This was configured to not overload the server collecting the data, but aimed to collect more data than could be conveniently loaded into Excel.

Students were offered as much or as little data as they wanted, and were instructed to produce their own research question which could be answered using the data. Though unstructured, the data would contain positive and negative sentiments, and references to sports, countries, medals, people, brands and events. Ignoring the Games, they could treat the data as a large sample of text for analysis, think about how to extract meaning from the data, or look at interactions between users. Possible areas of investigation suggested by the lecturer included statistics, language processing, OR, graph theory (network theory), algorithm design or computational methods. Assessment was via a mathematical report, a 'public' lecture (to staff), and via an audio report (as if for a radio programme or podcast).

Reflection and feedback in 2012/13

Some groups took a while to come up with a good question, either because their first attempt was too closed or too difficult to answer. After negotiation, each group eventually came up with an interesting question and made a good attempt to answer it. They learned to handle questions that cannot be definitively answered and encountered various problems with messy data.

One issue was how lost some of the groups were without clear guidance. Although this was part of the point of the activity, at times some basic guidance might have been useful.

In an end-of-module student questionnaire, students were asked about the greater freedom they were given over this task. Responses were mixed, and include:

- "It was good to be given more freedom, but this was more than we ever had been before and took a while to come to terms with it all."
- "Felt that there was too much freedom in choosing our own project, this meant that we could easily put ourselves into trouble."
- "Although others in my group disagree i felt it was quite good as it gave independence and that if we got stuck we had to figure it out ourselves rather than being guided to the answer by someone".

- “It was good to be able to interpret the question in our own way. However, it was frustrating when we couldn’t get told if we were doing it right.”
- “I felt we should have been given abit more guidance.”

The final group project in 2013/14

For the 2013/14 academic year, the module was enhanced by collaboration with an industrial partner (an expert in marine radar) to set the final group project. Data collected from two radars in Wales on two different days and at two different times was provided to students. As in 2012/13, students set their own research problem.

The data was provided to students in raw form and the groups were given some possible areas to investigate but were also free to come up with their own ideas. A whole lab session was used for this initial introduction and brainstorming session.

The industrial partner was not available for every lab session in the module. It was suggested that this could be used to further emphasise the reality of working on a mathematical problem in an unfamiliar topic area. The expert suggested that a costing procedure should be introduced whereby groups could ask for his help (as the domain expert) but it would cost them after a certain point. It was hoped that this procedure would focus the groups on asking good questions and would also encourage them to persevere with problems which they could solve themselves.

The author (ER) decided that each group should be allocated five “free” emails to send to the domain expert. Groups were permitted to send further emails to contact the domain expert but each additional email would bring the deadline for the final report forward by one day.

Reflection and feedback in 2013/14

Students initially found the format of the data difficult to handle, requiring programming software to access, which proved to be a struggle for some groups and became a significant distraction from the main task.

Earlier in the module, good group work practices (including initial skills discussions and planning the approach to a task) had been emphasised and discussed. These were adopted in the first two group projects but were mostly bypassed in this final project. Without these key steps, many groups struggled to make progress.

Some groups did initial planning and split the project into smaller tasks. By contrast, other groups could be found huddled around staring blankly at one computer screen for extended periods and, even with encouragement from the module leader, were hesitant to contact the domain expert and use an email.

These situations can be concerning for a lecturer to observe and the instinct is to immediately rush over and resolve problems (or provide hints). In these circumstances, the greatest benefit for the students can be felt when they are forced to confront the fact that they are not making any progress working as they are and that something has to be done to address this, whether it be to send an email or to identify the smaller tasks which need to be completed to move forward. This is the most difficult aspect of working on a module like this as a lecturer. The lecturer can sometimes help students to achieve the learning objectives best by giving them greater ownership of the task and encouraging them to reflect on how the group operated.

Student feedback was collected at the end of the module via questionnaires. In particular, students were asked to give their opinions on the differences between mathematics at university and the mathematics in real world problems. Many students chose to discuss the final group project on marine radar. Some of the comments are given below.

- "I think only having 5 emails per group was actually a good idea since it stopped us giving up on the problem and asking for help when we could solve it ourselves. In addition, it enabled us to experience what it would be like working for a business and to decide when it would be appropriate to contact the client."
- "Although originally I thought the project was unrealistic and that it was unfair to leave the groups with very little guidance, I think that it was a valuable learning experience that enabled me to choose the method for working and the way in which to approach it."

There were many comments which echoed these thoughts and it was clear that students had felt that the experience on this final group project was beneficial for their future employment. There were however some comments which indicated that the benefits of the experience had not been felt by all students. An example of this is given below.

- "With project two when we found a problem we simply asked the appropriate person for help, as we might expect to in a real world scenario, so we can easily move on to reach our goal within the task. This meant the project (project 2) ran much smoother and felt much more realistic."

Discussion

The final group project in the module has forced students to think about the practicalities of working as a mathematician on a real research project. The 2013/14 run of the module featured a final project which gave the students direct experience of working for a mathematical consultancy. The incorporation of the costing procedure forced students to confront the fundamental consequences of paying for someone's time.

Initial reactions to the final project in both 2012/13 and 2013/14 were similar in the sense that students found the freedom in setting the research question and unfamiliarity with the topic area unsettling at first. The unstructured nature of the project and the requirement to juggle many considerations at the same time (when to contact the domain expert, how to present the findings to a public audience) gave students exposure to the multi-tasking and thought processes required by employers.

Keele has a strong offering in terms of "skills" strand modules but this final year module has advantages as it gives students direct contact with employers and lets them experience working on genuine problems set in the work environment. A formal analysis of the impact on students will follow in a future paper.

References

Benjamin, O., Homer, M., Lawry, J. and Rossiter, J. (2012) “Industrial Problem Solving for Higher Education Mathematics.” In J. Waldock and P. Rowlett, eds. Employer Engagement in Undergraduate Mathematics. Maths, Stats and OR Network, pp 23-25.

Chadwick, E., Sandiford, K. and Percy, D. (2011) Assessing student teams developing mathematical models applied to business and industrial mathematics. MSOR Connections, Vol. 11 (No. 3):22-24.

Chadwick, E., Waldock, J., Bradshaw, N., Orpin, L., McNulty, D., Singh, M., Haydock, T., Ellis, C., Rowlett, P. and Steele, N. (2012) “How realistic is work-related learning, and how realistic should it be?” In J. Waldock and P. Rowlett, eds. Employer Engagement in Undergraduate Mathematics. Maths, Stats and OR Network, pp 47-51.

Challis, N., Gretton, H., Houston, K. and Neill, N. (2002) “Developing transferable skills: preparation for employment.” In P. Kahn and J. Kyle, eds. Effective Learning and Teaching in Mathematics & its Applications. Kogan Page, pp 79-91.

Hibberd, S. (2002) “Mathematical modelling skills.” In P. Kahn and J. Kyle, eds. Effective Learning and Teaching in Mathematics & its Applications. Kogan Page, pp 158-174.

Hibberd, S. (2005) Use of Projects in Mathematics. MSOR Connections, Vol. 5 (No. 4):5-12.

Inglis, M., Croft, T. and Matthews, J. (2012) Graduates’ Views on the Undergraduate Mathematics Curriculum. Maths, Stats and OR Network.

Lowndes, V. and Berry, S. (2003) Benefits of using Industrially based Group Projects within Mathematics Programmes. MSOR Connections, Vol. 3 (No. 1):20-22.

Waldock, J. (2011) Learning, Teaching and Assessment Approaches to Developing Graduate Skills for Employability. In J. Waldock, ed. Developing Graduate Skills in HE Mathematics Programmes – Case Studies of Successful Practice. Maths, Stats and OR Network, pp 26-27.

Making Mathematics real and relevant: the engagement of first year undergraduate students with a joint assessment in Business Mathematics and Management Principles

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Abstract

The challenges facing undergraduate students of non-specialist or service mathematics are widely documented in the literature. As a practitioner lecturing Business Mathematics, the author has been exposed to negative discourse surrounding student engagement with their compulsory Business Mathematics module; the perceived lack of context for much of the material, a willingness to 'get by' or pass in order to meet the learning outcomes, and poor commitment to the subject matter are some of the reasons given anecdotally as to why the students dislike service mathematics.

In 2011 the author was assigned to lecture on the Management Principles module as well as the Business Mathematics module to the same first year cohort in the first academic term; the author used this opportunity to introduce a joint continuous assessment, involving a practical application of Business Mathematics. The purpose of this joint assessment was to enable students to apply their knowledge of descriptive statistics (from Business Mathematics) and environmental analysis tools (from Management Principles) in a practical way. The culmination of this endeavour was a considerable improvement in the students' attitudes towards business mathematics, and an appreciation of the application of mathematics to the business world, and indeed the local community. In this paper, the author presents the context for the project, the structure of the assessment, the challenges faced in the roll-out of the project, and the outcomes of the experience.

Introduction

Undergraduate students face numerous challenges as they enter higher education for the first time, particularly when faced with non-specialist or service mathematics modules as part of their studies. As a practitioner lecturing Business Mathematics since 2007 to first year undergraduate students on concurrent Initial Teacher Education (ITE) programmes at St. Patrick's College Thurles[i], the author has been exposed to negative discourse surrounding student engagement with their compulsory Business Mathematics module; students' perception of a lack of context for much of the module material, or their willingness to simply 'get by' or pass the module in order to meet the learning outcomes, as well as poor commitment to the subject matter are some of the reasons given anecdotally as to why the students dislike service mathematics.

In 2011 the author[ii] was assigned to lecture on the Management Principles module as well as the Business Mathematics module to the same first year cohort in the first academic term; the author took advantage of this opportunity to introduce a joint (interdisciplinary) continuous assessment, involving a practical application of Business Mathematics for the continuous assessment component of both modules. The intention behind this endeavour was that students would gain an appreciation of Business Mathematics in a real world context, and thereby change their attitudes and discourse towards mathematics.

Context for change

Inherent in the transition to higher education are a variety of challenges and uncertainties for undergraduate students to negotiate; they may lack confidence in their ability, both socially and academically, and uncertainty may prevail in terms of what is expected of them (Gosling, 2009). As they encounter service mathematics some students may be negatively predisposed towards mathematics (Klinger, 2005), which can impact on their level of engagement with the subject. Some students' life experiences of mathematics have been influenced by perceptions of the discipline as irrelevant, and not applicable to daily life (www.NCCA.ie, 2006; Ryan, 2014). The minimum entry requirement in mathematics for the ITE programmes at St. Patrick's College is a grade D3[iii] in the Leaving Certificate Mathematics (Ordinary Level) examination (www.StPats.ie, 2015); consequently proficiency in mathematics among the first year student cohort varies (Denison, 2009), as students enrol with very different levels of ability and knowledge bases in mathematics, posing considerable challenges for the lecturer in "knowing where to pitch the lecture and how to keep all students interested." (Morton, 2009: p. 58).

The role of the lecturer in advocating a more holistic pedagogical approach to mathematics (Foster, 2013) is central to enabling students to appreciate the application of mathematics in a broader context that goes beyond the educational setting (Bishop, 1999; Ryan, 2014); while this approach poses challenges for both lecturer and student, it affords the lecturer a professional space for the creation of new possibilities (Skovmose, 2011; Ryan, 2014), and allows students to build on their own experiences and knowledge (Benn, 1997), and feel involved and engaged, with the feeling that they have learned something (Morton, 2009). In this regard, small group activity is conducive to the learning process, and the development of key skills, such as communication, self-confidence, teamwork and inter-personal skills, as well as the potential to develop innovation among students (Griffiths, 2009). The student-centred approach to education recognises that students come to the table with their own experiences and perspectives, and attempts to counteract many of the students' uncertainties and anxieties (Gosling, 2009). Central to this approach is the acknowledgement of interdisciplinary learning outcomes achieved through encouraging higher-order thinking and information skills (EIC, 2004).

Roll-out of the assessment

Having been assigned to lecture on both Business Mathematics and Management Principles modules, the author used the opportunity to introduce a practical application of Business Mathematics in the form of the continuous assessment (CA) component for both modules. Prior to this, the CA component for the Business Mathematics module involved students being presented with a data file, which they had to manipulate according to a set of requirements. The nature of that assessment resulted in a detachment of Business Mathematics from a realistic business context, and prompting some students to question the need to have a Business Mathematics module (Gill & O'Donoghue, 2005). Rather than simply examining what the students had learned from their business mathematics module, the author asserted the importance of students being aware of the application and relevance of what they learned in a real way; this opportunity was afforded through co-delivery of the Management Principles module. The author wanted to let the students experience Business Mathematics in context, and use the assessment component of the module to allow students to 'step forward' (Birenbaum, et al. cited in Norton, 2009) and improve their learning, rather than being assessed as an end point (Norton, 2009). From the author's perspective, the impetus was identifying what was important for the students to learn, rather than what the lecturer wanted to deliver (Norton, 2009).

The purpose of this joint assessment was to enable students to apply their knowledge of descriptive statistics (from the Business Mathematics module) and environmental analysis tools (i.e. SWOT[iv] and PEST[v] analyses from the Management Principles module) in a practical and relevant way. The design of the joint assessment reflected this fact, and allowed for the development of the required learning outcomes within the context of a small group setting (4-5 members). Students were given the assessment remit in week 2; they were asked to choose a product or service used by students of St. Patrick's College, and were to examine the product/service using the SWOT and PEST analyses; they also had to conduct a survey in relation to an aspect of that business that they had identified from the environmental analysis as needing further exploration. In addition, this assessment required that the students would communicate with relevant staff of the chosen business, to enhance their knowledge of the business, and as part of the conclusion to their assessment, they would make recommendations to the business based on their research findings. The students had 7 weeks to complete the assessment, which accounted for 50% of each of the 2 modules. The deliverables comprised a 20-page document plus appendices, as well as the presentation of work to the plenary group.

Engagement of students with the process

For many students the transition to third level can pose challenges that can be alleviated through a range of supports offered to students (Selden, 2005). Support for mathematics learning has been shown to be effective for students who consistently engage with such support services over the course of a semester or academic year (O'Sullivan, et al., 2014). The nature of such support – typically on a one-to-one or small group basis – acknowledges the standpoint of the student, and the knowledge they already possess, and fosters positive discourse and feelings about mathematics (Luk, 2005; Ryan, 2013; O'Sullivan, et al., 2014). To this end, the author arranged weekly meetings with members of each group, in order to get a sense of the progress the groups were making, and an indication of the level of interest and engagement of the students with the subject matter. From the author's perspective this endeavour required much planning and preparation, and regular engagement with the individual student groups. Instructions and advice pertaining to the different stages of the assessment were emailed to students during the earlier weeks of the term. When required, the author provided additional guidance and feedback on various aspects of the assessment, either at the meetings or by email correspondence. Feedback to students on both deliverables was provided within two weeks of the submission date.

Reflection and conclusion

The need to situate learning and learning outcomes in real life contexts is central to the students' appreciation of the discipline of mathematics. The culmination of this endeavour was a considerable improvement in the students' attitudes towards Business Mathematics, and an appreciation of the application of mathematics to the business world, and indeed the local community. The early introduction of subject-specific project work engaged the students in the learning process, and encouraged them to get involved (Gosling, 2009). In addition to meeting the module learning outcomes and assessment requirements, students were immersed in group work from Week 2, which helped them get to know other members of their cohort quickly; they also gained additional higher-order skills, particularly organisational and leadership skills, computing skills, and communicative skills. Finally, being part of the small group setting facilitated positively the achievement of the learning outcomes of both modules. Comments from students' module evaluation forms depicted many positive experiences of the CA (sample provided in Box 1).

As a practitioner, the author appreciated the professional space afforded in order to implement this joint CA (Looney, 2014), and in doing so, become more engaged with the module content (Ryan, 2014). The focus for the lecturer with this type of CA is on fostering an environment conducive to student learning with a depth of understanding, and involves considerable investment on the part of the academic (Blackie, et al, 2010). While the CA gave the author a good insight into how the students handled both modules and inter-related the topics, it would have been useful on many levels to have worked with a co-operating lecturer. However the college does not have the resources to facilitate this. Nevertheless, the CA has been a feature of the first year programme for four years, and with much enthusiasm from the students. The impact of the learning within the CA has been felt in subsequent Business modules, like Marketing, Organisational Behaviour, and Strategic Management, with references being made during lectures and tutorials to aspects of the CA on a number of levels. Commendation for the CA came from the students themselves, from other staff members, as well as from External Examiners to the programme. The author would recommend this mode of assessment for other modules and disciplines, where commonalities across disciplines can be identified.

Box 1: Selection of Comments from Students' Module Evaluation Forms

- Engaging, enjoyable experience
- The project is a good way to understand the course content in the real world
- Much learned from the company project; I believe it helped focus and cement elements of the module.
- Interacting with everyday maths while doing the project is very useful.
- The project is a good way to put the maths to use.
- Excellent assessment which made it a lot easier to understand surveys and statistical analysis
- It wasn't too difficult
- Very practical and challenging, a great combination of the two modules
- Really enjoyed the project
- Helped us to see how a proper business functioned daily
- Project was very useful
- Thoroughly enjoyed this
- The project was really interesting and I felt I learned a lot from it
- The project was a great way to give a chance to more practical learners
- Very good, interesting and I liked working in a group
- Provided a great understanding of business in the town
- Project gave me a great understanding of the topics covered in it.
- Linking theory with practice – helped understanding

References

Benn, R. (1997) Adults Count Too: Mathematics for Empowerment, Leicester: National Institute for Adult Continuing Education (NIACE)

Bishop, A. J. (1999) Mathematics Teaching and Values Education: An Intersection in Need of Research, reprinted in P. Clarkson and N. Presmeg (Eds.) (2008) Critical Issues in Mathematics Education – Major Contributions of Alan Bishop, New York: Springer, pp.231-238

Blackie, M. A. Al., Case, J. M., and Jawitz, J. (2010) Student-centredness: the Link between Transforming Students and Transforming Ourselves, Teaching in Higher Education Vol. 15 (6), pp. 637-646

Denison, K. (2009) Assessment strategies that benefit all learners, Research Report, Bradford College

Educational Initiative Centre (EIC) (2004) What is Student Centred Learning?, University of Westminster, sourced at https://www.westminster.ac.uk/__data/assets/pdf_file/0004/41782/StudentCentred Learning.pdf on 30/08/2015

Foster, C. (2013) Resisting Reductionism in Mathematics Pedagogy, The Curriculum Journal Vol. 24(4), pp. 563-585

Fry, H., Ketteridge, S., and Marshall, S.(2009) Teaching and Learning in Higher Education, Abingdon Oxon: Routledge

Gill, O. and O'Donoghue, J. (2005) What Counts as Service Mathematics Teaching in Irish Universities? Paper presented at First National Conference on Research on Mathematics Education (MEI 1), Dublin

Gosling, D. (2009) Supporting Student Learning, in Fry, H., Ketteridge, S., and Marshall, S.(2009) Teaching and Learning in Higher Education, Abingdon Oxon: Routledge

Griffin, R.W. (2011) Management Principles and Practices,10th Edition, Houghton Mifflin.

Griffiths, S. (2009) Teaching and Learning in Small Groups, in Fry, H., Ketteridge, S., and Marshall, S.(2009) Teaching and Learning in Higher Education, Abingdon Oxon: Routledge

Klinger, C. (2005) Challenging Negative Attitudes, Low Self-Efficacy Beliefs, and Math-Anxiety in Pre-Tertiary Adult Learners. Paper presented at Adults Learning Mathematics 12, Melbourne, pp.164–171.

Looney, A. (2014) The Emergence of 'Evidence' as Policy Technology, Keynote Presentation: Proceedings of International Winter School, University of Limerick, 24th-26th January, 2014

Luk, H.S. (2005) The Gap between Secondary School and University Mathematics, International Journal of Mathematical Education in Science and Technology Vol. 36(2-3), pp.161-174

Morton, A. (2009) Lecturing to Large Groups, in Fry, H., Ketteridge, S., and Marshall, S.(2009) Teaching and Learning in Higher Education, Abingdon Oxon: Routledge

National Council for Curriculum and Assessment (NCCA) (2006) Review of Mathematics in Post-Primary Education: Report of the Consultation, Dublin: NCCA

Norton, L. (2009) Assessing Student Learning, in Fry, H., Ketteridge, S., and Marshall, S.(2009) Teaching and Learning in Higher Education, Abingdon Oxon: Routledge

O'Sullivan, C., Fitzmaurice, O., Mac an Bhaird, C., and Ní Fhloinn, E. (2014) Adult learners v traditional learners - insights from a large scale survey of Mathematics Learning Support in Irish HEIs, sourced at http://supportcentre.maths.nuim.ie/mathsnetwork 26/04/2014

Ryan, M. (2013) Using a Distributed Leadership Approach to Facilitate Peer-Led Mathematics Support for Students, Assignment submitted in part completion of Structured PhD (Education),University of Limerick

Ryan, M. (2014) A Comparison of the Numeracy Policies of Ireland and England using Critical Discourse Analysis, Assignment submitted in part completion of Structured PhD (Education),University of Limerick

Schwab, J. (1973) The Practical 3:Translation into Curriculum, The School Review Vol. 81(4), pp.501-522

Selden, A. (2005) New Developments and Trends in Tertiary Mathematics Education: Or, More of the Same? International Journal of Mathematical Education in Science and Technology Vol. 36(2-3), pp.131-147

Skovsmose, O. (2011) An Invitation to Critical Mathematics Education, Rotterdam: Sense Publishers

St Patrick's College (www.StPats.ie) (2015) Programme Information: Student Entry Requirements, sourced at http://www.stpats.ie/courses/ba_in_education_bs_acc on 30/08/2014

Trant, M. (2002) The Quest for an Inclusive Curriculum and Assessment Culture: The National Council for Vocational Awards 1991–2001, Irish Educational Studies Vol. 21(1), pp. 19-32

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[i] St. Patrick's College, Thurles is a small third-level college of Initial Teacher Education, with approximately 230 full-time students. The college offers 4 full-time undergraduate Honours (Level 8) concurrent teacher education degree programmes accredited by the University of Limerick and recognised by the Teaching Council of Ireland. Graduates are qualified to teach 2 subjects from a choice of Business Studies, Accounting, Religious Studies, and Gaeilge in Secondary Schools.

[ii] The author is the only Mathematics lecturer at the college, and lectures on a number of modules across the Business Studies discipline.

[iii] Representing a mark in the range 40% to 44.99% (www.education.ie)

[iv] SWOT: (acronym) Strengths, Weaknesses, Opportunities, Threats, enabling analysis of the business environment (Griffin, 2011)

[v] PEST: (acronym) Political-Legal, Economic, Socio-Cultural, and Technological analysis of the external business environment (Griffin, 2011)

Personal reflections on running a school wide mathematics and statistics support service solo

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Abstract

In the conference presentation I wanted to share my personal experiences of running a School-wide mathematics and statistics support service as the only such tutor in my institution. I believe this situation is quite common in many higher education (HE) institutions and I hoped that sharing my experience could help colleagues elsewhere.

After a brief introduction to Birkbeck College and its student body the main focus of the talk was about the challenges and the rewards of my position. Amongst the challenges I talked about the difficulties of effectively communicating to colleagues and students what the support role entails and what solutions we found that worked for us. I also talked about the challenges of student attendance at generic workshops, pastoral care and how to deal with high demand. I went on to talk about the difficulties of combining statistics support with mathematics support; it is very often assumed that if one is trained in either then one can do both. I mentioned how I was able to bring my own knowledge of statistics up to a better standard to be able to help students with their sometimes very specific needs. I talked about the challenges arising from being the only mathematics support tutor in the School, how I overcame the solitude and how I kept myself motivated.

Finally, I moved on to talk about the rewards that being in a support role provides. I gave examples of students' and colleagues' positive feedback and described the supportive ethos of Birkbeck for students and colleagues alike which makes working there very enjoyable.

This brief article is a personal reflection on my experience in this role.

Birkbeck and the support role

Birkbeck has a unique place in the HE landscape as it is the only institution that provides its lectures in the evening. It is traditionally an institution for part time students, but new 3 years full-time degrees have become increasingly popular since the recent fee changes. The student body contains mostly mature students who are seeking career change, career development or realizing the need for a degree at a later age. Up until 2006 the College did not have any dedicated support staff. In 2006 the Law department piloted an academic English support post which was very successful. Two more English appointments had been made in the departments of Management and Psychology in the next academic year.

Following the government's decision on funding changes to Equivalent or Lower Qualifications the College had to seriously rethink its position and went through reorganization. This reorganization included the appointment of Learning Co-ordinators in every newly established School, rather than within independent departments. At this stage, there was no mathematics support offered via similar roles. The first and so far only full-time dedicated mathematics support role in the College was established in the School of Business, Economics and Informatics (BEI) in 2013 and this is the role I describe here.

Challenges

Challenges are unique to HE institutions and individuals. In this section I would like to share those aspects of the role that I found challenging and hopefully offer some insight to colleagues regarding the solutions I came up with to address them.

Probably one of the most important and pressing challenges of being a mathematics support lecturer is communication. How can support tutors communicate to academic colleagues the purpose of their role accurately and effectively? When I started my position my Director of Studies had made sure I was introduced to Programme Directors and key administrative staff. Personal contact greatly helped me to build an idea of the different programmes and modules and the unique mathematical needs within them.

Communicating the available support to students is also challenging. Every new term an email with workshop schedules, available support and relevant contact details is sent to every student in the School. We make sure these emails are very brief, but even then I am unsure as to how effective they are.

What seems to work better is taking part in induction events for both new staff and new students. These events, combined with the programme handbooks where all relevant information is collected together, seem to have a better effect. There are a few modules which are ‘maths heavy’ in certain programmes. For these I usually attend the first or second lecture to further emphasise the availability of the service and advertise the workshops and other resources that have been devised for supporting specific modules. Recently, we also designed some flyers and are yet to find out if they will have an effect.

Given Birkbeck’s unique position it is very hard to predict when students are free to attend extra workshops. Last year I organized workshops during the afternoons, evenings and some Saturdays. By far the best attendance was for the Saturday workshops. Afternoon and evening workshops had attendance somewhere between 1 and 5 students, while the weekend workshops usually attracted around 20 students.

Email support has started to become increasingly popular with our students as an easy and fast way of communication. Via email I have been able to answer many questions on statistical concepts and explain why certain research questions cannot be answered with the given data or survey. However, supporting mathematics via email proves to be more difficult - electronic communication does not handle mathematics well. My way around this problem is to answer the students’ questions on a piece of paper using different colours adding many side note explanations for clarification. I then scan and send these to the students. I have also run Skype tutorials with students, which can be quite productive when the technology works well. Skype allows screen sharing, so I have been able to show the students how to carry out mathematical calculations with the help of a scratch pad. Having to explain mathematics to students over the phone, especially when they call about two hours before an examination and then get into a panic mode, is quite a bit more difficult! In these situations I mostly try to calm the student down and become an examination coach rather than try to give particular explanations to difficult concepts.

Mathematics does bring out some extreme fear in some students, especially if the examination with difficult mathematics content carries a significant weight for the student’s degree. I have had grown adults burst into tears in my office and students being so anxious that they are not able to concentrate and articulate the difficulties that they are having with mathematics. Luckily the College has been supportive in this respect and every support lecturer has been able to attend internal training run by the counselling team. This has provided practical skills to help deal with these difficult situations.

I am the only mathematics support in a large School and one-to-one tutorials are always in high demand. There have been days when I offered six tutorials. As this is very time consuming I am trying to manage my time better by offering preventative support. Over the last couple of years I have built up a good understanding of the topics students find difficult and I started producing handouts around these topics. These handouts were then published on the Moodle site of the relevant module for the benefit of all students. I have also provided links to videos, for example from the Khan Academy and mathcentre websites, to accompany different topics. Recently I have started to record short video tutorials on common mathematical topics e.g. calculator use and computing mathematics.

As the School of Business, Economics and Informatics is one of the largest Schools, with four very distinct departments, the topics I have to deal with also have a great spread and depth. For example, Computer Science students have to develop some specialist mathematics skills. Also, although Business and Economics degrees use similar mathematical topics these are vastly different in terms of the depth required. Mathematical modules on Economics degrees demand optimization and differential equations whilst on a Business course the mathematical skills needed usually only reach the level of differentiation.

Many people falsely assume that if someone is good at mathematics then they must be good at statistics as well. Very few people outside these two areas know how very different mathematics and statistics are. I have recently completed one of our BSc Statistics modules to refresh my theoretical and practical knowledge in statistics to address this challenge. This module was highly theoretical which proved to be very useful to support modules in economics that need a more theoretical application of statistics such as calculating the marginal distribution of a multivariable distribution function. Also, I believe I now have a better understanding of the importance of the basic assumptions of the different statistical tests and can advise students better on degrees with lesser theoretical demands too.

It is also quite difficult to be able to deal with very different queries in statistics. Students mostly need help with deciding the correct test to use in a particular research project or help with interpreting results of tests. However, as mentioned above, some of our modules need highly theoretical knowledge.

One more challenge arising from statistics support needs is the variety of software packages used across the School. Depending on which module students study they might have to learn SPSS, STATA, S+, R or EVIEW. It is impossible for me to know the ins and outs of all of them. On many occasions I explain the theoretical background of the test the student is to use and which values need careful attention/consideration, but when it comes to the software questions I usually direct them to YouTube or other relevant websites, such as STATA's own video tutorials.

In many institutions support lecturers are positioned between professional and academic staff. This carries the advantage of students being able to open up more freely to us, but it also means that support lecturers often work in solitude. In my institution the support lecturers (Academic English and Mathematics) are directly managed by the Management department, which is the largest in the School. It gives us a feeling of inclusion, as we are expected to attend the departmental meetings and have dedicated time for feedback. However, most of the department's daily life still does not apply to us.

Rewards

In this section I would like to highlight the rewards that keep me going and make my job enjoyable and inspirational.

Birkbeck students are very committed to their studies and are very grateful for any help they receive outside the lectures and seminars. As our degrees are taught in the evenings and many of our students work during the day time, they don't have much time to learn and revise. For them, someone who can help them with being effective with their time and enable them to move on with their studies faster is very valuable.

After my first year in the position at Birkbeck, our department was scheduled to have its regular internal review. The focus was on teaching and learning enhancement, and therefore the English and Mathematics support tutors had been asked to be part of the group that presented to the panel. When I introduced myself the Chair of the panel turned to me and said that when they interviewed students the previous day the students had praised me highly for the support that I provide. I have to say that this reassured me that I am in the right job with the right organization.

Our Economics, Mathematics and Statistics department has a specialist conversion course, the Graduate Diploma in Economics. It allows students who already hold a degree to get a BSc Economics equivalent qualification. It is quite popular but is a very intense programme. The Quantitative Techniques module takes students from basic algebra to differential and integral calculus in a mere 3 months. As there are no special requirements as to which degree students had studied previously we regularly take on students with degrees that have little or no mathematics in them, such as Biological Sciences, Media or Law. My support becomes crucial for these students. I had one student who had a degree in Social Policy from Oxford and in her final year she was introduced to economics, which really sparked her interest. She was given an offer to start a Masters course at Oxford, conditional upon her achieving a distinction in our mathematical modules. It was really rewarding to work with her and see her progress through a very intense year. The first questions she brought to me were about working with fractions and from this stage she was able to progress to understanding and solving common differential equations in economics. Thanks to these students who aren't just interested in passing their examinations, but want to excel in their studies I feel that my role is more than just firefighting and I am helping students fulfil their potential.

Partly due to the nature of Birkbeck, we have a very supportive staff team. I don't really interact with the subject lecturers on a daily basis, but they are very supportive and appreciative. They are aware of my work through students' feedback. It really makes a difference to me to know that the job I do is valued by the department.

Last year I applied for **sigma** funding to produce video tutorials for Computer Science students. The department recognised the opportunity and importance of the work and told me that we would go ahead and make these videos even if funding was not awarded. I am pleased to say that it was. As Birkbeck is a widening participation institution and flexible teaching is high on the College's agenda this project won even the department head's attention and backing. I have to say having all this support has made this project a very enjoyable experience. In our School we have a dedicated media specialist, who has very high quality recording equipment and valuable knowledge of editing. This meant that all I had to do was turn up and deliver the teaching session for the camera and he was able to take care of the rest.

Conclusion

Although there are many challenges for mathematics and statistics support lecturers such as communication, managing students' demand and balancing mathematics support with statistics support there are also many rewards that make these jobs very enjoyable and fulfilling.

I think the solution to communication difficulties in my case lies with building up personal relationships with Programme Directors and module lecturers and identifying modules with mathematical needs and directly addressing the students in their lectures. To manage students' demand what seems to work best is to deliver programme and module specific workshops at times when students can attend. In this case students see the relevance and are more likely to participate, which takes pressure off one-to-one tutorials. I still provide generic workshops, but I have to say that attendance at these is much poorer. Another solution that seems to work well for us and our students is provision of video tutorials of difficult topics, as our students have to balance work, family life and study. My way of addressing one of the challenges arising from managing statistics support was to undertake some training in statistics by studying a statistics module.

As I stated earlier, and for all the reasons mentioned above, I believe I am in the right job with the right organisation!

Senior management perspectives on mathematics and statistics support in the HE sector in England

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Abstract

In 2013 the **sigma** Network was funded by the Higher Education Funding Council for England to implement a three-year programme to further embed mathematics and statistics support in universities across the Higher Education sector. A key part of that work is to investigate the existing and future needs of the sector in relation to the provision of such learning support. The aim of this study therefore, is to identify both the support institutions might welcome from the Funding Council, and how the **sigma** Network can assist senior management in universities by ensuring that the provision continues to meet institutional needs in ways that are fit for purpose and sustainable. To that end, semi-structured interviews were conducted with senior representatives (typically Pro-Vice Chancellors) of a sample of 23 universities. That sample included institutions drawn from different mission groups, and a balance of high, medium and low entry tariff providers (UCAS, 2014). The report (Tolley and Mackenzie, 2015) on which this summary is based offers a synthesis of a number of the findings and conclusions drawn from the analysis of data collected by means of those interviews.

Introduction

In 2013 the Higher Education Funding Council for England (HEFCE) funded the **sigma** Network to implement a three-year programme of work aimed at further embedding mathematics and statistics support in institutions across the Higher Education (HE) sector. A key component of that work was a commitment to investigating the existing and future needs of the sector in relation to the on-going provision of such support. The report of the research undertaken by the authors (Tolley and Mackenzie, 2015) identified the challenges faced universities in relation to mathematics and statistics, the means by which institutions are currently responding to those challenges, and their future vision with regard to the provision of mathematics and statistics support (MSS).

Research aims, questions and methods

The aims of the research were to produce the evidence that could be used to inform the future activities of **sigma** and offer an analysis to HEFCE of the strategic needs and priorities of the HE sector in England with regard to learning support for mathematics and statistics as perceived by senior managers. It was concluded that these aims would be best served, by the adoption of qualitative methods, using in-depth semi-structured interviews (Kvale and Brinkmann, 2009) rather than a questionnaire survey. Interviews were conducted with senior representatives typically Pro-Vice Chancellors (PVCs) from a sample of 23 universities drawn from across the mission groups. Within that sample, average entry tariffs were evenly distributed across all three of levels of 'tariff providers' (UCAS, 2014). The interviews were structured around research questions which enabled the following issues to be discussed: the challenges faced by students in relation to mathematics and statistics; how those challenges were being addressed; the degree to which learning support was embedded and visible; plans and intentions with regard to the provision of support; how institutional priorities were determined; and, the external support that the universities think they might need. Additional information about each HEI was collected from its website and Office of Fair Access (OFFA) statements. The resultant data were subjected to a process of analysis known as 'thematic induction' in order to identify themes judged to be significant (Braun and Clarke, 2006). In keeping with the ethical guidelines offered by the British Educational Research Association (2011) with regard to confidentiality and anonymity those questioned and their institutions were not named in the report.

Setting the research in context

A literature review enabled the research to be set in the context of: a HE system that is rapidly changing in response to government-led reforms in a period that has been called an age of 'supercomplexity' (Barnett (2000); and, post-16 education in England particularly with regard to the small number of students who continue to study any form of mathematics prior to entering HE (Hodgen et al., 2010 and 2013, and Hillman, 2014).

Challenges

All of the HEIs in the sample irrespective of their status with regard to their entry tariffs reported that they have students who are challenged by mathematics and statistics, and whilst those challenges varied in detail between universities, they can all be related to the students' transitions into and within HE, and to employment. Those challenges are multi-faceted and are not confined to mathematical sciences and the STEM disciplines. They extend to subjects such as Economics, Geography and Social Sciences that make use of quantitative research methods, and even to those such in the Arts and Humanities that make little or no use of mathematics or statistics - but whose graduates face numeracy tests when seeking to enter employment. Additionally, the challenges are not restricted to students on undergraduate programmes of study – they extend to a wide range of postgraduates. Challenges were also said to arise from the size and heterogeneity of student cohorts that result in teaching groups that include students with a mixture of AS, A-level and BTEC qualifications in Mathematics, mature and standard entry students, international and home based students along with students with special educational needs. The difficulties that arise from these challenges can be exacerbated by the presence of students who have not studied anything involving numeracy since they were sixteen, and others who lack confidence and/or have negative attitudes to studying any form of mathematics or statistics. It was widely recognised that unless appropriate forms of learning support are provided, it is inevitable that the challenges universities face with regard to mathematics and statistics will have an adverse impact on students' experiences, and ultimately on their satisfaction, retention, achievement and employability.

Responses

Learning support for mathematics and statistics was found to range from that which is embedded into the design and delivery of selected modules within particular programmes of study through to comprehensive and highly visible systems of university-wide support including Mathematics and Statistics Support Centres (MSSC) where resources and tutorial guidance are available to all students on a drop-in basis. Decision-making concerning the latter is undertaken at senior management level, and is increasingly linked to a wider set of strategic considerations that include: outreach; access; and, student recruitment, retention, achievement, progression and employability (Department for Business, Innovation and Skills, 2011). Significant variations occur between institutions both in terms of the support that is currently available to students, and the stages reached in the development of that provision. In some universities support is integrated into the design and delivery of the curriculum, and there are no references to it in the content of either their websites or OFFA Agreements rendering it invisible. In others, comprehensive support systems have been established that combine access to on-line and other resources with one-to-one tutorial support made available via a MSSC. In such cases, MSS is often part of wider systems of learning and other forms of support made available to students.

Future vision

Many of the senior managers questioned indicated that they recognised the need to go on improving the effectiveness of their MSS, and that its provision is increasingly seen as being integral to the university-wide systems of support that institutions now offer to students as part of their core provision. From their perspective this has given rise to the need for accredited continuing professional development (CPD) for: specialist staff working in MSSCs; academics seeking to embed MSS into the design and delivery of their courses; and, senior managers responsible for the strategic planning of the student experience. There was however, a shared assumption amongst those interviewed that in the absence of external funding for new teaching and learning initiatives, universities will need to couple self-reliance with the support available to them via the **sigma** Network, the Higher Education Academy (HEA), subject associations such as the Institute of Physics (IoP), Mathematics Statistics and Operational Research (MSOR), Royal Society of Chemistry (RSC) and Royal Statistical Society (RSS), and other professional bodies. Further collaboration between universities was also advocated, with some senior managers in favour of the sharing of experiences being facilitated through the **sigma** Network's regional hubs, and others expressing a preference of groupings of 'like universities' on the grounds that the latter would have problems in common that needed to be addressed, and would be able to build on existing partnership arrangements. Overall, positive suggestions were forthcoming about the support that institutions across the sector would welcome in order to further develop and professionalise the delivery of their MSS, and it was recognised that in this respect the **sigma** Network has the intellectual capital needed to fulfill a leadership role in the ongoing development and dissemination of effective practice.

Conclusions

Whilst it is recognised that steps are already been taken by the government to change the post-16 curriculum and the related examination system in England through, for example, the introduction in 2015 of 'Core Maths', and the changes to AS and A-level Mathematics that are currently at the planning stage, it will be several years before students (who hopefully will have benefited from their experience of the reformed system) enter HE. During that time the need for MSS in institutions across the whole HE sector will be as great as ever. The **sigma** Network has demonstrated over the lifetime of its funding that it has the capacity to fulfill a vital leadership role in the development and dissemination of effective practice in MSS during the five-year transitional phase that lies ahead of the HE sector in England.

References

Barnett, R. (2000) University Knowledge in an Age of Supercomplexity. Higher Education, vol. 40 (4) pp.409-422.

Braun, V. and Clarke, V. (2006) Using thematic analysis in psychology. Qualitative Research in Psychology, vol 3. pp.77-101.

British Educational Research Association (2011) Ethical Guidelines for Educational Research. [Online] Accessed via: http:// www. bera.ac.uk/wp-content/…/2014/02/BERA-Ethical-Guidelines-2011-pdf. (02 January 2014).

Department for Business, Innovation and Skills (2011) Students at the Heart of the System. June 2011. [online] Accessed via:http://www.bis.gov.uk/assets/biscore/higher-education/docs/h/11-944-higher-education-students-at-the-heart-of-system,pdf (11 Juen 2014)

Hillman, J. (2014) Mathematics after 16: the state of play, challenges and ways ahead. London: Nuffield Foundation.

Hodgen J., Pepper D, Sturman and Graham L. and Ruddock G, (2010) Is the UK an outlier? An international comparison of upper secondary mathematics education. London: Nuffield Foundation.

Hodgen, J. Marks, R. and Pepper, D. (2013) Country profile: England. London: Nuffield Foundation.

Kvale, S. and Brinkmann, S. (2009) Interviews: Learning the Craft of Qualitative Research Interviewing (Second edition). Los Angeles, London, New Delhi and Singapore: SAGE Publications.

Tolley, H. and Mackenzie, H, (2015) Senior Management Perspectives on Mathematics and Statistics Support in Higher Education. **sigma** & HEFCE. [Available online from www.sigma-network.ac.uk]

UCAS (2014) End of Cycle Report (2014): UCAS Analysis and Research. Cheltenham: UCAS.

Acknowledgements

The authors would like to express their appreciation for the help and support they have received in the conduct of the research from the **sigma** Directorate (Professor Tony Croft, Professor Duncan Lawson and Michael Grove), from Professor Les Ebdon (Director of Fair Access to Higher Education) and from a senior member of staff (and their personal assistants) from each of the HEIs that participated in this research.

How do our students revise?

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Abstract

Student strategy in planning and executing revision for examinations appears to be an under-investigated area of educational research, frequently subsumed, where considered at all, under the more general category of theories of learning. Since students are known to exhibit strategic behaviours in their approach to learning, one should expect that student revision takes on a distinctive form due to the time and performance pressures that are exerted.

In order to contribute towards filling the knowledge gap in this area, we have investigated the revision habits of a cohort of joint honours (Maths and X) students on a recent first-year module at the University of Leeds.

We found that the students principally use traditional sources of revision material (lecture notes, example sheets, past papers), together with online materials such as e-assessments (where available) and web resources. Students revise both individually and in groups. They tend to use resources they perceive as giving high utility, and on-line access data showed evidence of some last-minute and late-night cramming. A key finding of interest is the possibility of a change in perception of the reasons for using web-based and textbook resources, with the Internet functioning as a source for exposition and textbooks being seen as a source for exercises.

We conclude that lecturers should consider how to support student revision through judicious choice of online resources and supplying exercises that are designed for use by groups of revising students.

Introduction

University mathematics relies heavily on the closed-book examination as the dominant mode of assessment (Iannone and Simpson, 2011). Since students are not permitted to take notes of any kind into the examination, and may have access to at most a limited formula sheet in the examination, revision of course material and basic mathematical facts is necessary in order to perform well in an exam.

Readers may be able to recall how they revised for their own examinations: perhaps working through lecture notes methodically, analysing past papers for patterns, or cramming at the last minute. Whatever activities were used, and whatever overall blend and strategy were employed, it is likely that there were great difference from the way in which learning occurred during teaching, where time pressures were far less obvious and the learning was less immediately directed towards passing a closed-book examination.

One might consider approaching the question of student revision from a theoretical standpoint. However, it is well known that students exhibit strategic behaviour around learning (Marton and Säljö, 1976); it is reasonable to expect no less at examination time. It seems unlikely, therefore, that a general theory of learning with little room for time pressure, test anxiety or student strategy can accommodate revision comfortably.

Nevertheless, understanding student revision is an important activity. A recent report found that degree class correlates with employment outcomes, both status and salary (de Vries, 2015); indeed, degree class is treated as a proxy for wider educational outcome. Given the dominance of closed-book examinations in university mathematics, revision strategy is likely to form a significant component of student success throughout their degree.

It is therefore surprising to observe that student behaviour around examinations has not been given much rigorous scholarly attention. It may be that this is a consequence of assumptions made by lecturing staff: that students revise in the way that they did, or perhaps did not, or that students revise the way that staff think is best, or perhaps worst. If this picture is true, then student revision practices constitute a gap in our knowledge whose filling is long overdue.

In pursuit of filling this gap in knowledge, we conducted a study of student behaviour. The research questions that we were able to pursue through this study were the following.

1. What revision activities do students conduct?
2. How does the students' emphasis on these activities relate to the utility they perceive them to give?

Methods

The cohort of students considered in this study was taking a first-year differential equations module (MATH1400) for joint honours students, with 144 students at the end of the year. One of us (PJW) was the lecturer for the module. Since previous experience had shown that it can be difficult to encourage students to engage with studies of this type when the immediate researcher contact is also the lecturer, the other of us (SH) was recruited as an undergraduate summer intern.

The sources of data used in the study may be categorised, firstly, by the involvement of the study subjects. From the point of view of the students, the collection of some of the data requires them to take the initiative in responding (active), while for others the data collection is passive (Table 1). Students were all informed of the study's aims and offered the opportunity to withdraw from the collection of data and, before they engaged actively in surveys or studies, were informed of their rights of withdrawal and the way in which their data would be handled.

Passive	Active
Lecture video access data. Dewis e-assessment access data. Maths Support Centre data. Lecturer experience.	Survey of student cohort. Interviews with student volunteers.

Table 1: Sources of data interrogated during the study

The initial survey asked students to consider their revision for MATH1400, and within that context to rank various sources of revision material by perceived utility and by amount of use. They were also asked for any additional activities they had participated in, and about whether they thought some of the materials provided by the lecturer or university were adequate.

Students who completed this survey were offered the opportunity to participate in more in-depth interviews that probed some of the themes emerging from the survey answers.

Outcomes

Unfortunately, the intention to increase student engagement with the study appeared not to have worked as much as hoped, with only 17 students participating in the survey, and only 2 engaging with the interviews.

Nevertheless, despite the disappointing turnout for the active components of the study, some useful results arose from the data. Many of the results were predictable: for instance, students reported making most use of lecture notes, example sheets, past papers, online assessments and web resources, and they reported making least use of lecturer contact, textbooks and the Maths Support Centre (MSC). In particular, the MSC's data identified only one student who used it for the module under consideration: we suspect that the others saying they used the MSC did so for other modules. Two students of the 17 reported that they revised as part of a group of friends.

We observed good correlations between the utility that students ascribed to their sources of revision material and the amount that they reported using those same materials. The one noticeable deviant from the general trend was direct contact with the lecturer, where students rated its usefulness some little way higher than their use of it. (The lecturer's own experience was of an abnormally low rate of contact.) We conjecture that this might in part have been due to the fact that staff offices were temporarily located around campus while the Maths building was being refurbished. Unfortunately, no students exhibiting a large gap between these two figures was interviewed so we were unable to test this conjecture in detail.

Within the access data, we looked at time of access. Although quite a small proportion of students used the lecture videos during the revision period, of those who did a noticeable fraction of the accesses occurred late at night or early in the morning immediately preceding the examination. This was not the case for the e-assessments. We conjecture that students performing late-night cramming would not feel able to carry out an activity that required serious mental engagement, such as solving a differential equation, but would be able to do something more passive, such as watching a video.

Among other themes, we explored the difference between textbooks and online resources in the interviews, during which a student volunteered that they used webpages for exposition and textbooks for exercises (Quote 1).

"If a webpage is useless for you because you do not understand the procedure, you can go through another. In a book, you cannot do that. However, to find examples and exercises, I think a textbook is easier."

Quote 1: Student comment on textbooks and webpages

Discussion

Much of the material gathered confirmed ideas that likely exist among academics: past papers, lecture notes and example sheets feature heavily in student revision, and some students engage in last-minute cramming. However, alongside this stand some observations with potential implications for practice, particularly if they are indicative of wider trends.

The lack of usage of the Maths Support Centre was a concerning feature, since joint honours students are squarely within its remit. We suggest that lecturers think carefully how to encourage their students to make use of this resource: clearly, merely encouraging students (both in person and by email) to go was insufficient.

The issue of lecturer support for revision is one that arose from the data: student requests for more exercises, especially for revision purposes, are a well-known feature of teaching. Joined with the issue of revising in groups, it may be that a worthwhile approach would be to develop exercises, games or other revision aids that work optimally in groups so that students are encouraged to band together with friends in order to learn from each other.

Finally, the student comment (Quote 1) on the distinction in usefulness for textbooks compared to online resources suggests that the way lecturers think about reading lists may be worth revisiting. Certainly, if students often go to textbooks for their exercises, then the reading list should be chosen more for the exercises at the end of a chapter than the text within the chapter; and if students make use of the Web for expository resources, then perhaps lecturers should consider adding Web resources to their reading lists in order to encourage the use of resources of known quality. It may also be that good practice could include annotating or sectioning reading lists to signal resources with strengths in explanation or example.

Further study

One immediate avenue for further study is to repeat this study, with some extension and improvement, for a wider cohort or cohorts of students. Collaboration with other institutions, and across cohorts with different characteristics (carefully considered), would enhance the applicability of any findings.

The topic of student revision naturally extends itself over a wide range of interesting research questions. It is clear that in addition to identifying activities in which students might engage, one might wish to probe the strategies that students deploy: that is, the ways in which different activities are blended into an overall approach to revision. In that context, one would have to consider the appropriate use of relaxation time as well as work time, the time of day at which activities were conducted, and the question of intentional structuring of revision schedules.

The most obvious long-term goal of any study of this nature is to identify successful and unsuccessful revision strategies. Currently, the abundance of advice that is offered to students about revision is apparently ungrounded in any robust research; it would surely be better were such a grounding to be found, and the advice tailored accordingly.

However, the ultimate goal must be to change how we examine students. Firstly, by helping students to revise better, we are freed to set more stretching examinations, but beyond that we may consider changing the way in which we examine altogether. Closed-book examinations require lots of memorisation, and tend to encourage a mind-set in which students forget what they learnt for the exam as soon as it is over. If we wish to see students carry what they learnt through to subsequent units of study, then we must find out how to construct examinations that reward the retention of mathematical understanding for the long term, and determine which revision strategies meet this goal.

Acknowledgements

This work was funded by the School of Mathematics at the University of Leeds under an internally-administered EPSRC Summer Intern scheme.

References

De Vries, R. (2014). Earning by Degrees. Sutton Trust.

Iannone, P., & Simpson, A. (2011). The summative assessment diet: how we assess in mathematics degrees. Teaching Mathematics and Its Applications, Vol. 30 (No. 4), 186–196. doi:10.1093/teamat/hrr017

Marton, F., & Säljö, R. (1976). On qualitative differences in learning: I - Outcome and process. British Journal of Educational Psychology, Vol. 46 (No. 1), 4–11. doi:10.1111/j.2044-8279.1976.tb02980.x

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