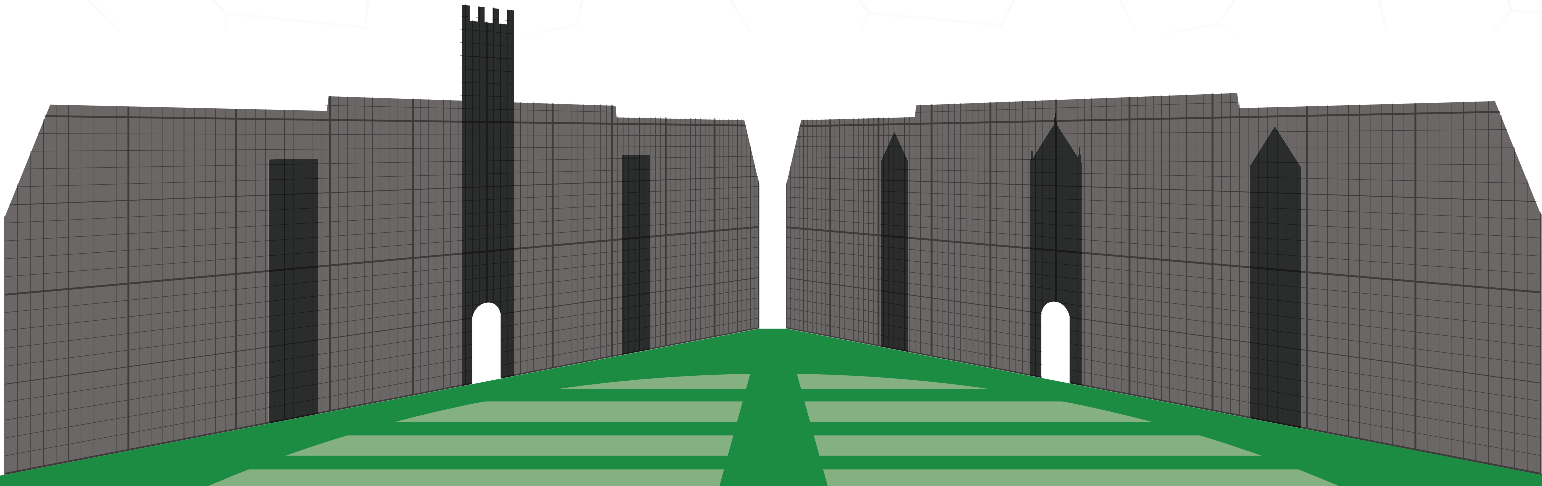
Conference Proceedings



Brave New World

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6th - 7th September

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Contents

Engaging students through peer mentoring: engaging & collaborative teaching & learning of mathematics at FHEQ Level 4 in engineering degree programmes

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Abstract

Teaching mathematics to engineers continues to be a challenge, with different approaches in use across the HE sector. At Southampton Solent University, our widening participation agenda means the inclusion of students who might not otherwise participate in Higher Education (HE). This compounds the challenge of getting all students to the standards required by our IET-accredited degrees. The teaching of mathematics at level 4 has been the focus of a series of improvements, including piloting Peer Mentoring during 2015-16. Previous improvements have aimed to engage students in their learning in mathematics, and pass rates have increased since the introduction of these improvements.

To address student engagement, a peer mentoring programme was implemented in the 2015-16 year, following the model demonstrated by Pugh at Leeds. Student volunteers were recruited and trained, with mentoring sessions running on alternating weeks until the spring break. Although take-up of the mentoring sessions reduced as the year progressed, there was a further increase in pass rates this academic year. From the answers to a questionnaire, it is clear the students who participated in the mentoring sessions felt very engaged in their learning. The peer mentors also valued the experience. A very enthusiastic group of students have volunteered to become mentors in 2016-17, with suggestions to broaden the remit from solely mathematics to all first year engineering topics. The commitment of the volunteers for 2016-17, along with the increased pass rate for the unit suggests the pilot programme has been a success and should be continued!

1. Introduction

Engineering in all its variations is important for the UK, thus educating engineers must be seen as a key task of the UK education system: "*The appropriate education of engineers and scientists is an important element in the economic well-being of the United Kingdom, in common with other industrialised countries. Within that education, the mathematics component has a central role.*" (Mustoe, 2001:2).

Mathematics allows engineering to go from ideas to plans and from plans to reality, and getting students able to use mathematics to solve engineering problems is one of the key teaching concepts within an engineering degree programme. The task is made more difficult by widening participation in HE which has produced some students less well qualified for starting courses (Mustoe, 2001:2), and has been exacerbated by the perception that the mathematics background of students is continuing to decline, "*For many years concern has been expressed about the decline in mathematical skills* *possessed by the entrants to engineering and science degree programmes*." (Mustoe, 2001:2).

Furthermore, the students' feeling about their ability to do mathematics is important, with a failure cycle and a success cycle proposed by Ernest: "*Positive achievement and success in mathematics often lead to enhanced attitudes and raised confidence, resulting in increased effort and persistence, and further success*" (Ernest, 2001:4). Poor performance in mathematics can be serious, "*a minority of students caught in such a cycle may be discouraged enough to give up their studies*" (Ernest, 2001:4).

2. Teaching, learning & assessing mathematics in engineering at Southampton Solent University (SSU)

2.1. Current teaching practices in mathematics in HE

There are a number aspects of / approaches to teaching mathematics to engineering students at university that are discussed in the literature. Examples include:

- Streaming students by ability, with varied teaching style.
- Traditional vs utilitarian approaches to mathematics teaching (Blockley & Woodman, 2001:6).
- Mathematics teaching handled by a Mathematics Department, or taught as needed within an Engineering Department.
- Integrating the teaching of mathematics into engineering and other applied sciences (Ernest, 2001:5), (Christy, 2001:18), (LTSN MathsTEAM, 2001:3).
- Interactive lectures, using personal response handsets (McKay, 2001:16).
- Problem-driven teaching of mathematics (Otung, 2001:36; Yates 2001:40; Beale, 2001:30).
- Variations in structure of teaching, such as the Keller plan (self-paced worksheets-based learning) (Hubbard, 1991).
- Small group learning, to reduce mathematics anxiety (Hubbard, 1991:21).

2.2. How does this fit with other teaching theory?

In general, the approaches in teaching mathematics by other universities align well with teaching theory. For example, the use of tutorials, problem sessions, interactive lectures and group working could be considered Biggs' active learning style, and will better engage some types of learner (Biggs, 2003:3). Many of the learning activities mentioned will support social interaction in learning (Hedegaard, 1996:171), including problem sessions, small group learning, and use of interactive lectures. Most approaches recognize the need for students to do some work themselves to learn, rather than a passive experience such as that offered by lectures (Van der Veer and Valsiner, 1994:355). Proponents of teaching methods which utilise a variety of activities are planning inclusive teaching methods to engage all students (May and Thomas, 2010:8). The interactive lectures used at Strathclyde (McKay, 2001:16) and small group learning proposed by Hubbard (1991:21) seem quite student-centred, and focus on "*creating activities and giving opportunities for students to discuss, explain and debate during class*" (million+, 2012:5).

2.3. How mathematics in engineering is taught & assessed at SSU

Presently the delivery mode for mathematics at SSU is a one-hour lecture and a 2 hour tutorial session each week. Each concept is presented in a lecture, and then appears in a tutorial problem set, in a homework problem set, and in the following week's formative test. Assessment is by an exam (60%) and the best 4 grades from 5 'phase tests' (40%), with a minimum of 30% required in each assessment element, before aggregation can be applied, and a 40% minimum aggregated score as a required pass threshold, as required by the accrediting body. The phase tests are in class tests which cover only one topic area from the syllabus, (e.g. pre-calculus, complex numbers, vector geometry with linear algebra, calculus, or applications of calculus), and are thus an intermediate step in assessment between the weekly formative test and the end of year exam.

Engagement of students has been identified within the Engineering group as being extremely important, and is assessed by student attendance, as well as by formative test scores and attempts at homework. Students with low attendance at mathematics lectures or tutorial sessions are identified as part of the Engineering-wide attendance monitoring effort; students with poor engagement in mathematics or other units are invited for interview in weeks 6 and 12 to emphasize the importance of engagement.

Our teaching style combines traditional elements, lectures, with more interactive sessions, tutorials and support sessions. The students are encouraged to learn actively (Biggs, 2003:3) during the tutorial sessions, as they must use the theory they have learned to work through problems, which require the application of that theory (Van der Veer and Valsiner, 1994:355). The tutorials allow group working (Hedegaard, 1996:171), as the students may work on problems together. In the tutorial, there is time for individual help, or help for groups of students. There is a formative test each week during the tutorial session, which allows the students to see if their understanding of the previous week's material is sufficiently embedded to be usable, and which recognizes assessment and feedback are crucial to learning (Race, 2012:40). The solutions to the test questions are worked through on the board, ensuring the students see how the problem was approached and solved, as well as seeing the correct answer - as emphasized by Hubbard, both are important in teaching mathematics (Hubbard, 1991:61).

3. Introduction of peer mentoring to support teaching, learning, & assessment of mathematics in engineering at SSU

One additional hour of small group teaching was provided prior to 2015-16, however uptake was low. Following some good practice exemplified by the PAL programme setup by Dr Samantha Pugh, in the Faculty of Mathematics and Physical Sciences, at University of Leeds, a decision was made to replace the optional staff-managed support sessions with Peer Mentoring Sessions.

Student volunteers were recruited at the end of the 2014-15 academic year, and, following training, ran the mentoring session every fortnight. Engagement in the sessions started at good levels; when attendance dropped off the sessions were stopped.

From the answers to a questionnaire, it seems that both the mentors and the mentees gained confidence and generally benefitted from the experience. A group of students have volunteered to become mentors in 2016-17, and the remit of the sessions will be broadened to include general first-year engineering topics. An analysis of the effectiveness of the mentoring in the light of unit assessment results will now be considered.

4. Results/analysis of introducing peer mentoring to support teaching, learning, & assessment of mathematics in engineering at SSU

4.1. Mathematics assessment results prior to introduction of peer mentoring at SSU

Figure 1 and Tables 1 and 2 summarises the assessment results in the academic years directly prior to the introduction of Peer Mentoring at SSU.

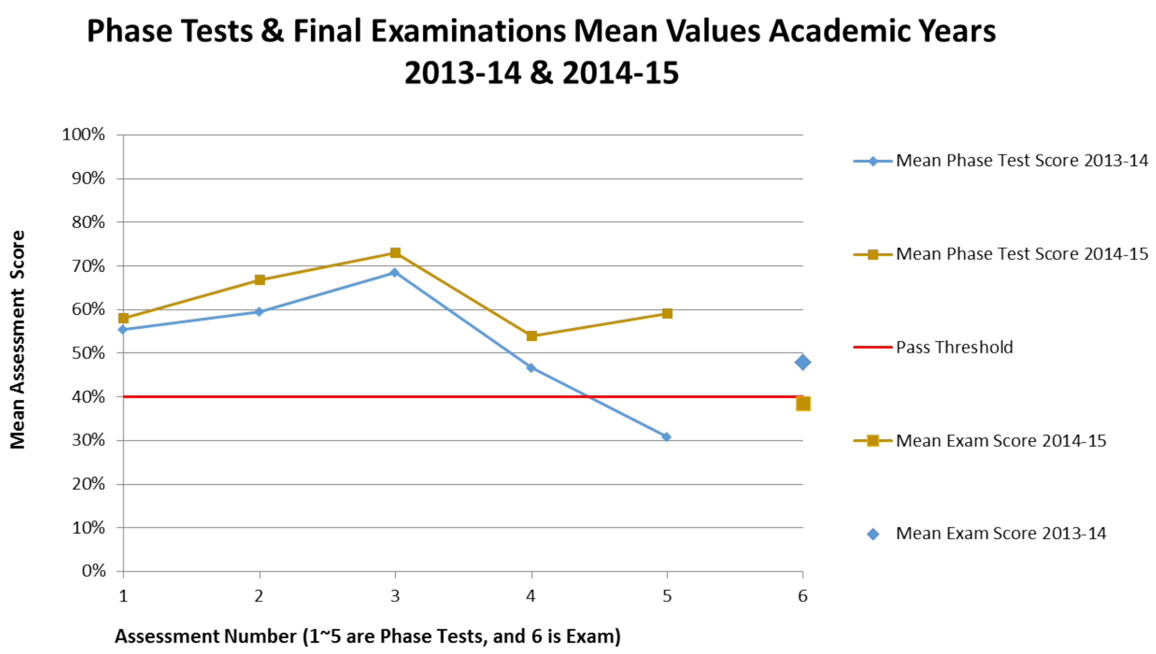

Figure 1. Phase tests and final examination mean values for academic year 2013-14 and 2014-15.

	2012-13	2013-14	2014-15
BEng (EMS400)	49%	70%	54%

Table 1. Unit pass rates prior to peer mentoring.

	Overall For 2014-15	BEng (Hons) Electronic Engineering	BEng (Hons) Mechanical Engineering
Unit Pass Rate	54%	71%	33%
Unit Mean Average	47%	53%	39%
Unit Standard Deviation	24%	24%	23%

Table 2. BEng (EMS400) 2014-15 cohort breakdown.

There appears to have been a clear cohort issue in 2014-15 with the BEng (Hons) Mechanical Engineering students.

4.2. Mathematics assessment results after introduction of peer mentoring at SSU

Figure 2, along with Tables 3 and 4, summarises the assessment results in the academic year directly after the introduction of Peer Mentoring at SSU.

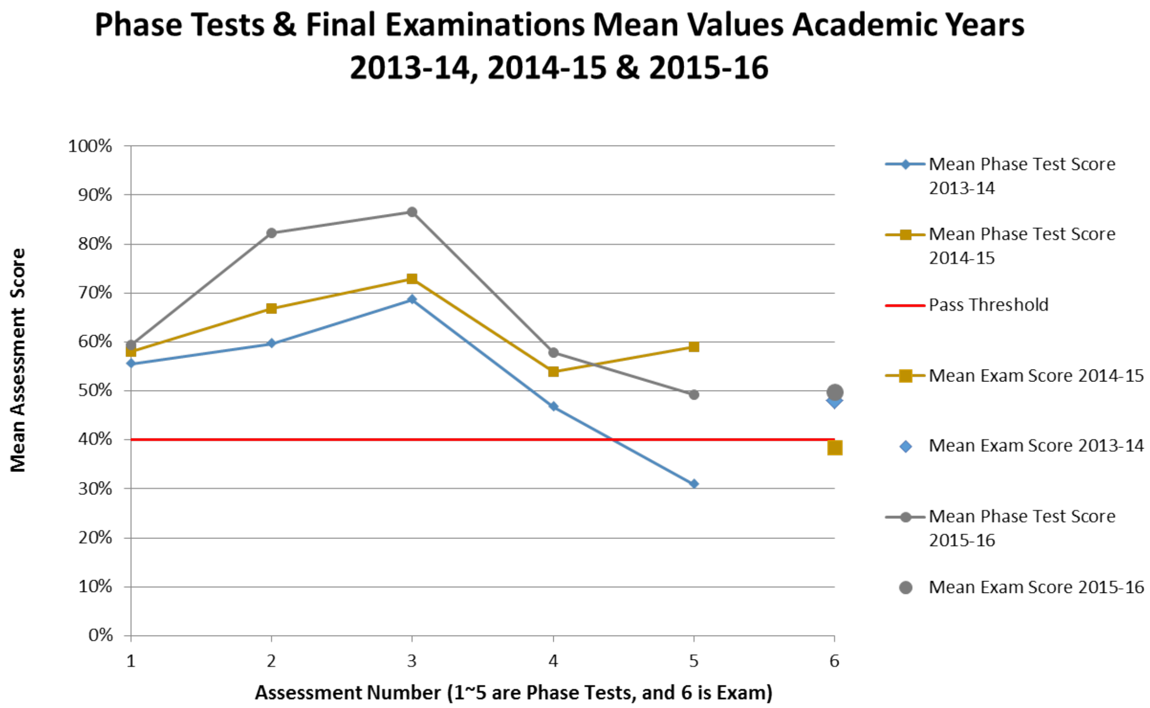

Figure 1. Phase tests and final examination mean values for academic year 2013-14 2014-15 and 2015-16.

	2012-13	2013-14	2014-15	2015-16
BEng (EMS400)	49%	70%	54%	83%

Table 3. Unit Pass Rates After Peer Mentoring.

	Overall For 2014-15	BEng (Hons) Electronic Engineering	BEng (Hons) Mechanical Engineering
Unit Pass Rate	83%	89%	81%
Unit Mean Average	56%	55%	56%
Unit Standard Deviation	21%	15%	23%

Table 4. BEng (EMS400) 2015-16 cohort breakdown.

4.3. Analysis of results of introduction of peer mentoring at SSU

Figure 3 explores the potential correlation between overall unit scores and attendance at peer monitoring sessions.

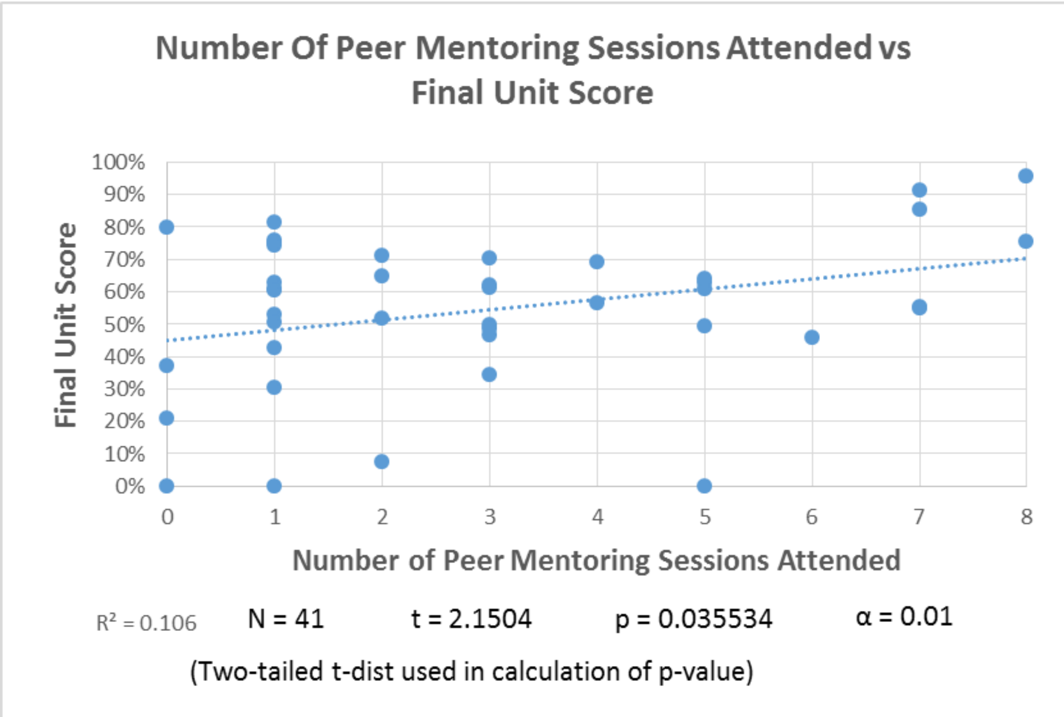

Figure 3. Number of peer mentoring sessions attended vs. final unit score. Note: (NB: The square of the Pearson correlation coefficient (r-value), and t-value, p-value, etc., shown above, are only shown for sake of completeness. Clearly, on inspection, the data spread doesn't suggest a linear correlation, so calculation of these is not strictly necessary in this case. The p-value was computed, based on a calculated t-value, which was then applied to a two-tailed t-distribution, with N=41).

5. Discussion of results/analysis

Based on the above results/analysis it seems clear that mathematics unit assessment results within engineering have improved overall at SSU since the introduction of peer mentoring.

There also appears to have been a ‘leveling-out’ of cohort differences between mechanical engineering and electronic engineering BEng (Hons) students.

Questionnaire responses from student mentors and mentees were highly positive, suggesting that a critical mass of students *felt* that they benefitted from the experience.

Perhaps surprisingly, though, the data thus far does not appear to support a statistically significant correlation between attendance at peer mentoring sessions, and overall student performance on assessments.

6. Conclusions and recommendations for future action

6.1. Practical recommendations

Based on the above discussion of the results/analysis, coupled with the overall highly positive questionnaire responses of students involved in the peer mentoring programme in the 2015-16 academic year, the mentoring programme will extend the topics covered to include general engineering, link mentoring to Engineering Society activities, to further encourage engagement, and increase the visibility of the mentors by including them in Welcome Week activities.

6.2. Recommendations for further monitoring, data collection/analysis, and hypothesis testing

Despite the apparent improvement in results, the data/analysis doesn’t seem to support a statistically significant correlation between students’ attainment and attendance at peer mentoring sessions:

- **Question 1:** Why do we suspect that Peer Mentoring is actually helping students, in its current form, and hence might be usefully extended, as outlined above?
- **Question 2:** If we suspect Peer Mentoring helps students, then what further data might we gather, and what analysis might we perform, in order to test this suspicion, and to support decisions on future continuous improvement plans?

6.2.1. To address question 1

Our Hypothesis: Based on anecdotal evidence, we suspect that students who do attend peer mentoring sessions frequently, are then forming ad-hoc peer networks, that include students who don’t attend those sessions as frequently/at all, and that students in these networks are then assisting each other in their study processes outside of both formal and peer mentoring sessions. We suspect that, without the peer mentoring sessions to act as a seeding process, generating an environment in which collaboration is encouraged, these ad-hoc peer networks would not form in the current manner.

6.2.2. To address question 2

- We will administer questionnaires, via a third party, who will be unaware of the intention behind the questions asked.

- We will endeavour to determine if students are attending peer mentoring sessions, and how often, and if they are also working with students who don't attend.
- We may find that some students did not attend any peer mentoring sessions, or other study groups. This group of students would form a control group.
- Analysing the data could then start with simple correlative analysis against phase test and exam results, with an appropriate statistical significance test to support it.
- The conclusions we will draw will not be as robust as a truly rigorous study, but will guide us in directing our efforts for future improvements.

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A combination of industry collaboration and flipped classroom to increase learners' confidence and skillset

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Ben Nicholas, GlaxoSmithKline

Abstract
This paper discusses a new 15-credit module on Data Analytics taught at the University of Greenwich to level 6 students in the Department of Mathematical Sciences. The module was designed with significant input from industry which is documented here.

The paper starts by explaining the motivation behind the module from both the employer's and the University's perspective. It then discusses the reasoning behind the way in which the material is presented to students and ends with a summary of the results and student feedback.

Noel-Ann Bradshaw is the Faculty Director of Employability in the Faculty of Architecture, Computing and Humanities at the University of Greenwich. She has instigated several employability innovations within her teaching in the Department of Mathematical Sciences and is now responsible for rolling out a set of Employability Descriptors at Greenwich in order to help firmly embed employability within the undergraduate curriculum.

Ben Nicholas is the Director of Global HR Reporting and Analytics at GlaxoSmithKline. His role focuses on ensuring the company's management has the people-related reports required to manage the workforce and delivering analytical projects to provide specific insights to improve decision making and track corporate strategies.

1. Background
The University of Greenwich has a mix of mature students and school leavers among its 20,000 on-campus student body, with 39% over the age of 24. Over half the student body is classified as non-white. The Department of Mathematical Sciences is within the Faculty of Architecture, Computing and Humanities and is based at the Old Royal Naval College in Greenwich, south-east London. The Department currently has around 300 undergraduate students.

In the last three to four years there has been a strong steer from University Senior Management for Departments to implement activities and module content designed to improve and enhance the University's Graduate Employment Outcomes as measured by the Destination of Leavers of Higher Education Survey (DLHE). In order to accomplish this the Department has introduced many innovations such as "Maths Graduates: Where are they now?" (Bradshaw, 2012); the IMA Business Game (Bradshaw, 2013); an employer-endorsed assignment (Bradshaw, 2014); mock-interviews with employer involvement (Ramesh et al., 2015) and the promotion of credit-bearing work-based learning placements as well as encouraging the usual sandwich placements (Ramesh et al., 2013).

1.1. Employer's motivation

In common with most companies, analytics roles are becoming more numerous and important at GlaxoSmithKline (GSK). Within Human Resources (HR), GSK has a reporting and analytics function that is responsible for the provision of management information and analytical insights on its 105,000 employee workforce whom work in over 130 different countries. For many years now Industrial Placement (IP) students have been a critical component of the team. The roles are incredibly beneficial to both the company and the students alike as the students quickly acquire the skills needed to perform the role and become integral members of the team.

When recruiting for these roles, experience suggests that the more successful candidates have some general work experience and are better than merely proficient in Microsoft Excel. Being able to demonstrate higher levels of Excel skills in the interview is a good indicator that the applicant has experience in analysing large data sets and the capabilities required to be able to work independently and acquire for themselves the other technical skills required to perform the role in GSK. Therefore the interview includes an Excel test that the majority of shortlisted students interviewed fail emphatically even when they profess to having excellent advanced Excel skills in their applications.

Over recent years, GSK has hired many Greenwich University students into HR Analytics Industrial Placement (IP) roles and onto project teams such as data migration analysts. This has led to a partnership involving a GSK representative attending year-end celebrations and using the GSK Volunteering Day (part of the Corporate Social Responsibility (CSR) policy) to run some Excel master classes in the computer labs for second and third year students with input from IP students and other staff. This year our relationship progressed to helping design and deliver this Data Analytics module that was designed to provide the skills required to be credible in interviews and to perform the introductory tasks in analytical/data orientated roles in business, namely; Excel, SQL to interrogate databases, VBA and use of business intelligence systems to prepare dashboards and visualisations in order that more students may have the skills that are important to being viable as a data/business analyst.

1.2. University's motivation

Staff at the University noted that whenever graduates came to talk to students, regardless of their company role or the sector they were working in, they always talked about how important coding was. For some this was SQL whilst for others this was Python or VBA. All the graduates said how they wished they had done more coding on their degree programme and yet acknowledged that at the time they had not enjoyed the Matlab programming that they had covered and would have been loath to cover more.

1.3. New module

Having talked to both employers and graduates, the Department of Mathematical Sciences concluded that it could do more to equip students for the graduate job market in terms of their skill set but also their autonomy and confidence. It was decided to instigate a new optional module broadly based on data analytics which was becoming a popular employment route for students and which focused on the skills required by GSK and other employers whilst encouraging students to self-learn much of the material.

2. Module content and teaching methods

A day was set aside at GSK for the authors to get together with several recent graduates employed by their HR Analytics Department to discuss the module content.

The graduates at GSK agreed that the module should include Advanced Excel Skills, VBA, SQL and Data Visualisation techniques utilising software like QlikView or Tableau. Discussing this with the recent graduates was very helpful as they understood the restrictions of University systems and the basic structure of a 15-credit University module. Various teaching methods were examined and suggestions proposed for assessments.

The graduates were unanimous that one of the main skills students needed was the ability to be autonomous in the workplace and so to understand how to self-learn. They also required confidence about their ability to do a job in order to be successful in the job application process.

The module leader was already interested in the flipped classroom teaching methodology (Jungic et al., 2015) and was eager to use this in the teaching of new material. Knowing that students learn programming skills best by practice rather than listening to instruction, it seemed appropriate to harness a teaching method that encouraged active self-study rather than passive lecture attendance.

The module leader was also aware of the benefits of Inquiry-Based Learning (Kogan and Laursen, 2014) and was keen to see students develop an increased sense of ownership of their studies resulting in an increase in their self-confidence.

2.1. Assessments

It was decided early on that the module should be assessed by coursework as it is problematic to assess programming skills by examination.

There were two assignments. The first (worth 60% of the overall mark) tested the students' knowledge and understanding of advanced Excel skills, VBA and also asked for critical reflection on various aspects of data analysis in general.

The second required students to create a poster containing data visualisations created with Tableau to present a story to senior management and also included aspects of data mining and data protection. GSK offered a prize for the three best posters consisting of a day at GSK to find out more about the company and about careers in analytics in general.

Several employers from other companies have since commented that taking a large quantity of data and extracting relevant information from it to tell a story is an activity that is often used in assessment centres for graduate jobs.

3. Lecture structure

To encourage students in their self-study the module was designed in such a way that every week the students were encouraged to complete a 'before-lecture task' and watch a short (5 minute) 'before-lecture video' on something connected to the week's topic. This included videos on debugging code, recording (as opposed to writing) a Macro and creating a dashboard in Tableau. These were all activities that were not covered in class but that students were expected to be familiar with before the class by watching the video and doing the activity. This started in the very first week.

The class was timetabled to start with a two-hour lecture at 9am on a Friday morning followed by an hour's break and then an hour's session in a computer lab. This was not ideal but was the way that the timetable had been prepared and so was a given constraint.

Half of the first 'lecture' was spent explaining the motivation for the module and detailing how it would be run. This was designed to excite those who wanted this sort of experience but to put off any students who had chosen the module purely because it was coursework only or because their friends were taking it.

The lab session in the first week consisted of an exercise in Excel to teach basic data editing and manipulating using Excel formulae such as 'trim' 'right' 'mid' etc. The exercise caused so much interest and excitement that neither staff nor students were aware of the time and the class lasted for 15 minutes more than it should have done. This became a recurrent theme in the early lab sessions.

During the term three speakers from industry came to talk to the students during class time. These were Ben Nicholas (GSK) on the motivation behind his involvement in the course, Katherine Brewster (FDM) on how to apply for jobs in data analytics and the benefits of graduate training programmes, and Amir Khan (RBS) on the role of a data analyst. Out of these some other impromptu sessions arose such as interview skills training with RBS and a video interview workshop with FDM.

In the other classes, technical material was not taught as such but merely referred to. For example the explicit syntax of a loop in VBA was not taught but the concept of a loop was explained and discussed with the class as a whole.

Each week students had a very short recap session on the previous week using personal response systems to test their understanding. Some questions were designed to be humorous whilst others enabled the lecturer to see if the students had understood the previous week's content and also provided formative assessment for students on their own understanding. There were also group activities and discussions around data.

In general the classes went well although some finished a little early due to the group activities not lasting as long as had been expected. This is something that will be rectified next year.

4. Results

Initial feedback was very positive. The students were asked to provide their initial thoughts after the first week via the University VLE and 17 chose to do so – this is from students who had previously always refused to participate in similar requests for feedback. There was an overwhelmingly positive response, although a couple of students did express slight concern as to whether they were up to the rigor of self-study. Examples of this feedback can be seen in Table 1.

An informal paper-based survey of students was completed at the end of term. It should be noted that this was only issued to the students who attended on the final week which was a self-selecting sample and likely to be the most enthusiastic. However the comments they made (see Table 1) are particularly encouraging and representative of comments that students had been heard making throughout the course.

Quote	Week
A very interesting course, with lots of new things to learn about. Though it is not meant to be easy, it is a challenge which I am keen to deal with.	1st week
At first, during the lecture, I was unsure. Even when the lecture ended I was slightly on edge. However, after having completed the tutorial which was tough but enjoyable. I feel like I know I should be doing this course.	1st week
Seems like a challenge, will push me to work harder as methods aren't always there to refer to. Like the idea of having to self-teach some content, more likely to stick in my brain this way.	1st week
Employers made me realise how important Excel is.	Final week
Helped me decide what I want to do and pushed me to start applying for jobs.	Final week
I now know I am able to learn new things on my own.	Final week
Have become more confident.	Final week
I am now a step ahead of where I would have been if I hadn't taken this course.	Final week
The course encouraged me to think logically and pay attention to detail	Final week
The videos were a great way to introduce lecture material and useful resource for coursework.	Final week

Table 1. Examples of student feedback on the new module gathered after the first teaching week and then at the end of the module.

Initially the students engaged well with the 'before lecture tasks and videos'. However after the first coursework was released there was a significant drop in the number of students accessing the files. This was disappointing as the second assignment was based on the later material. However from the statistics presented in Table 2 it seems that many of the videos were accessed after the teaching of the course was completed, showing that numerous students decided not to engage with the material until they had to actually complete the second assignment. Interestingly at the time of writing this paper it was noticed that some students had accessed the files after all assessments had been completed presumably for preparation for job applications and interviews.

	Percentage of students undertaking particular activities			
Main topic each week	**Before class activity completed BEFORE class**	**Before class activity completed AFTER class**	**Watched video BEFORE class**	**Watched video AFTER class**
Advanced Excel	80.7	95.5	68.2	85.2
Lookup	71.6	89.8	67.0	93.2
Pivot	69.3	85.2	72.7	96.6
VBA1	72.7	85.2	71.6	98.9

VBA2 - Loops	53.4	68.2	44.3	73.9
VBA3 - User form	55.7	68.2	44.3	83.0
SQL/LinkedIn	36.4	62.5	10.2	26.1
SQL	31.8	51.1	31.8	59.1
Data protection	31.8	53.4	21.6	52.3
Data mining	17.0	37.5	18.2	62.5
Tableau 1	21.6	42.0	25.0	76.1
Tableau 2	13.6	28.4	13.6	45.5

Table 2. Percentage of students who completed various activities before or after class.

5. Conclusions and future work

The module has been very popular with students and final year students employed as ambassadors have been overheard talking positively about it to prospective students at open days and applicant taster events. Anecdotally there appears to be more of this year's cohort obtaining jobs within data analytics and being interested in this as a career. Also the number of students applying and obtaining places on Master's programmes in data science has increased enormously. What is particularly pleasing is that student feedback implies that this has helped increase confidence and their ability to be more proactive learners and indeed in the 2016 National Student Survey 91% of this cohort (BSc Mathematics) said that their degree had helped them present themselves with confidence putting Greenwich in joint second place for this question.

Input from other companies has been forthcoming with many employers endorsing the mindsets and skills that are being taught. One employer in particular is producing a series of case studies that can be used for small group work during the 'lecture' time. These are themed to fit in with the topics that the students will be focusing on and will encourage students to think through relevant real-world problems that they will not have come across before.

The initial overall evidence of the module's content and delivery style indicates this is delivering benefits across the spectrum. Potential employers have had the opportunity to input into academia the type of skills required in the ever-growing analytics domain and equally importantly building the ability of employees entering the workforce to self-teach and research the skillsets they need to build. At the same time the University of Greenwich is delivering a new popular module that meets industry's needs and enhances the marketability of their students.

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STEM Enable: a new website for locating information to assist disabled students

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Abstract
STEM Enable is a new website, currently hosted at http://stemenable.referata.com/, produced with the support of the Institute of Physics. It is designed to assist students and staff, in a variety of roles, to locate and share information to enable disabled students studying Science, Technology, Engineering and Mathematics (STEM). STEM Enable takes the form of a semantic wiki. This will allow registered contributors, who have specialist knowledge in accessing STEM subjects, to add information in a collaborative manner and so build the content of the site over time via crowd-sourcing. Visitors are able to query the site as if it were a database and to explore the complex structured information available in this specialist area. This is accomplished by providing a mechanism for contributors to input meta-information and so encode relationships between concepts, processes, technologies and document formats.

1. Background
Science, Technology, Engineering and Mathematical (STEM) studies can involve barriers not typically met by disabled students in other subject areas (Cliffe, 2015; Cliffe and Rowlett, 2012; Cliffe and White, 2012; Cooper et al., 2008; Cryer, 2013; Hughes and Leavitt, 2013; Maddox, 2007; Naysmith, 2011; Rowlett, 2011; Spybey, 2012; Whapples, 2007; Williams and Irving, 2012). As previously reported, these barriers may not be anticipated or successfully resolved due to the lack of clear guidance for staff and students in locating, understanding and using specialist technologies, processes and document formats.

For example, a disabled student studying a mathematical subject may need to use specialist reading and authoring tools for working with mathematical text and may also need to replace pen and paper when *doing* mathematics. Authoring mathematics and recording rough work without using pen and paper are advanced skills and advice may be required on selecting software or hardware, how to *do* mathematics effectively without pen and paper as well as on the independent and efficient production of output others can read. For a student to use specialist reading and authoring tools they require resources in which the text, formulae, images and tables are all accessible. The student, their lecturers, support staff and possibly librarians may all need to produce these. Unfortunately, most common production methods for mathematical and scientific documents are *lossy* as the structure of the mathematical formulae is lost or never encoded. This is true of PDF, print, images, PowerPoint and many Ebook formats. Hence, students and staff need information on specialist accessible formats suitable for use in mathematical subjects.

The software and formats used to achieve the above are rapidly changing. However, complex combinations of software are still required to produce accessible formats, access reading and produce mathematical text using assistive technologies. It can be difficult for staff without a mathematics accessibility background to install, test and use these complex combinations without careful guidance. Finally, the difficulties are interconnected: the approach a student needs to use is dependent on the formats that can be produced and this in turn depends on the working methods of the authors and on software availability. It is therefore essential that staff and students collaborate to find working methods that are effective for all.

Such a collaboration can be supported by separating information for each role while linking to that aimed at other roles. For instance, a disability adviser may only need to know that there *exists* some method. However, when assessing feasibility in context they may need to direct document conversion staff to the details; give computing support precise purchase, installation and test instructions and communicate to lecturers the detail of the specific formats needed.

A student, while they have every right to access the full range of information – particularly for reference post-graduation – is unlikely to want all this information simultaneously at the start of their degree. In fact, it is reasonable for them to expect to be guided by a needs assessor and assistive technology trainer, who will usually have little experience with specialist STEM technologies and so will themselves also need facets of the above information appropriate to their role.

It has previously (Cliffe, 2015; Hughes and Leavitt, 2013; Naysmith, 2011) been established that producing such guidance locally is time-consuming and costly. The solution often proposed (Cliffe and Withington, 2013; Cryer, 2013) is the collation of a central knowledge base, suitable for multiple roles and which enables institutions to build on good practice rather than re-inventing the wheel.

1.1. Previous attempts to capture the information

Previous attempts have been made by UK practitioners to capture STEM accessibility guidance. Some of these have merit and should not be discounted while others floundered due to the difficulties of capturing such complex information. Static resources have become rapidly out of date in this changing context, and in no case was the scope wide enough to capture the full range of approaches including necessary technical details.

Strategies for Creating Inclusive Programmes of Study (SCIPS), led by Val Chapman (2008), is a resource which brings out some of the barriers faced in STEM subjects. However, SCIPS did not seek to communicate technical information so does not document many solutions. Various projects and publications were made through the Higher Education Academy Mathematics, Statistics and Operational Research (MSOR) subject centre (e.g. Ball, 2008; Cliffe, 2009; Cliffe and Rowlett, 2012; Cliffe and White, 2012; Cooper, 2006, 2006; Draffan, 2001; Maddox, 2007; Pfluegel et al., 2011; Rowlett, 2009, 2008, 2010; Rowlett et al., 2008; Rowlett and Rowlett, 2009; Trott, 2003a, 2003b; Webb, 2011; Whapples, 2007) but the content necessarily reflects the knowledge and interests of those who submitted papers and many are now out of date.

The National HE STEM Programme funded some of the latter but also a project entitled *Visual Impairment & STEM.* This was a participatory project to develop good practice in assisting visually impaired STEM students with emphasis on inclusive laboratory provision and positive pre-entry outreach but some facets of the project considered the provision of information regarding STEM access to non-specialists. The event *Are we doing it right?* (Cliffe and Withington, 2013) reported a recommendation that a national resource capturing clear guidance be produced. A website *STEM Learning and Teaching Reconfigured* (Waterfield and Draffan, 2012) which aimed to "*demonstrate ways to help you support visually impaired and blind students who join your Science, Technology, Engineering and Mathematics (STEM) courses*" made some progress. However, the lack of technical details on the site have left it misleading to non-specialists in places and it is difficult to implement full solutions based on it. Again, this static resource is now out of date.

There are many other partial knowledge bases and mailing lists aimed at those who understand the context, processes and technologies in use and by scanning a wide range of these it is possible to build a more or less complete picture. However, these resources tend to be extremely difficult for non-specialists to access.

Where suitable resources already exist these will be signposted, commented on with respect to updates and placed in context for non-specialists, if necessary, on the STEM Enable site.

1.2. Taking a new approach

To avoid the issues with the above resources the STEM Enable project aims to produce a platform in which content can be easily updated and in which visitors can locate information suitable for their background and context while still ensuring that specific technical information was clearly linked.

As well as producing a platform which would enable this a critical mass of content on accessing mathematics, seen as core to all STEM subjects, is to be provided. Beyond that the project seeks to kick off, support and encourage crowd-sourcing of further content and respond to visitor's experiences of the site by improving the structure as required.

The platform, a semantic wiki, offers the ability for registered contributors to add content via small easy edits and enables relationships between concepts, software, processes and formats to be stored. At the most simplistic a semantic wiki can be imagined as a cross between a wiki, a website which can be edited collaboratively, and a database containing structured information which can be queried for specific aspects of that information.

2. Building STEM Enable

The STEM Enable website is a semantic wiki built using Semantic Mediawiki (Herzig and Ell, 2010; SMW project, 2016). Semantic Mediawiki incorporates Mediawiki, the wiki platform most widely used – it is developed and used for Wikipedia – and semantic extensions which turn the wiki into a collaborative database. These extensions enable the administrators to guide or control how authors edit and add information via imposed structure and forms. Hence, it is easier for authors to provide content than in a standard wiki as there is no requirement to take charge of the structure or to produce content of whole pages at once.

The key concepts of a semantic mediawiki are:

- **Properties:** Used to specify a single piece of information about the topic of the page e.g. if a page describes a process for document conversion then properties might include *input format* and *output format.*
- **Categories:** Used to sort pages into different types e.g. there may be a page type of *conversion process* and all pages which describe a conversion process will have that page type. Pages of the same type are displayed to visitors in the same way via **templates** and are created and edited in the same way using **forms**. Authors enter all information, including properties but also sections of freeform text to be used to create the page, via these structured forms which can be partially completed and re-edited later by the same or a different author.

Pages on the site are *data* points within a category and with properties via which they are connected to other pages. Hence, it is possible to query the site for all pages which satisfy a certain set of properties, perhaps with a specific type. The results of such queries can be embedded directly into pages enabling aggregations of information which are automatically generated and updated. For instance, it is possible to query for all processes which take a Word document as an *input format*. In fact, the results of this query are embedded into the *Word document* page and the list updates as new processes which meet the criteria are added elsewhere on the site.

2.1. Extensions and crowd-sourcing

A complete structure of categories, properties, templates, forms and queries is now relatively stable after many iterations of development and testing. Rapidly changing templates and forms which stabilize seem to be typical when building this form of site (Herzig and Ell, 2010). Still, this underlying structure is not set in stone, as contributors and visitors use the site it remains possible to improve or add to the underlying construction without disturbing the content already available. A critical mass of content is being added before additions are sought through crowd-sourcing. The site will then be promoted to end users, slowly at first to allow for bug fixing.

The immediate focus is on mathematical elements of degree level study but it envisaged that content, using the same underlying structure, will be extended over time via crowd-sourcing, to include other facets of STEM, such as diagrammatic material, laboratory work, access to chemistry notation, design work and programming.

2.2. A call for contributions!

Contributors can range from those who submit one complete piece, such as a case study or personal experience to regular registered contributors adding a deep knowledge of one facet or a breadth of experience across many facets of STEM access. Case studies and personal experiences enrich such sites bringing to life technical and process information for those new to the area. Those working in mathematics support, teaching or lecturing mathematics, including service teaching, might consider whether they are able to contribute such a piece.

A case study might report on a single context including how multiple roles collaborated. For example, how a mathematics department evaluated and improved provision of accessible notes working with students and support staff. A personal experience may be based in a specific context or may capture changing experiences over time. For instance, an account of barriers experienced and working methods used throughout a mathematics degree, written by the graduate themselves or a reflective piece on how a member of staff evaluated and changed one aspect of their practice.

3. Conclusion

STEM Enable aims to assist UK students and staff in locating and sharing information to reduce barriers to Science, Technology, Engineering and Mathematics. It is a semantic wiki with editable content which also captures relationships between that content to form a collaborative database. Once a critical mass of content is in place updates and additions, which are made via forms, will be crowd-sourced. Visitors will be able to query the site as if it were a database and to explore the structure of the often complex information available in this specialist area.

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Increasing the focus on conceptual understanding to help students improve their long-term mathematics skills

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Abstract

Helping students to develop their conceptual understanding, and mathematical reasoning skills, provides a memory framework to make recall easier and helps to improve their long-term retention (Schmittau, 1993). On the other hand Novak (2002:549) is concerned that knowledge learnt by rote "*soon becomes irretrievable from long-term memory, and even if recalled, seldom can the learner utilize the knowledge in new contexts, as in novel problem solving*". This paper will briefly review literature relating to the problems within mathematics education generally before moving on to look at ways that the University of Bradford's Academic Skills Advice team are considering addressing this. The challenge is to identify opportunities, within the context of mathematics support, for this sort of development.

1. Literature

There is a wealth of literature highlighting problems with traditional mathematics education dating back many years. For example, in 1987, a symposium was held by the International Commission on Mathematical Instruction at Udine, in Italy. It drew authorities from around the world to look at the teaching of mathematics as a service subject (Howson et al., 1988). Given the rise of computing capabilities, the delegates were looking for ways to prioritise the teaching of concepts over repetitive techniques. In addition, the possibilities for application and development, within the context of many other disciplines, were positively emphasised. However, there was also a consensus that change was needed and that "*a lack of conceptual mastery [by students] may raise severe doubts as to whether the traditional courses are as useful as we think they are*" (Simons 1989:41). Almost 30 years later, the situation remains largely the same. Traditional approaches to mathematics education are still widespread and their effectiveness is increasingly being questioned.

Various 'progressive' changes to mathematics teaching have been seen negatively in some quarters and have even been labelled "*half baked*" (Mathematics Association, 1997:4). This has led to a tendency to rely on familiar, traditional teaching techniques. However, they have been shown to develop a person's ability to follow instructions more than their ability to solve problems, develop reasoning powers or understand concepts (Howson, 1988; Boaler, 1998; Epstein, 2007). There is also a tendency to focus on teaching those skills which are easier to assess and the Office for Standards in Education (Ofsted, 2012) have raised concerns about schools teaching to the test. Higher education institutions need to be aware that their students may be arriving without the conceptual understanding, or reasoning skills, that are necessary for long-term success (Novak, 2002). As a result, there is a danger that university mathematics support can, unwittingly, be perpetuating a techniques-focused 'get through the exam' approach that is quite limited in scope and doesn't help some students' long term development.

Overall a picture emerges that confirms there is a "*mathematics problem*" (Croft and Grove, 2006:4), particularly that current mathematics education is largely unchanged over many years and is still failing a large proportion of students in the long-term (Stotesbury & Dorling, 2015:6). Whether it is that learners need more support (Pell & Croft, 2008), that learner confidence needs to be considered (Parsons, Croft & Harrison, 2009), that there is a lack of engagement with the underpinning philosophy (Ernest, 2002), or that conceptual learning needs to be fostered (Möller, 2005), are questions still of interest today.

A research project from Brooklyn's Polytechnic University in the United States is interesting because some of the lecturers were sceptical of modern methods and felt that the traditional lecture was a tried and tested approach. However, when they researched their own practice they found evidence that strongly implied traditional lectures were not effective for the students, particularly with regard to long term conceptual understanding (Epstein, 2007). There was fairly compelling evidence that something needed to change. The academic staff were particularly influenced by reforms in physics education associated with the Force Concept Inventory which found that "*Interactive-Engagement (IE)*" was a more effective teaching method than a "*Traditional Lecture (TL)-based*" approach (Epstein, 2007:165). Given the weight of evidence, the lack of change within the sector, enacted to date, reflects the complexity of the problem. This is probably due to systemic issues at work, and any analysis which generally 'blames students' or 'blames teachers' is clearly unproductive.

Educators are left wondering if much of the current way of teaching at university adequately achieves what it sets out to do. Individuals and small teams of staff, particularly within mathematics support, who are seeking to make changes, can feel that their options are limited. However, they encounter students who are engaging with key concepts in a meaningful way, for the very first time while at university. They may have only engaged superficially, without much understanding, previously. Therefore conceptual understanding is an issue within the support context even though it may be hard to address.

2. Problems with traditional mathematics

Traditional mathematics teaching typically:

- relies on exposition
- is formal
- upholds 'standards'
- involves mastery of techniques
- focuses on individual performance
- is influenced by a view that ability is somewhat innate or fixed
- prepares for higher study
- emphasises mathematics for its own sake
- requires a passive learner role
- is focused on getting things right and executing procedures
- is isolated as a subject.

Partly, as a result of some of these features there are a number of criticisms of this type of teaching:

- regimented and does not question itself
- pushes learners when they are not ready
- tends to ‘blame’ the student
- elitist
- puts some learners off for life
- often does not develop problem solving skills or mathematical reasoning powers
- leads to setting
- makes learners risk-averse
- avoiding mistakes
- avoids messy ‘real life’ problems
- contributes to embarrassment/anxiety/performance if you ‘can’t do it’
- it does not incorporate new technology very well (e.g. students could use Excel instead of number crunching)
- commonly fails to account for context, history or social factors
- learners find it hard to connect it to their wider understanding of the world.

3. Considering the support setting

At the MSOR-CETL conference 2016 the opportunity was taken to involve **sigma** Network colleagues in discussion on the matter. This activity confirmed that there are perceived limitations on the role of support in promoting conceptual understanding and mathematical reasoning. Generally it was thought that this was best achieved within the wider context of the curriculum and associated teaching and learning activities. However, at the University of Bradford, the maths advisers have always prioritised promotion of conceptual understanding in one-to-one and small group interactions and review this approach regularly through formal and informal mechanisms. Some **sigma** colleagues confirmed that time with a student is often short and pressured and an emphasis on conceptual understanding may not meet the expectations of a student for whom rote learning is default behaviour. Nevertheless, in our experience, we agree with the literature that students struggle to remember certain techniques and their application because they do not have a conceptual framework to help them in their understanding. A jigsaw analogy has been made where the techniques are the pieces and if you know how they fit together to make a big picture you will find it easier to work with the pieces as they are given a context. A common example is when a student can solve a quadratic equation in one scenario but seems completely stumped in another. Similarly, there are students who cannot distinguish between the line $x=5$ and the point (5, 0) despite being ‘told’ and ‘shown’ repeatedly. Crucially, even if students can demonstrate a technique this is not, necessarily, evidence of understanding. Working with these students to develop their conceptual understanding of the Cartesian system, for example, has proven to transform their understanding and allow them to move onto alternative systems (e.g. polar) with more confidence.

4. Things we are doing

Given the differing needs of learners, different modes of support are needed. To this end we have identified additional areas where we can increase the opportunities to develop conceptual understanding and mathematical reasoning ability among students.

Firstly, we are developing a mobile mathematics application (App) provisionally entitled "Maths you should just KNOW" (without pen & paper or too much thinking!). The app will hopefully be used, by learners, for regular practice of mathematics skills that they should already have, and probably require, in order to grasp new concepts. Quiz style questions are being written to cover:

- Multiplication & division
- General number (order of operation, -ve numbers, FDPs, Rounding)
- Drug calculations
- Algebra (simplifying, factorising, substitution)
- Graphs (gradients, intercepts, recognising graphs)
- Differentiation (meaning, finding grads, TPs and type)
- Integration (meaning, method).

Due to technical difficulties we are currently looking at creating an online activity as the first step towards making this tool available to students.

This project was inspired by Lindemann and Fischer's (2013) research which suggests that having to solve arithmetic problems on a mobile phone may help maths learning. We hope it will address the problem of learners not being able to transfer skills as well as the issue of being distracted by relatively trivial maths when their focus should be on new material being learnt.

Secondly, we are looking to liaise with key lecturers in our institution to assess the feasibility, and usefulness, of standalone workshops. These 'shadow' workshops will cover mathematics skills and concepts that lecturers may assume students already know and understand, or which are identified as particularly valuable graduate attributes. We are considering the following workshops:

- Introduction to graphs and coordinates
- Introduction to powers & logs
- Introduction to differentiation
- Introduction to functions
- Introduction to statistics
- Introduction to graphical data representation.

Thirdly we will take a fresh look at our resources, specifically seeking further opportunities to develop long-term conceptual understanding and mathematical reasoning. They are reviewed regularly, anyway, and are very popular with students so even small changes could be beneficial.

5. Discussion

We have seen that there is a problem with mathematics education and lack of conceptual understanding plays a key role in this. It may be that the problem is more readily addressed through the work of academics, perhaps through 'flipped classroom', group learning opportunities and investigations, etc. However, we consider that there is still an obligation within the support setting to maximise opportunities for conceptual understanding, however slight, should they arise. This is because it could help students prepare, more effectively for a particular assessment, and also equip them for future careers or further learning by helping them to retain their skills in the long term.

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Most commonly occurring mathematical difficulties - eight weeks in the life of a Maths Support Centre

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Abstract

The Maths Support Centre (MSC) in University College Dublin (UCD) was established in 2004 and has seen an annual increase in the number of visits to the centre, with just over 5,600 visits for 2015-2016. For each visit, there is an electronic record of the module for which the student is seeking support, along with details, inputted by the MSC tutor and available to the module lecturer, on the exact nature of the mathematical difficulty experienced by the student.

In Semester 1 2014 we undertook an eight week qualitative study of the mathematical topics, for which students attending the MSC, sought support. We focused on identifying and recording the areas of mathematical difficulty which students encountered while working through problems in the centre. There are approximately 2000 entries on our database over this period.

In this paper we present our findings. We describe the most commonly occurring areas of mathematical difficulty experienced by those who visited the MSC during the eight weeks of the study, and highlight those areas for which students from across a number of modules sought support. Some examples used demonstrate where even students from higher-level modules struggled with basic mathematical concepts.

We briefly address what possible forms of support that may be provided for students as a result of this study.

1. Mathematical Transition to Higher Education

Serious concerns have been expressed in relation to the mathematical preparedness of entrants to Third-level courses in mathematics, science and engineering in the UK (The Royal Society, 2006). Similar to the UK, issues concerning the level of mathematical skills of new entrants to HEIs in Ireland are noted (O'Donoghue, 2002). Diagnostic testing as carried out in many higher level institutes is effective in highlighting widespread areas of mathematical weakness (Lawson et al., 2003).

A major response in both the UK and Ireland to the Mathematics Problem has been the introduction of mathematical and statistical support centres. These centres were most frequently introduced to provide mathematical support to students in the transition from post-primary to higher education. Mathematics Support, is described 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, lectures, tutorials, seminars, problem classes, personal tutorials, etc.*" (p.9). The authors also note that support offered by MSCs can vary significantly but almost universal aspects are the voluntary nature of attendance and the one-on-one support offered either by drop-in or by appointment.

Kyle (Marr and Grove, 2010), remembering his description of the early mathematics support as "*a form of cottage industry practiced by a few well-meaning, possibly eccentric individuals*" (p.103), notes that MSCs now play a respected and widely expanded role in higher education. The increase in the number of MSCs is substantial, especially over the last fifteen years. Independent surveys demonstrate this growth (Lawson et al., 2001, Perkin and Croft, 2004, Perkin et al., 2013, Gill et al., 2008, Cronin et al., 2015). See Table 1 below.

Date of report	**UK**			**Ireland**	
	2000	2004	2012	2007	2014
Number of MSCs	46	66	88	13	26

Table 1. Number of MSCs in UK and Ireland

Lawson (Marr and Grove, 2010:16) reminds us that "*the most fundamental issue that must be addressed regarding mathematics support is funding*". Possible improvements to the efficient running of a centre are an important consideration in this respect.

2. What data should a Maths Support Centre collect?

In September 2013, we embarked on a research project in UCD Maths Support Centre to develop a process of qualitative data collection. We believe that the information gathered by the UCD MSC, particularly the comments entered by the tutors on students' difficulties, is a very valuable resource not alone for the centre but also for the module lecturer.

Given that student demand for mathematics support is increasing and funding is limited, a fundamental issue that must be addressed is how to maintain the high level of quality teaching and at the same time increase the service in a cost effective manner.

This research focuses on identifying and recording areas of mathematical difficulty which students encounter while working in the centre and on analysing the data to address the following research questions:

i. What if any are the common mathematical difficulties which students present at the Maths Support Centre with from across modules?
ii. Does this level of detailed data collection contribute to the efficiency of a centre by aiding development of effective supports for students?
iii. What level of feedback, if any, would lecturers like to receive on their students' visits to an MSC?

In this paper we will address the identification and categorization of the mathematical difficulties and discuss the development of effective supports. A discussion of the third research question is beyond the scope of this paper.

3. Methodology

3.1. Collection of data

In order to identify the mathematical topics with which students experience difficulty firstly, we needed to determine the nature of the data we required to do this rigorously and secondly, to work with the tutors to find ways in which they could classify this data and record it efficiently. Data collection for our pilot study commenced in February 2014. For eight weeks the first author cross-checked the tutor entries on the database with the entries in the A4 carbon copy notebooks used by the tutors while working with students in the MSC. Tutors were asked for more information if the basic problem was not clearly identified. In September 2014, we commenced our data collection. This involved eight weeks of intensive collaborative work with the tutors to ensure the quality and authenticity of the data collected and resulted in entries recorded, and coded by mathematical area, for over 2,000 student visits. Further details of this collection process are available in Curley and Meehan (2015a).

3.2. Analysis of data

The first step in the analysis involved the first author reviewing the codes assigned by the tutors to each topic entry. Following this the second author and Dr Anthony Cronin, manager of the MSC, verified 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 problem arose, became apparent. We therefore altered the focus of our analysis from individual entries to entries by module. Further details of the analysis can be found in (Curley and Meehan, 2015b).

4. Results

For this paper we focus on 17 large modules varying in size from 61 to 522 students. Over the eight weeks of data collection, the MSC had a total of 981 visits from students enrolled to these modules, with 191 of these visits having no entries submitted to the database. In our analysis, we identified a total of 1,400 mathematical difficulties in the remaining 790 entries. Our findings are summarised in Table 2 below.

A row in Table 2 represents the areas of mathematical difficulty identified in the particular module. A column displays the topic or category of mathematical difficulty. Students from each of the seventeen modules examined experienced difficulty in at least one of the topics listed.

The major topics of difficulty for students were numeracy and algebra. Students from eleven modules out of a total of seventeen examined, experienced problems here.

Mathematical Difficulties	Numeracy	Algebra	Indices & Logs	Trigonometry	Graphs & Functions	Differentiation	Statistical tables
Modules							
Introductory Maths	*	*	*			*	
Discrete Maths	*	*			*		
Calculus A	*	*		*	*	*	
Calculus B		*	*	*	*		
Calculus C	*	*	*		*	*	
Calculus D	*	*	*	*	*	*	
Linear Algebra A	*			*			
Linear Algebra B	*	*	*	*			
Number theory A	*	*	*				
Number theory B	*	*	*				

Applied Maths A		*	*		*	*	
Applied Maths B	*	*	*	*			
Applied Maths C				*	*		
Physics				*	*		
Statistics A	*						*
Statistics B							*
Statistics C							*
Total difficulties	11	11	9	8	8	5	3

Table 2. Mathematical difficulties experienced by MSC students in 17 modules.

Keeping in mind, that we are also analysing the data with a view to answering the question does this level of detailed data collection improve the efficiency of a mathematics support centre by aiding development of effective support for students, we need to find areas of mathematical difficulty present across modules and capable of explanation in a short video or online resource? Disappointingly our analysis of the data provides only one suitable category of difficulty. This we find common across the three statistics modules. In this case development of suitable support in the use of normal distribution tables may potentially contribute to improvement in the efficient management of the centre.

5. Discussion of results

Overall, the absence of similar mathematical difficulties common to a number of modules is surprising given the number and detail of entries. One possible explanation for this may indeed be the high level of detail reported. The broad range and varying level of mathematical difficulty for which students sought support and the skilful uncovering and reporting of specific issues by the tutors gives a very detailed knowledge of a difficulty that might otherwise be classified in general terms.

To explain this reasoning further we give some examples of the specificity of algebraic mathematical difficulties expressed in tutors' comments.

> *When doing following question the classic cancellation problem occurred of cancelling across addition as below;*
> *a/(b+c) + b/(a+c) + c /(a+b)=(a(a+c)(a+b) + b(b+c)(a+b) + c(b+c)(a+c)) / (b+c)(a+c)(b+a). (Student) wanted to cancel (a+c) underneath with (a+c) in first part on top. Tutor showed example of when you can cancel and when you can't cancel: (3x+5)/x and 3(x)(y)/3. (Introductory Maths).*
>
> *Student also had a problem with solving quadratic ax^2+bx=0. They asked but there is no number? This problem would be a more common problem with students whose algebra is weak. (Calculus C).*
>
> *Actual problem was with the algebra at the end to make the two sides look the same: LHS n(n+1)(2n+1)/6 + (n+1)^2; RHS (n + 1)(n + 2)(2n +3)/6. (Number Theory B).*
>
> *How to find the fixed points of u^2 +u(1-A) = 0. Student was confused I think by how complicated it looked, once I pointed out that in ax^2+bx=0, there was no c, students realised that they could take out the u. (Applied Maths).*

Where two entries, as shown above, need mathematical knowledge to solve a quadratic equation perhaps a tutor, entering less detail might have entered “problem with quadratic equations”. But the level of detail entered has shown the knowledge required in both cases is quite different. We suggest that a basic video demonstrating the solution of quadratic equations, suitable for the less detailed entry suggested, would not provide for either of these students the level of support required.

The reason perhaps, that many tutor comments have recorded the reading of statistical tables as a problem is they believe that just as solving a quadratic by using the formula may simply be the application of a specific method so also methods can be devised for reading tables without necessarily a full understanding of the outcome.

6. Conclusions and further research

To answer the second question as to whether this level of detailed data collection improves the efficiency of a centre by aiding development of effective supports for students, the analysis of the data would indicate if the sole purpose is to increase the efficiency of a centre, and keeping in mind the loss of tutoring time it may not be an efficient process to do so.

But our question of what data should a centre collect has not been fully explored.

What level of feedback, if any, would lecturers like to receive on their students’ visits to an MSC? As mentioned earlier our tutor entries are available to the module lecturer in our school and we are currently analysing interviews with lecturers in an attempt to address this question.

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Assessment for learning: resources for first year undergraduate mathematics modules

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Abstract

This paper reports on two initiatives designed to address the lack of basic mathematics skills among new entrants to higher education in Ireland, namely, Building Mathematics Competencies using Khan Academy Playlists and The Use of Student-Authored Screencasts as a Formative Assessment Tool. The resulting resources constitute part of the outputs from a multi-institutional project, funded by The National Forum for the Enhancement of Teaching and Learning in Higher Education (NFETL) in Ireland, focused on developing formative assessment resources for use in first year undergraduate mathematics modules.

1. Introduction

The lack of basic mathematics skills among new entrants to higher education has been of concern to the mathematical community in Ireland for some time (Gill et al., 2010). This was re-iterated in a recent national survey of academic staff involved in teaching mathematics at first year undergraduate level in Ireland. This survey conducted in conjunction with a student survey, attempted to identify topics that pose difficulties for new entrants (Ní Shé et al., 2015). Survey responses provided the focus for the subsequent development of formative assessment resources for use on first year undergraduate mathematics modules. Further information on the overall project and resources developed can be accessed through the NFETL website (http://www.teachingandlearning.ie/wp-content/uploads/2015/04/Assessment-for-Learning.pdf) or alternatively see Ní Shé et al (submitted).

We report here on the effectiveness of two of these initiatives as derived from performance data and/or student feedback surveys. Both investigations concerned the use of technology in the creation of learning tasks that produce evidence of learning, allowing students to assess their understanding and encouraging them to take ownership of their learning. The first of these, Building Mathematics Competencies using Khan Academy Playlists involved repackaging existing free online resources to support a diagnostic testing cycle. Its focus was on building core skills. The Use of Student-Authored Screencasts as a Formative Assessment tool involved an investigation of their use as a self-learning tool aimed at providing opportunities for students to develop their conceptual understanding.

2. Literature review

Resource development was guided by Black and Wiliam's (1998) definition of 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*". The emphasis was on providing information as feedback within the assessment process, allowing learner and teacher to adapt their strategies as required and giving students opportunities to improve both their procedural skills and conceptual understanding. The resources developed within this project achieve this by addressing the five key strategies of formative assessment proposed by Black and Wiliam (2009). The two initiatives being discussed focus on a subset of these, they use technology to assist in the creation of "*questions and learning tasks that elicit evidence of learning, providing feedback that moves learners forward and activating students as owners of their own learning*".

The use of online quizzes in mathematics has been the subject of much discourse. Broughton et al. (2013) surveyed nine lecturers and interviewed six of those regarding the use of Computer Aided Assessments (CAA) in a university in the UK. The lecturers all taught on first-year undergraduate mathematics modules for science and engineering students where CAA was used. Some lecturers maintained that the feedback encouraged students to learn a procedure which they often cannot apply to a new context; overall, lecturers found that such quizzes were a useful tool that allowed students to practise their mathematical skills and obtain immediate feedback. In agreement, Trenholm et al. (2015) also suggested that the use of CAA can promote surface rather than deep learning unless feedback is carefully constructed. Muir (2014) also noted the focus on procedural understanding. In this study Muir surveyed a group of students after they had viewed a self-selected Khan Academy clip on a problem or new topic. Students reported increased understanding of the material covered, they liked the step-by-step nature of the explanations and the fact that clips could be paused and replayed. While the use of online quizzes would appear to be beneficial in building procedural skill, the development of conceptual understanding may be further enhanced through the use of alternative technologies.

"*A screencast is a digital movie in which the setting is partly or wholly a computer screen, and in which audio narration describes the on-screen action*" (Udell, 2005). The creation of student-authored screencasts for use as instructional tools by other students has been investigated in the literature (Shafer, 2010; Croft et al., 2013) and suggests a number of potential benefits. These include the creation of a more active learning environment, deep as opposed to surface learning due to the reflective process required of students in the creation of screencasts, together with the development of transferable skills such as organisation and presentation skills. Focusing on the learning which can be gained from the reflective process involved in the creation of their own screencast we investigated their use as a self-learning tool.

3. Methodology

Building on existing resources and following on from the successful school-level Mathletes (Learnstorm) project (http://mathletes.ie/) the first initiative involves the use of Khan Academy resources to support a diagnostic test-retest cycle and subsequently as an assessment for learning tool. At the onset of the 2015/16 academic year a diagnostic test-retest cycle was implemented with 175 first year undergraduate Computing Students at Dundalk Institute of Technology (DkIT), with a view to assisting students to both identify and address gaps in their basic mathematics skills. Students completed a standard mathematics diagnostic test, were quickly informed of their mathematical weaknesses, as determined by the diagnostic test, and were advised of the mathematical resources and supports available to assist them in addressing these issues and in preparing for a subsequent re-test.

The main resource provided to students was a Khan Academy playlist, specifically designed by members of the project team to support this diagnostic testing initiative. The playlist, provided through Moodle (the virtual learning environment used in DkIT), was designed to guide students to relevant videos and quizzes to assist them in building competence and confidence on problem topics. Playlist topics were derived from preliminary survey feedback and included equations, transposition of formulae, logs and exponentials, functions and graphs. The Khan Academy mastery structure also provided students with a means of monitoring their own progress.

Following the second diagnostic test, students were invited to complete a questionnaire on the effectiveness of the Khan Academy playlist and their confidence in their mathematical ability. A follow-up study designed to address issues raised in questionnaire responses, relating to the level of the material targeted in the playlist and its lack of relevance to module content, was subsequently conducted at DkIT.

Khan Academy masteries were incorporated as a Continuous Assessment component on a Linear Algebra module taken by a subset of the DkIT cohort. The class/coach functionality in Khan Academy was utilised by the lecturer to make recommendations, assess student engagement with targeted material, monitor student progress and identify specific problem tasks to be addressed directly in class or through mathematics learning support.

The second initiative involved an investigation of the use of student-authored screencasts as a formative assessment activity with a view to creating a more active learning environment, as reported by Croft et al. (2013). 69 Computing and Games Development students taking a Geometry module were set an assignment to complete a sequence of tasks that demonstrate the relation between parametric equations and motion, a construct they typically struggle with. Students were required to create a screencast walk-through of their solution. Clear guidance was given in respect of the questions they needed to address in their screencast and they were advised that marks would be awarded on the demonstration of their conceptual understanding and achievement of desired learning outcomes as opposed to their completion of the procedural tasks. The aim was to facilitate deep learning by encouraging students to actively engage with the material.

4. Results

4.1. Building Mathematics Competencies using Khan Academy Playlists

Preliminary analysis found that overall 65% of the students who sat both diagnostic tests (n=104) improved their score on the second diagnostic test, with a higher percentage 83% of students who used the Khan Academy playlist (n=18) showing an improvement. The uptake of the Khan Academy playlist was low, usage was reported by just 20% of the 115 students who completed the questionnaire, however the majority of those students considered Khan Academy a useful resource and indicated that they would use it again. A related study was carried out in Dublin City University (DCU); the data from that study are currently being analysed but initial findings are similar. For example one student said that using the Khan Academy playlist “Helped me to judge what areas I needed help in”. (DCU Student1).

Issues reported ranged from technical difficulties, in moving between the playlist in Moodle and the Khan Academy website, to the level of the material and its perceived lack of relevance to their modules: "I feel that this system should be re-done with maths more relevant to our modules", (DkIT Student1) and "It was very basic, maybe too much at times". (DCU Student2)

As expected engagement on the second phase of this study, in which the use of Khan Academy resources was linked to CA, was considerably higher, "from our students point of view, assessment always defines the actual curriculum" (Ramsden, 1992). The mean number of masteries achieved by the group was 9.5 (out of 23) with 35% of students scoring 75% or more on this CA component. Notably those students who used the Khan Academy resources (Time spent in Khan Academy > 120 minutes) had a mean score on the final examination that was more than double the mean mark achieved by those who did not engage with the resource (t-test, $n=75$, $p<0.001$). There was also significant correlation between scores on the Khan Academy mastery CA component and the Final Examination ($r=0.59$ (Spearman), $n=75$, $p<0.001$).

While it could be argued that these results relate more to the nature of the higher achieving students who are more likely to engage with all assessment components than to any impact of the Khan Academy resources on their learning, student feedback may provide a counter argument. An exit survey ($n=39$) was conducted to assess student opinion on their learning from Khan Academy resources: 74% felt that "Using Khan Academy enhanced their learning of Matrices", 55% agreed that it is "a useful resource which I will use when I encounter problem topics in future mathematics modules" and 65% recommended "including relevant Khan Academy Masteries as part of the Continuous Assessment on other Mathematics modules". However not all students felt this way with one student commenting that "Khan Academy ruined my life."

4.2. The Use of Student-Authored Screencasts as a Formative Assessment Tool

57 of the students enrolled ($n=69$) on the Linear Algebra module, completed the screencast assignment and their average mark on the assignment was 64%. After submission, students were invited to complete an online questionnaire on their views of the assignment. Participation in the survey was low at 28% of the cohort.

While no general conclusions can be drawn from the survey data, three themes arose in student responses to open questions relating to their learning from creating a screencast. Eight students pointed to the increased engagement required in planning and producing their screencast leading to a deeper understanding of parametric equations; some sample quotes are: "Felt like I needed to be able to explain every line that I wrote which is good for learning" and "A screen-cast assignment was new to me and a very beneficial project that helped me learn a topic more in-depth than other projects have previously". The benefit of providing the student with a voice in the assessment process was also mentioned by three students, for example "It allowed me to talk through my maths work". Finally three students compared screencasts and presentations with differences in their preferences; one student said "It helps me to explain the concept that I had understood, but may not be able to express in front of many people" as opposed to one of their peers' statement "It's a bit awkward to talk to the computer, I would prefer to talk to people."

These responses together with the high completion rates of the assignment seem to suggest that student-authored screencasts are an effective tool in promoting deeper learning. However, not all students saw the benefit of creating a screencast with seven students who completed the assignment not submitting a screencast and six students disagreeing that creating a screencast was a worthwhile exercise, with one adding "No, it just puts stress on you".

5. Conclusions

The aim of these initiatives was to attempt to address the lack of basic mathematics skills among new entrants to higher education. While both are still only in their first or second iterations, certainly at a local level in DkIT both initiatives appear to have been successful, with high levels of engagement. In addition, while student feedback levels were low, a common problem particularly with online surveys, those who responded were largely positive.

These projects are ongoing. Survey results on the Khan Academy project will be presented to students and further investigated through semi-structured focus groups.

The use of student-author screencasts as a self-learning tool will be pursued, in particular their use in providing students with a voice in the assessment process will be investigated (Trenholm et al., 2012).

Analysis of these developments will be disseminated once completed.

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Does Context matter? An exploration of the impact that teaching mathematics in context has on performance and anxiety levels

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Abstract

Radical changes have been taking place in mathematics education in Ireland. Central to these changes was the introduction of a new curriculum 'Project Maths' at second-level, designed to promote an investigative approach as students encounter mathematics in context and explore new mathematical concepts.

This paper reports on a case-study of a module which extended this approach to a higher education setting and explored its impact on mathematics performance and mathematics anxiety. The Digital Systems module has been designed to introduce Computing students to the foundations of networking and hardware while providing them with both procedural knowledge and understanding of the underlying mathematics. However, if the module objectives are to be fully realised then the impact of barriers to learning mathematics, particularly mathematics anxiety have to be considered.

The study provides unique data on existing levels of mathematics anxiety amongst a cohort of first year Computing students in an Irish Institute of Technology. The findings also suggest that the context-driven approach has had a positive impact on performance. Whilst no claims of generalisability are made, the paper provides insights into the potential benefits of this approach to the teaching of mathematics in Computer Science in higher education and the consequent potential impact on student retention.

1. Background

The motivation for this research project arose from a number of sources: an acknowledgement of the importance of mathematics in a globalised world and the resulting desire to develop in all core mathematical skills, the changing landscape of mathematics education in Ireland in which a more context-driven investigative teaching approach is being promoted; an increased awareness of the existence and impact of mathematics anxiety on student performance and retention issues in the Irish third-level sector. Allied to this was an awareness of a lack of normative data on mathematics anxiety levels amongst Computer Science students in higher education in Ireland.

One manifestation of poor mathematics competency within the third-level sector in Ireland is low first year retention rates, particularly within the Institutes of Technology (IoTs). Table 3.1 drawn from the most recent Higher Education Authority report (Liston et al., 2016) on progression rates illustrates the extent of the challenge amongst Computer Science students in the IOT sector.

Table 3.1 *Non-Progression Rates by Field of Study and NFQ Level in Institutes of Technology*

SECTOR	LEVEL	EDUCATION	HEALTHCARE	SOCIAL SCIENCE BUSINESS AND LAW AND ARTS AND HUMANITIES	SCIENCE AND AGRI AND VET	ENGINEERING (EXCL CIVIL)	CONSTRUCTION AND RELATED	SERVICES	COMPUTER SCIENCE	ALL
Institutes of Technology	Level 6	n/a	13%	25%	24%	34%	44%	28%	32%	26%
	Level 7	9%	16%	28%	19%	34%	41%	28%	32%	28%
	Level 8	11%	10%	17%	18%	20%	21%	20%	26%	17%
All IoT		11%	12%	21%	19%	32%	33%	26%	29%	23%

Higher prior mathematics attainment has been identified as the strongest predictor of successful progression of new entrants into higher education (Mooney et. al., 2010). One initiative to address this persistent issue within the Department of Computing and Mathematics at DkIT has been the adoption of a more holistic learning approach to the teaching of first year content, through the introduction of a number of new integrated modules.

Digital Systems is one such module as it aims to "introduce the foundations of networking and hardware and to provide students with a knowledge of the mathematics underlying these subject areas…. in an integrated and practical way". The two main reasons presented for learning in context concern the motivation of students through an enhanced syllabus and the enrichment of transfer through a clear demonstration of the relevance of the mathematics (Boaler, 1993). However the contexts typically employed in school mathematics problems are neither real, "*they are school problems coated with a veneer of "real world" associations*" (Maier, 1991), nor relevant as they usually concern adult world problems. In aligning the mathematics with related networking and hardware elements, this new integrated module ensures that the context and relevance of the mathematics is clear.

However, in introducing any approach to the teaching of mathematics, consideration must be given to its potential impact on student self-efficacy and, in particular on mathematics anxiety levels. Schunk (1991) argues that "*In their instructional planning, teachers need to take into account how given procedures affect students' sense of efficacy*". Richardson and Suinn (1972) define mathematics anxiety as "*feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems.*" The increase in students' anxiety about mathematics observed in PISA 2012, with Ireland scoring levels significantly above the OECD average, indicating that students in Ireland are more likely to be anxious about engaging in mathematical tasks (Perkins et al., 2013) makes this increasingly relevant. Mathematics anxiety has been identified as a possible factor in the low numbers taking higher mathematics for the Irish Leaving Certificate (Lane, 2013) and more generally in depressed performance and the avoidance of mathematics courses at third level (Hembree, 1990). Despite this, there appears to be a dearth of data on mathematics anxiety levels in the third level sector outside North America (Hunt, Clark-Carter & Sheffield, 2012).

2. Methodology

This case-study set out to investigate the effectiveness of the Digital Systems module. Its aims were two-fold (i) to monitor performance on the mathematics strand of a context based mathematics module, with a view to assessing the impact of such an approach on performance and (ii) to investigate the level of mathematics anxiety within the module cohort, assess possible links to performance and any counter-effects that teaching in context might have on mathematics anxiety.

The second of these objectives was carried out with a view to providing normative data on mathematics anxiety levels in an Irish third-level context, as a first step in countering its effects. Additionally, students on this module were drawn from a number of different programmes and levels. Analysis was conducted at these sub-levels to investigate any differences in anxiety and performance.

2.1. Participants

Digital Systems is a core module common to a number of level 7 and level 8 Computing programmes at DkIT. While entry to all these programmes requires that students have passed Leaving Certificate mathematics only the Games Development programme has a specific mathematics minimum entry requirement. 150 of the 190 students enroled on the Digital Systems module initially signed up to the study, however the final sample consisted of 93 students (L8-Games (20), L8-Computing (30), L7-Computing (43)) for whom we had complete records. For the purposes of investigating any impact the module might have had on anxiety levels within this cohort, a subset of 63 of these students (L8-Games (19), L8-Computing (19), L7-Computing (25)) agreed to a re-test of Anxiety levels and provided their views on completion of the Digital Systems module.

2.2. Materials

Data relating to performance, anxiety, attitudes towards mathematics and views on the Digital Systems module were collected.

Performance Data consisted of: pre-module diagnostic test results and module related performance data (including overall marks on the Digital System module (DS Overall); overall marks on the mathematics strand (DS Maths Overall); broken down into continuous assessment scores (DS Maths CA) and scores on the mathematics section of the final examination (DS Maths Exam)).

Anxiety data: Mathematics Anxiety levels were measured at the start (93 students) and end (63 students) of the semester using the MAS-UK Mathematics Anxiety Scale.

The MAS-UK anxiety test (Hunt, Clark-Carter & Sheffield, 2012) is a 23-item mathematics anxiety scale, in which respondents are presented with statements relating to mathematical situations such as *Sitting in maths class* and asked to indicate how anxious they feel on a 5-point Likert scale ranging from not at all (1) to very much (5). Unlike other mathematics anxiety scales such as MARS (Richardson & Suinn, 1972) and sMARS (Alexander & Matray, 1989) which focus on a north American population with resulting terminology issues, MAS-UK was developed for an English speaking European population. It is also a more easily administrable tool when compared to the 98-item MARS scale.

In addition two short questionnaires were administered to participants. A four-item questionnaire on attitudes towards mathematics at the beginning and a five-item questionnaire on the effectiveness of the Digital Systems module at the end of semester. Responses to both were measured on a 5 point Likert scale ranging from strongly agree (1) to strongly disagree (5).

3. Results and discussion

3.1. Mathematics performance

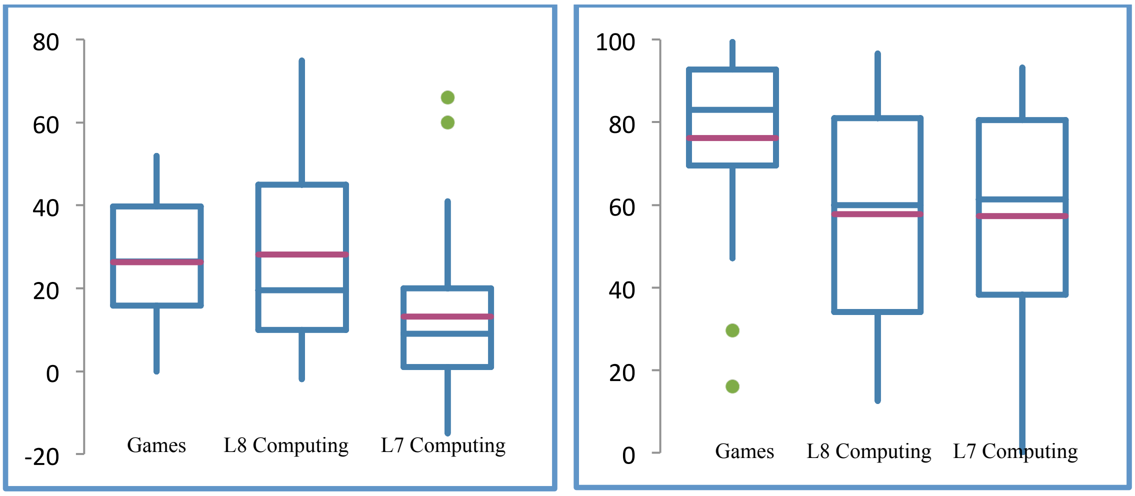
Results obtained on the pre- and post-module tests were quite different. This was not surprising as, although both tests measured mathematical ability, the knowledge being assessed and the scoring used were quite different. The pre-test was a standard diagnostic test assessing basic arithmetic and algebraic skills with a scoring scale of -20 to 80 while the module related performance data related to concepts in logic and number systems.

	Diagnostic Test (-20 to 80)	Digital Systems Maths CA %	Digital Systems Maths Exam %	Digital Systems Maths Strand Overall %	Digital Systems Overall %
Complete Cohort (93)	20.83 (19.891)	66.80 (26.582)	52.47 (31.457)	61.49 (27.051)	56.49 (16.109)
L8 Games (20)	26.35 (15.510)	79.8 (21.282)	70 (29.408)	76.17 (23.122)	65.65 (12.521)
L8 Computing (30)	28.17 (22.6)	63.67 (27.527)	47.73 (28.709)	57.77 (26.638)	56.4 (15.956)
L7 Computing (43)	13.14 (17.078)	62.93 (26.775)	47.63 (31.950)	57.26 (27.207)	52.30 (16.243)

Table 1. Mean (St. dev.) of Performance Data by programme.

What is interesting is the change in the distribution of marks over the two testings. As can be seen in figure 1(a) L8 Computing students performed marginally better than L8 Games students and had an average score of more than twice that of the L7 Computing students on the diagnostic test (pre-test). However, L7 Computing results on the mathematics strand of the Digital Systems module (post-test) were on a par with L8 Computing results (mean= 57.26 & 57.77, St. dev= 27.2 & 26.6) and on average just under 20% lower than the marks obtained by L8 Games students (mean= 76.17, St. dev.= 23.1) (see figure 1(b)).

Figure 1: Boxplots of Performance data by programme.



1(a) Pre-module Diagnostic Test Results (Diagnostic Test (scale: -20 to 80))

1(b) End-of-Module Mathematics Marks (Digital Systems Maths Strand Overall %).

While the mathematics pre-requisite on the Games programme, together with their reported higher levels of Enjoyment of Mathematics may explain their increased performance no such factors exist for the L7 Computing students. The considerable increase in the grades of L7 Computing students on the Digital Systems module, together with the low correlation between their pre- & post- performances (r=.36, (Pearsons), n=93), point to the possibility that the context-driven approach of Digital Systems had an impact on their performance.

3.2. Mathematics anxiety

As is evident in Table 2 below, some level of anxiety was detected within the cohort (mean = 42.46), scores on MAS-UK can range from 23 to 115, the higher the score the more anxiety has been detected. The anxiety levels observed are in line with those reported in similar studies, once adjusted for variations in the number of items in different instruments (Hunt, Clark-Carter & Sheffield, 2012). Consistent with Hembree's finding that the relation between mathematics anxiety and ability is small (Hembree, 1999), levels were similiar across all three sub-groups, L7 Computing students scored marginally higher (mean =43.86) than L8 Computing students (mean =40.66) who had the lowest scores.

Consistent with other scales MAS-UK has a factorial structure, with three intuitively valid subscales: <u>maths evaluation anxiety</u>, relates to being examined or observed doing calculations e.g. *being given a surprise maths test in class,* <u>everyday/social maths anxiety</u> concerns calculations that occur in everyday situations such as *adding up a pile of change* and <u>maths observation anxiety</u> for example *sitting in maths class* or *Reading the word "algebra".* In line with findings in previous studies (Núñez-Peña, Suárez-Pellicioni, & Bono, 2013) the *Maths Evaluation Anxiety* factor, which corresponds to Maths Test Anxiety in other scales, contributed most (aver =2.3 /item) while among this cohort Social/ Everyday Mathematics Anxiety scored least (aver =1.5/ item) suggesting that mathematics in everyday contexts causes less anxiety and may be more accessible to students.

FACTOR (Range)	MARS-UK Score (23-115)	Maths Evaluation Anxiety (9-45)	Social Maths Anxiety (8-40)	Maths Observation Anxiety (6-30)	Useful-ness (1-5)	Perceived Competence (1-5)	Enjoyment (1-5)	Self-Confidence (1-5)
Complete Group (93)	42.46 (12.155)	20.258 (6.620)	12.18 (4.491)	10.18 (4.384)	1.79 (0.675)	2.62 (0.757)	2.82 (1.018)	2.82 (0.783)
L8 Games (20)	42.35 (10.664)	19.7 (5.263)	12.3 (4.692)	10.35 (4.196)	1.65 (0.671)	2.5 (0.827)	2.25 (0.851)	2.7 (0.733)
L8 Computing (30)	40.66 (13.515)	18.93 (6.053)	12.41 (5.329)	9.31 (4.465)	1.78 (0.700)	2.59 (0.572)	2.67 (0.832)	2.74 (0.712)
L7 Computing (43)	43.86 (11.780)	21.26 (7.245)	11.90 (3.894)	10.69 (4.518)	1.88 (0.670)	2.69 (0.841)	3.19 (1.087)	2.93 (0.867)

Table 2. Mean (St. dev.) of Mathematical Anxiety (by factor) and Attitudes to Mathematics, by programme.

Regarding attitudes towards mathematics, students appeared to be aware of the usefulness of mathematics however they were closer to neutral on their levels of competence, confidence and enjoyment. L7 Computing students reported more negatively on all of these measures, in particular there was a marked difference between their enjoyment of mathematics (3.19 average) and that of the Games students who reported a 2.25 average. Finally differences in scores on the anxiety testings are summarised in Table 3 below. No significant change is reported between the two testings; mean overall anxiety scores differ by 1.01 (0.044/ item). This lack of impact of a context-driven approach to mathematics on mathematics anxiety levels is not surprising as other studies have reported that curriculum-type interventions have little impact on mathematics anxiety levels (Hembree, 1990).

	MEAN of Differences	ST. DEV. of Differences	Test Statistic	p-level	95% Confidence Intervals
MARS-UK Score	1.01	7.75	1.04	0.3023	(-0.94, 2.97)
Maths Evaluation Anxiety	0.62	4.52	1.09	0.2812	(-0.52, 1.76)
Social Maths Anxiety	0.22	3.32	0.53	0.5975	(-0.61, 1.06)
Maths Observation Anxiety	0.2	2.4	0.57	0.5699	(-0.44, 0.79)

Table 3. Comparison of Means (Paired t-test) of Anxiety by factor (n=63).

4. Conclusion

This case-study examined the impact that Digital System, an integrated computing and mathematics module, had on a cohort of first year L7 and L8 Computing students in an Irish Institute of Technology.

A considerable increase in the grades of L7 Computing students relative to their L8 counterparts was observed over the course of the module, closing the gap between L7 and L8 mathematics attainment. This is suggestive of a positive effect on the performance of students with lower prior mathematics attainment due to the context-driven approach taken. This possibility is reinforced in the results of the exit questionnaire in which 82% of L7 students agree that “Maths is easier to understand when you see that it links to other subjects”. Further investigation is warranted particularly when the Irish retention issue is considered, as L7 dropout rates (32%) are much higher than L8 rates (26%). If teaching in context can begin to address this in DkIT then similar approaches adopted in other IOTs, whose students are broadly similar, could have a significant impact on Level 7 progression.

The study provides unique data on existing mathematics anxiety levels in the Irish third-level sector. Low to moderate levels of mathematics anxiety (average 1.85(out of 5)/item) were found to exist within the cohort with a small portion (3%) of students reporting very high mathematics anxiety levels. Mathematics anxiety levels observed were comparable with levels reported on other studies and no real difference in the anxiety levels between level 7 and level 8 students was evident. No significant change in mathematics anxiety levels was detected over the course of the module. As with previous studies these findings suggest that mathematics anxiety is not necessarily related to ability and that context does not appear to reduce anxiety levels (Hembree, 1990). Although others disagree, Ma & Xu (2004) concluded that prior low mathematics achievement leads to subsequent high mathematics anxiety, this relation being more consistent for boys than girls, while prior high mathematics anxiety does not result in subsequent lower mathematics achievement.

Finally the self-reported low levels of competence, confidence and enjoyment of mathematics among L7 students point to the need for behavioral interventions which focus on attitude change, building confidence and eliminating negative self-statements (Hembree, 1990).

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Standards of university teaching – what, if anything, can be learned from schools?

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Abstract
The recent White Paper (BIS, 2016a) talks of 'teaching excellence' and how this can be 'measured' using 'core metrics'. The accompanying Green Paper (BIS, 2016b) considers in detail as to what is meant by 'teaching excellence' (BIS, 2016b). The Green Paper proposes Assessment criteria to form the basis of the assessment across the three main aspects of quality' for the Teaching Excellence Framework (TEF), and what evidence a 'TEF Panel member/assessor' may be looking for to make their judgements. The proposals include assessing the first of the three aspects, 'Teaching Quality', against a number of criteria. The Green Paper makes reference to evidence collected from observations of teaching sessions, peer review, etc., to demonstrate teaching excellence.

While there are clearly differences between school and university teaching, this paper examines whether the *standards* of teaching that apply to schools could be applied to universities, with appropriate interpretation, and whether these could form part of review mechanisms that provide evidence to support the 'Teaching Quality' aspect of TEF.

1. Introduction – the Teaching Excellence Framework
The recent White Paper (BIS, 2016a) talks much of 'teaching excellence' and how this can be measured using 'core metrics'. The accompanying Green Paper (BIS, 2016b) considers in detail as to what is meant by 'teaching excellence' (BIS, 2016b).

The response from BIS to the public feedback on the TEF Technical Consultation (BIS, 2016b) is still awaited, although it must certainly be the case that there will be considerable emphasis placed on 'core metrics' such as student satisfaction, progression and achievement data, graduate employability prospects and graduate earnings, career progression, 'value-added' measures, etc., with universities able to charge higher tuition fees where they are performing well against such metrics.

The Minister of State for Universities, Science, Research and Innovation (Johnson, 2016) is committed to "*…putting high quality teaching at the heart of higher education.*" and that the TEF "*…will put clear information in the hands of students so they know where teaching is best…*". But what does 'teaching excellence' mean in an HE context, and do such metrics give any measure as to where 'teaching is best'? Are any of these metrics about teaching at all, let alone teaching *excellence*?

This paper does not seek to answer these questions, but instead considers directly the aspects of the Technical Consultation (BIS, 2016b) which *are* demonstrably about teaching. We consider whether the standards of teaching that are established in schools could be applied to HE, with appropriate interpretation, and provide a starting point for supporting evidence for TEF on teaching excellence.

2. TEF expectations on 'Teaching Quality'

The Green Paper (BIS, 2016b) gives an indication as to what is meant by 'teaching excellence' and proposes "*Assessment criteria to form the basis of the assessment across the three main aspects of quality*" for the TEF, and what evidence a 'TEF Panel member/assessor' may be looking for to make their judgements. The proposals include assessing the first of the three aspects, 'Teaching Quality', against a number of criteria. The Green Paper makes reference to evidence collected from observations of teaching sessions, peer review, etc., to demonstrate teaching excellence.

The first criterion is the extent to which "*Teaching provides effective stimulation and chal-lenge and encourages students to engage*". 'TEF Panel members/assessors' are guided to be 'looking for evidence that students are sufficiently challenged and engaged', and evidence that supports this might include 'teaching observation schemes'.

The second criterion is the extent to which "*Institutional culture recognises and rewards excellent teaching*". TEF Panel members/assessors are guided to be "*looking for evidence that the ethos promotes and values teaching excellence*", and evidence that supports this might include "*reward and recognition, promotion and progression opportunities*".

Examples of additional evidence for the 'Teaching Quality' aspect again features observation of teaching sessions and peer review, including: "*Impact and effectiveness of teaching observation schemes*" and "*Recognition and reward schemes, including progression and promotion opportunities for staff based on teaching commitment and performance*".

While institutions will have no choice over the 'core metrics' they are measured against, it is likely that institutions will have complete autonomy on what mechanisms it can put in place to provide evidence to address the criteria above on 'Teaching Quality'. It also seems clear that one key component is the use made of peer observation, peer review, and appropriate recognition and reward schemes for teaching.

The highly-commendable article by Seldon (2016) provides a comprehensive set of proposals on how to address the requirements of TEF, and what needs to be done to best serve the interests of students and put excellent *teaching* (and not just first-rate metrics) at the heart of a university's mission.

3. Are school teaching standards applicable to HE?

While there are clearly differences between school and university teaching, there is also much in common in terms of the standards that could be applied to both sectors. We challenge the notion that the standards that are well-established for teachers in schools (Glaister & Glaister, 2013) are not appropriate to apply to university teachers. We believe that standards along these lines are appropriate – in all cases it is merely a matter of interpretation. Moreover, such standards can be incorporated into recognition and reward schemes to inform progression and promotion (Glaister, 2016), and would promote and support teaching excellence. We believe universities have much to learn from schools in this regard.

A teacher's primary responsibility is to facilitate learning. An excellent teacher does their utmost to ensure that every student reaches his or her potential. In England the current criteria that teachers are expected to meet to achieve this is laid out in the Department for Education's Teachers' Standards (DfE, 2011). These represent a demanding set of standards which all teachers have to meet on an ongoing basis. So what changes when school students enter university and encounter a greater variety of styles of university teaching, a greater number of university teachers and, more importantly, university teachers with a wider range of attributes and aptitudes for teaching?

The following set of eight standards is based on ones which apply in schools. Which of these could apply to university teachers, or how could these could be revised to suit the needs of HE, and could these facilitate better recognition and reward of teaching excellence?

1. Set high expectations which inspire, motivate and challenge students
    - set goals that stretch and challenge students of all backgrounds, abilities and-dispositions.

2. Promote good progress and outcomes by students
    - be accountable for students' attainment, progress and outcomes in conjunction with any staff supporting their teaching
    - be aware of students' capabilities and their prior knowledge, and plan teaching to build on these
    - guide students to reflect on the progress they have made and their emerging needs
    - demonstrate knowledge and understanding of how students learn and how this impacts on teaching
    - encourage students to take a responsible and conscientious attitude to their own work and study.

3. Demonstrate good subject knowledge
    - have a secure knowledge of the relevant subject areas, foster and maintain students' interest in the subject, and address misunderstandings
    - demonstrate a critical understanding of developments in the subject, and promote the value of scholarship
    - demonstrate an understanding of and take responsibility for promoting high standards of the correct use of standard English.

4. Plan and deliver well-structured teaching sessions
    - impart knowledge and develop understanding through effective use of teaching session time
    - promote a passion for learning and students' intellectual curiosity
    - set formative (and, where relevant, summative) coursework, and guide students to engage in other independent learning activities outside teaching sessions to consolidate and extend the knowledge and understanding they have acquired
    - reflect systematically on the effectiveness of teaching sessions and approaches to teaching
    - contribute to the design and provision of an engaging curriculum.

5. Adapt teaching to respond to the strengths and needs of all students

- know when and how to differentiate appropriately, using approaches which enable students to be taught effectively
- have a secure understanding of how a range of factors can inhibit students' ability to learn, and how best to overcome these
- have a clear understanding of the needs of all students, including those with special educational needs; those of high ability; those with English as an additional language; those with disabilities; and be able to use and evaluate distinctive teaching approaches to engage and support them.

6. Make accurate and productive use of assessment
   - know and understand how to assess the relevant subject areas effectively
   - make use of formative and summative assessment to secure students' progress
   - use relevant data to monitor learning and plan subsequent teaching sessions
   - give students regular feedback, both orally and through accurate marking, and encourage students to respond to the feedback.

7. Manage behaviour effectively to ensure a good learning environment
   - have clear rules and routines for behaviour in a teaching session, and take responsibility for promoting good behaviour in teaching sessions
   - manage teaching sessions effectively, using approaches which are appropriate to students' needs in order to involve and motivate them
   - maintain good relationships with students and exercise appropriate authority.

8. Fulfil wider professional responsibilities
   - develop effective professional relationships with colleagues, knowing how and when to draw on advice and specialist support
   - deploy administrative and teaching support staff effectively
   - take responsibility for improving teaching through appropriate professional development, responding to advice and feedback from colleagues
   - take advantage of continuing professional development opportunities, both locally and nationally, and to incorporate best practice in their teaching.

We would argue that every one of these applies to a university teacher, with appropriate interpretation in an HE context as necessary, depending on the nature of their teaching responsibilities.

Such standards could be used to help establish a fair, robust, transparent and objective mechanism for recognising and rewarding university teaching. This could be based on a review process that is supported by documented evidence which addresses each of these standards. These outcomes can be fed into performance and development reviews, and used to inform decisions about reward and promotion, as well as the review of probationary status where appropriate. This could provide the evidence sought in the 'Teaching Quality' aspect of the TEF outlined in Section 2.

It goes without saying that any scheme which is designed to recognise and reward teaching should not become a 'tick-box' exercise, whether it is one based on the standards above or something else entirely. To reap maximum benefit from any scheme of this kind it is essential that colleagues engage in the spirit in which it is intended - as a developmental tool which supports colleagues to enhance their teaching. If this provides supporting evidence for TEF then so much the better.

For those in HE looking to develop professional academic skills for teaching to enable them to become effective, excellent teachers, the handbook by Fry, Ketteridge and Marshall (2009) has much to commend it. This covers: teaching and supervising, focusing on a range of approaches and contexts; teaching in discipline-specific areas; approaches to demonstrating and enhancing practice, and goes a long way to supporting the needs of those in HE aiming to provide evidence in support of TEF and addressing standards such as the ones above.

4. The HEA Professional Standards Framework

The current overarching framework for professional standards for HE within the UK is the Professional Standards Framework (UKPSF) (HEA, 2011) developed by the Higher Education Academy (HEA). As its first aim, the UKPSF "*supports the initial and continuing professional development of staff engaged in teaching and supporting learning*". The Academy supports the Framework by providing a recognition and accreditation service which enables staff providing teaching and/or learning support to be recognised, depending on their role and experience as either: Associate Fellow, Fellow, Senior Fellow or Principal Fellow of the Academy, based on a set of statements outlining the key characteristics of someone performing in four broad categories of typical teaching and learning support roles within HE. Any institutional-level professional development activities for probationary members of staff should enable them to meet the criteria for the designation of Fellow.

The UKPSF has much to commend it, and it is to be expected that universities will use data on numbers of staff in each category as evidence for TEF to demonstrate that teaching and professional development in teaching is valued, and supports the delivery of excellent teaching.

To what extent does category of Fellowship confer levels of teaching excellence, though, and how far does data on numbers of staff in each category support any claim of teaching excellence as expected of TEF? The Technical Consultation (BIS, 2016b) refers to teaching observations, but it is not clear how much evidence from this activity is required to meet the requirements of the criteria for each level of Fellowship, and yet TEF does make a number of references to such schemes. One could argue, however, that *if* a Fellowship confers a certain level of teaching excellence as required by TEF, and if achieving an elevated grade of Fellowship is rewarded through promotion or other financial incentives, *then* the TEF requirement of having 'Recognition and reward schemes, including progression and promotion opportunities for staff based on teaching commitment and performance' is met. Universities will tacitly assume this hypothesis and use this as a driver to increase numbers of staff in all categories of Fellowship. Is this what TEF means by teaching excellence, though? The UKPSF does an excellent job in promoting strong professional development, but does it actually measure teaching excellence for TEF purposes?

5. Conclusions

We encourage colleagues to reflect on the eight standards outlined above and consider for themselves whether these could apply to university teaching, or how these could be revised to suit the needs of HE, and how these could facilitate better recognition and reward of teaching excellence.

The title of this conference is 'A Brave New World' and a key theme is "Demonstrating and evidencing teaching excellence in the mathematical sciences". Establishing standards of university teaching along these lines would indeed be a brave step in this new world of accountability and TEF, but if established these could contribute strongly to demonstrating and evidencing teaching excellence as will be required by TEF.

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Building mathematics: how artefacts can be used to engage students with their learning of mathematics

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Abstract
There has been much discussion about what techniques can be employed successfully to engage students with their learning of mathematics. At university level these include problem based approaches and enrichment activities. Work also identifies the importance of engaging students in meaningful mathematical discussion as an essential component of students' mathematics learning.

At pre-undergraduate level there is a range of evidence supporting the use of mathematical objects or artefacts to introduce new concepts. It is argued that this type of activity gives a visual and physical perspective to the learning and reinforces newly introduced concepts. However this notion is not widely used to support the learning of undergraduate level mathematics.

The Mathematics team at Middlesex utilised and built on ideas and techniques within these areas to develop a series of tasks and activities to engage students with mathematics and promote understanding of advanced concepts. These included the construction of mathematical artefacts that supported concepts and ideas that the students were learning within the mathematics curriculum. The series of activities developed are referred to as 'Building Mathematics' activities. The process of constructing, use of these artefacts, and the discussion it promoted is shown to help develop a deep understanding of mathematical concepts.

In this article we will discuss the types of activities used, the artefacts produced and the impact on students learning of mathematics. We will reflect on the successes and challenges of the venture and discuss plans for future development and enhancement of the initiative.

1. Background
The step-up from pre-university mathematics learning to undergraduate mathematics has been studied for a number of years. It has been argued that pre-university mathematics fails to prepare students sufficiently for many of the more abstract concepts studied, (Smith, 2004; Hawkes & Savage, 2000). One of the resulting issues is disengagement. Indeed the QAA benchmark statement, (QAA, 2015), highlights the importance of engagement in the learning process. In (Borovik & Gardiner, 2006) the authors indicate that "*mathematics requires a high level of motivation and emotional involvement on the part of the learner*", a sentiment that most mathematicians and mathematics educators will agree with. Engagement is thus seen as core to developing a deep understanding of the subject. Providing an engaging and intellectually stimulating learning experience is a key component to this. Techniques used to do this include problem and activity based learning and enrichment activities.

One method often utilised to develop engagement with mathematics at pre-university level is the use of mathematical artefacts and instruments. In the current article we define an artefact as a physical object. This can be generalised, and has been in the literature, to any object produced by humans including sounds, physical gestures, technology and so on, although there is some discussion on the precise definition of an artefact.

This follows a Vygotskian approach, (Vygotsky, 1986). Vygotsky put forward the theory that meaningful activity plays a role and is a generator of understanding. According to Vygotsky higher mental functions should be viewed as the products of mediated activity. In the case of mathematical learning we see the artefact as the mediator between the learner and the concept. Vygotsky also indicated that knowledge and understanding could be facilitated through social activity. The social aspect of activities is also, then, a vital part of the learning process.

In Crawford et al. (1993), and as cited in Crawford (1996), the authors claim that traditional approaches to teaching mathematics at universities have limited mediated activity. The authors found that 80% of students felt that mathematics was simply a set of techniques designed to solve particular problems. Furthermore it was claimed that students merely learnt mathematics in order to perform well on assessment and did not seek a deeper understanding of the subject. More recently, Bartolini and Mariotti (2008) discuss the role, use and contribution of artefacts and instruments as tools to develop a deeper understanding. Despite this research being done at the pre-university level we expect the use of artefacts to have a similar impact at more advanced levels.

Drawing on the research described here the programme team at Middlesex University designed a number of tasks and workshops designed to engage students with their learning of mathematics. A weekly timetabled session was introduced called ‘Engaging with Mathematics’ and embedded activities were used in modules throughout the year. The current article will discuss details of and the general aim of some of the activities where artefacts were used. Some of these activities have previously been reported by the second author in (Megeney, 2015) in the context of employability skills.

2. Engaging students using artefacts

In this paper we will discuss two of the engagement activities the team developed although other activities were designed.

2.1. Visualising higher dimensions

Students often find the move from two and three-dimensional geometry to higher dimensions difficult. Indeed the fact that one cannot visualise these dimensions requires an abstract understanding of the links between geometric objects and their mathematical descriptions. In order to allay these concerns in students the programme team designed a visualisation activity to demonstrate objects in four dimensions by considering their shadows in three dimensions. This, of course, is a familiar technique in lower dimensions where, for example, one might draw a cube on a piece of paper.

Using the construction kit Zometool™ students were asked to build various three dimensional objects and study their shadows using a torch or a projector. Students learned that familiar objects like cubes, tetrahedrons, dodecahedrons and so on produced shadows that often bared a resemblance to the original shape, but also occasionally did not. In particular producing a hexagonal shadow from a cube was facilitated by the team and demonstrated by the students.

Using the students' familiarity with these shapes allowed them to develop a deeper understanding of four dimensional objects. For example students found that the two-dimensional square shadow of a cube allowed for a generalisation of the cube as a three-dimensional shadow of the four-dimensional hypercube. This led students to the notion of projections from higher dimensions.

It was found that these activities helped students overcome their initial fear of working in higher dimensions. The programme team found that, by the end of the sessions, students were not only able to work in higher dimensions but were comfortable doing so. In fact the final activity includes working together to build a shadow of the four-dimensional equivalent of a dodecahedron, the 120-cell. And this part of the activity promoted communication and group discussion.

These activities fed directly into the content of their first year courses where Zometool™ and the students' familiarity with it facilitated their understanding of the abstract concepts including finite-dimensional vector spaces and linear algebra where higher dimensions are frequently discussed and, importantly, treated no differently from two and three dimensions.

2.2. Sierpinski Tetrahedron

The second activity was designed as an enrichment activity. This activity reinforced the notions of recursion and induction that the students encounter in their modules. These concepts are introduced pre-university and are often taught as a series of steps with little emphasis on the understanding of what can be a challenging idea. Examples encountered of the principle of induction in particular often follow a similar familiar style. The programme team felt that working with these concepts constructively using the self-similarity of fractals would improve students' confidence in applying these ideas to less familiar situations. Furthermore it offered the opportunity for the team to challenge the ideas of measurement in space in preparation for more advanced concepts like measure and Hausdorff dimension that they may encounter later in their degrees.

Students worked together to produce a model of a Sierpinksi tetrahedron. Some groups worked on smaller tetrahedrons, others on fitting these together. Each group required coordination and communication in order to correctly construct their parts.

Towards the end of the first year, students take part in an external, public facing event designed to encourage children and young people to consider studying STEM subjects. At this event the students ran the Sierpinski tetrahedron activity themselves, communicating the ideas to children and young people. This required students to tailor their communication of more advanced ideas to the audience: some of the participants were happy to discuss concepts at length, some of the younger children simply wanted to play.

3. Discussion

Anecdotal evidence from staff and students confirm the influence of interaction with artefacts on the learning of more advanced topics. Reflections of students further solidify these links and suggest an increased confidence in working on advanced mathematics. One student said "I found the ideas behind symmetrical objects, especially higher dimension ones, extremely fascinating. … I find it hard to imagine anything higher than 3D, so I really appreciated having an idea of how things can be viewed". Another student told us "[the activities] helped each of us grow our knowledge [sic] and ability, but at the same time, have fun".

Other students confirmed that the communication of ideas reinforced their understanding of the ideas, one saying that "explaining what a Sierpinski tetrahedron is helped deepen my understanding".

The opportunity for social interaction between students and staff was also noted positively by students. One student said "we got to work closely with the staff during all these activities. This was very good to build up confidence and self-esteem". Yet another said that the "merits of interacting with staff, students and the public was that we were able to work together, learn together, and literally build together. This helped each of us grow our knowledge and ability, but at the same time, have fun; there were also a lot of successful teamwork and communication between each other". Another student said that "these activities created an environment of active, involved and explanatory learning".

The improvement in student engagement has been noted by staff teaching on the programme. This extends work done in (Megeney, 2015) on promoting the development of employability skills using mathematics engagement activities.

The project reported in this article is moving into its third year. Feedback received to date is very positive, both from students and staff. There is evidence that motivation and engagement of students in the subject and their course is improved. Students are more confident in expressing their opinions and questioning theory. There was, in particular, a notable improvement in student engagement following their participation in the external event described in section 2.2.

One consequence of this is that a number of students have indicated a wish to become involved with these and similar activities in the future. Furthermore there is an increase in involvement with peer assisted learning schemes at the university as a result of the activities.

The innovations discussed in this article are not without their challenges. The time required to design a meaningful mediated activity can be substantial and should not be underestimated. Ensuring the mathematical content of activities is sufficiently clear and communicated can be a challenge in itself. Furthermore balancing the fun element of an activity and the learning experience can be difficult, this should be considered carefully in the design of the activities.

It was clear that on occasion staff or students involved in the activities were not as receptive to the learning experience as we would have liked. Catering for different learning styles is therefore an important aspect of the design. Indeed including the student voice in the design of activities is an important aspect.

In the future we expect to continue and extend the range and type of activities following the success of the Engaging with Mathematics series and other activities. In particular the mathematics undergraduate programmes will continue to take an active part in external outreach events. Furthermore the team are planning on involving final year students in developing and delivering activity workshops akin to those described in this article.

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New A level maths qualifications: students' familiarity with large data sets and use of technology at the transition

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Abstract
Awarding Organisations are going through the process of having new AS and A level specifications in Mathematics and Further Mathematics accredited by Ofqual for first teaching in September 2017. This follows the introduction of new, more demanding GCSEs in Mathematics (and English) that are being taught from September 2015.

In the new mathematics A levels there will be a greater emphasis on problem solving, modelling, reasoning and proof. There will be a new approach to statistics; students are expected to explore a large real-world data set in class. Also, the use of technology, in particular graphing tools and spreadsheets, must 'permeate' the study of the qualifications.

This will mean those entering university with the new Mathematics A levels (and having studied the harder GCSE Mathematics) should be different in respect of their mathematical skills and knowledge. The 2017 Mathematics A level has prescribed content, which includes topics in statistics and mechanics, as well as in pure mathematics. The Awarding Organisations have more freedom within their A level Further Mathematics specifications (as only 50% of the content, which is pure mathematics, is prescribed). E.g. 'Modelling with Algorithms' and 'Further Pure with Technology' are options in the draft OCR (MEI) Further Mathematics specification.

This paper will consider in more detail some of the 'new' aspects of the revised specifications, namely the added focus on use of technology and analysis of large statistical datasets. It will consider what the implications may be for higher education, from students who have studied these reformed qualifications.

1. Introduction
It is anticipated that the first specifications for the 2017 AS/A levels in Mathematics and Further Mathematics will be accredited in September 2016. However, experience of other qualifications that have been through this process suggests that accreditation could be prolonged over many months.

Draft specifications were submitted to the regulator, Ofqual, in June 2016 and can therefore now be openly discussed. Thus, this article will act as a continuation of the September 2015 CETL-MSOR Conference paper – 'When, what and how are changes being made in 14-19 mathematics education – a view from a curriculum development body', Lee and Proffitt (2015).

2. The development of new mathematics AS/A levels for 2017

A levels are one of the most valued qualifications for students making the transition to higher education, Ipsos MORI (2012). Following research and consultation by Ofqual in 2012/13, wholesale changes to the structure of A levels were required – the qualifications would become linear, rather than modular, and AS levels would be standalone from A levels (rather than contributing to A level grades). Content would also be reviewed and the A Level Content Advisory Board (ALCAB) was established to provide advice to Ofqual in subjects identified by leading universities as particularly important. More than three-quarters of the ALCAB mathematics committee were from universities; the group was chaired by Professor Richard Craster.

2.1. Increased emphasis on mathematical reasoning and proof, problem solving and modelling

The draft content for the 2017 mathematics qualifications was carefully chosen by ALCAB. They wanted to promote increased emphasis on mathematical reasoning and proof, problem solving and modelling, DfE (2014:4). In the lifetime of the current mathematics specifications, which have effectively remained the same since 2004, the big changes to mathematics in academia, employment and everyday life have been the ubiquity of technology and the ways in which data are used.

An unusual feature of the qualifications landscape in England is that content and assessment are the responsibilities of different bodies, which have different accountabilities. The DfE content prescribes what should happen in classrooms, but one of the biggest effects on classrooms is what the examination questions and assessment look like. Ofqual is responsible for regulating the Awarding Organisations which produce the examinations.

In order to ensure that the intentions of the DfE content were met, Ofqual set up an expert panel to consider what problem solving, modelling and the use of large data sets might look like in examinations. This reported in December 2015, Ofqual (2015). It produced detailed content expectations and definitions, along with exemplars. These were selected by the working group and a supporting commentary was provided, which identified the features that made them problem solving exemplars. Draft mark schemes were also generated.

Another unusual feature of the qualifications landscape in England is 'competing' Awarding Organisations. Thus there needs to be regulation to ensure comparability; part of Ofqual's regulation is to use Assessment Objectives to regulate assessments. Clearly problem solving, and more especially modelling, is difficult to assess in timed written examinations. Some will be disappointed at what is on offer from the Awarding Organisations in their sample assessment material submitted with their draft specifications.

The intentions are clear. However, it remains to be seen what the effect will be on students' learning of mathematics. Will teachers respond with enthusiasm to what is expected of them in the classroom, or will they limit themselves to what is expected in the examination?

2.2. Use of technology

In the current specification the Assessment Object relating to use of technology, with a minimum weighting of 5% of the qualification, states (Ofqual (2011)):

> "*Use contemporary calculator technology and other permitted resources (such as formulae booklets or statistical tables) accurately and efficiently; and understand when not to use such technology, and its limitations.*"

This has been written into the content and strengthened considerably for 2017, DfE (2014:5):

> "*The use of technology, in particular mathematical and statistical graphing tools and spreadsheets, must permeate the study of AS and A level Mathematics. Calculators used must include the following features:*
>
> - *An iterative function;*
> - *The ability to compute summary statistics and access probabilities from standard statistical distributions".*

The strong language which states that the use of technology 'must permeate' the qualification is very clear. In their draft 2017 specifications none of the Awarding Organisations are to offer 'non-calculator' examinations. However, the main impact on the actual examinations could be changes to the use made of calculators, which includes to compute summary statistics and access probabilities from standard statistical distributions. Thus making a move away from more archaic listing of statistical tables, as was found previously – does anyone miss slide rules and log tables?

The current OCR (MEI) specification was successful in enabling a computer algebra system to be used in one paper and this is built upon in their draft 2017 specification. It would be a real missed opportunity if all Awarding Organisations didn't encourage exploration of mathematics with suitable software and tools, as per the intention of the outline guidance.

2.3. Large data set

In the 2017 specifications a new emphasis has been placed on large data sets; in AS and A level Mathematics it is stated that students are required to (Ofqual, 2014):

- become familiar with one or more specific large data set(s) in advance of the final assessment (these data must be real and sufficiently rich to enable the concepts and skills of data presentation and interpretation in the specification to be explored);
  use technology such as spreadsheets or specialist statistical packages to explore the data set(s);
- interpret real data presented in summary or graphical form;
- use data to investigate questions arising in real contexts.

With real data there will be a need to do data cleaning, something that is nearly always required when doing analysis 'in the real world' and the use of technology will be immensely helpful (necessary?) for undertaking analysis. The large data set should also provide a playground for exploring and interpreting data. E.g. when introducing the Normal distribution, real data could be used, and not even necessarily from the Awarding Organisation's specified data set.

The examination requirements from Ofqual in this respect are for there to be a 'material advantage' to students if they have studied the dataset. There were no exemplars in the expert panel report to illustrate this. However, the report did say that "*The familiarity candidates gain with contexts related to the large data set(s) will enable them to answer questions about interpretation of data that are often found difficult by candidates when the contexts are unfamiliar.*"

3. The transition to higher education

Firstly, a reminder that the students who will be taking the new AS/A level in Mathematics in 2017 will be the same students who have taken a new, more difficult, linear GSCE in Mathematics. It remains to be seen just how 'different' the students who have experienced the new GCSE Mathematics examinations will be.

In Lee and Proffitt (2015) we concluded the paper on changes in 14-19 maths education with a section on implications of all the changes. The points raised there are still of relevance, but we now know more about the overarching areas of change for the 2017 A levels cited in this paper, namely: increased emphasis on mathematical reasoning and proof, problem solving and modelling; use of technology; and large data sets.

It is widely acknowledged that inclusion of these aspects into Mathematics A levels should be seen as a positive development in pre-university mathematics education. It's also hoped that they will create impetus for a shift in pedagogy, with these characteristics more widely embedded in classroom practice. If teachers are motivated, by the curriculum and examinations, to use technology with their students, and to have the students use technology themselves, then this will result in deeper learning of mathematics as well as increased competence with software and hardware.

The requirement to consider a large dataset, the opportunity to incorporate use of technology, increased modelling and mathematical reasoning provides great potential for improved learning in mathematics. Such a teaching experience should enable students to be well-prepared to make the transition to university to study STEM-related subjects.

4. Concluding remarks

In a time of extensive change in 14-19 mathematics education, and beyond, there are many potential risks and rewards. Clearly teachers will need support in instituting these changes and this is at a time of difficulty in recruitment and retention of mathematics teachers (National Audit Office, 2016), at the same time as compulsory GCSE resit and growing take-up of new Core Maths qualifications.

However, as highlighted earlier – over the last decade the big changes to mathematics in academia, employment and everyday life have been the ubiquity of technology and the ways in which data are used. Modelling and solving problems can invariably benefit from incorporating technology to either facilitate the visualisation of abstract concepts, deepen overall understanding, or simply to compute calculations that would otherwise be time-consuming, or impossible by hand. The intention, that from 2017, students will be exposed to more technology, problem solving and data analysis in A level Mathematics, should be fantastic news for those working at the transition. It is hoped that there is the help and support for teachers and schools to provide students with a rich mathematics curriculum and that these intentions are not undermined by other factors outside the control of curriculum developers, such as funding for actually running the qualifications.

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Attitudes and anxiousness about maths

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Abstract
A fear or dislike of mathematical subjects is commonplace amongst students outside the mathematical sciences, but for some students, their anxiety about maths has a serious impact on their ability to study the subject effectively. Traditionally, students with maths anxiety (MA) have avoided subjects known to contain maths or statistics. The rise in the use of statistics within most disciplines means that this avoidance is not always possible. The most effective strategy for reducing anxiety is to receive one-to-one support, but a lot of students with high maths or statistics anxiety levels do not visit maths support centres. This paper reports on a part of a long term collaborative project between the Maths and Statistics Help Centre (MASH) and Specialist Learning Difference (SpLD) service at the University of Sheffield to address student maths anxiety, evaluate the effectiveness of a number of strategies, and encourage attendance at MASH. This paper will summarise the findings of an initial survey of University of Sheffield students designed to investigate attitudes and anxiousness about maths.

1. Introduction
Maths anxiety can be described as "*feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a variety of ordinary life and academic situations*" (Richardson & Suinn, 1972) and it is thought to affect up to 85% of students at some level (Perry, 2004). Whilst mild anxiety is to be expected, especially around exam time, 26% have moderate to high levels (Jones 2001), which has a serious impact on their ability to learn maths. Maths anxiety impacts on mathematical performance by interfering significantly with the working memory (Young et al., 2012), which is essential for successful problem solving. The thought of maths triggers negative memories and the default response is to run away. This leads to students not engaging with maths, poor preparation, and underperformance in exams which reinforces the students' view that they are bad at maths. This avoidance strategy also means that students opt out of maths as soon as possible, restricting their degree and career options (Ashcraft & Moore, 2009).

1.1 Causes of maths anxiety
The genesis of maths anxiety is thought to lie in negative learning experiences early in education. Primary school teachers exhibit some of the highest levels of MA (Hembree, 1990), often lacking confidence in their own subject knowledge. They can have negative beliefs about maths as a consequence of their own negative experiences with maths at school. As a result, they tend to stick to set rules and methods (Finlayson, 2014) and often pass on their own anxieties to their students. Rote learning, lack of enthusiasm and timed high-stakes tests also contribute towards negative attitudes to maths, which can start in the early school years (Scarpello, 2007). Maths teachers in secondary schools usually have broad mathematical knowledge but may be unable to explain concepts clearly, lack patience, make negative comments, or humiliate students in the

classroom. By the time students reach university, 93% of students have had a stressful or negative experience with maths (Jackson & Leffingwell, 1999).
Parental beliefs and attitudes about maths can also influence the maths anxiety of their children (Scarpello, 2007). Parents who themselves believe that they can't do maths are less likely to help their children with homework, and maths-anxious parents who provide frequent help with homework can increase a child's anxiety. In terms of gender differences, there is no difference between average maths scores of girls and boys, but girls report higher average maths anxiety levels, leading to underrepresentation in the field of maths (Tomasetto, Alparone and Cadinu, 2011). Finally, students with dyslexia (Jordan et al., 2014) and dyscalculia (Rubinsten & Tannock, 2010) are at greater risk of maths anxiety.

2. Methods

In order to collect views on studying maths and possible factors influencing maths anxiety, a questionnaire was designed and all students at Sheffield University were invited to take part between Sept–Dec 2015. They were also invited to give their university registration number so anonymised demographics such as faculty and gender could be obtained from the university record, and 487 of the 573 respondents provided this data.

The questionnaire contained questions on attitudes and achievements at school, expectations for their study and the UK MARS scale. The Mathematics Anxiety Rating Scale (MARS) was originally developed by Richardson and Suinn (1972) and was constructed to provide a measure of anxiety associated with the single area of the manipulation of numbers and the use of mathematical concepts. However, there were some issues with the size of this scale and its use with British undergraduates, so the 23-item UK version of the MARS was used (Hunt et al., 2011). Comparisons were made using the total score for each student.

3. Results

In order to assess whether the respondents of the survey were representative of the population, a comparison of gender and faculty proportions with university figures was made. 57% of respondents to the survey were female, compared to 51% in the general university population. The faculty percentages were mostly similar, but there was an underrepresentation of the Faculty of Social Science by 12% and overrepresentation of the Faculty of Science by 10%. This difference will impact on numerous results because science students are more likely to have studied maths at a higher level and may be less anxious.

3.1 Attitudes and achievements at school

Overall, 52% of respondents had a maths qualification above GCSE Maths and 9% did not achieve a grade A*-C at GCSE Maths the first time. Students were asked how they felt about maths at primary and secondary school on a 5 point scale ranging from 'Hated it' to 'Loved it'. It was expected that some students would dislike maths from the beginning, but this number would grow in secondary school. The results suggest that there were only small differences between attitudes at primary and secondary school. To investigate whether students change their attitudes towards maths between primary and secondary school, the change in rating was calculated. Figure 1 shows that just over half the students did change their attitude, but more found primary worse than secondary.

Maths attitudes	Freq.	%
Secondary worse	117	21%
Same	279	49%
Primary worse	172	30%
Total	568	

Figure 1. Change in attitudes to maths between primary and secondary school.

To assess differences in attitudes to maths by faculty, the 5-point scale was reduced to a 3-point scale and the results shown in Figure 2. As expected, Engineering had a much higher proportion of students who enjoyed maths at secondary school. However, over 40% of students in every faculty enjoyed maths, which is surprising given the number of people who claim to dislike maths in general.

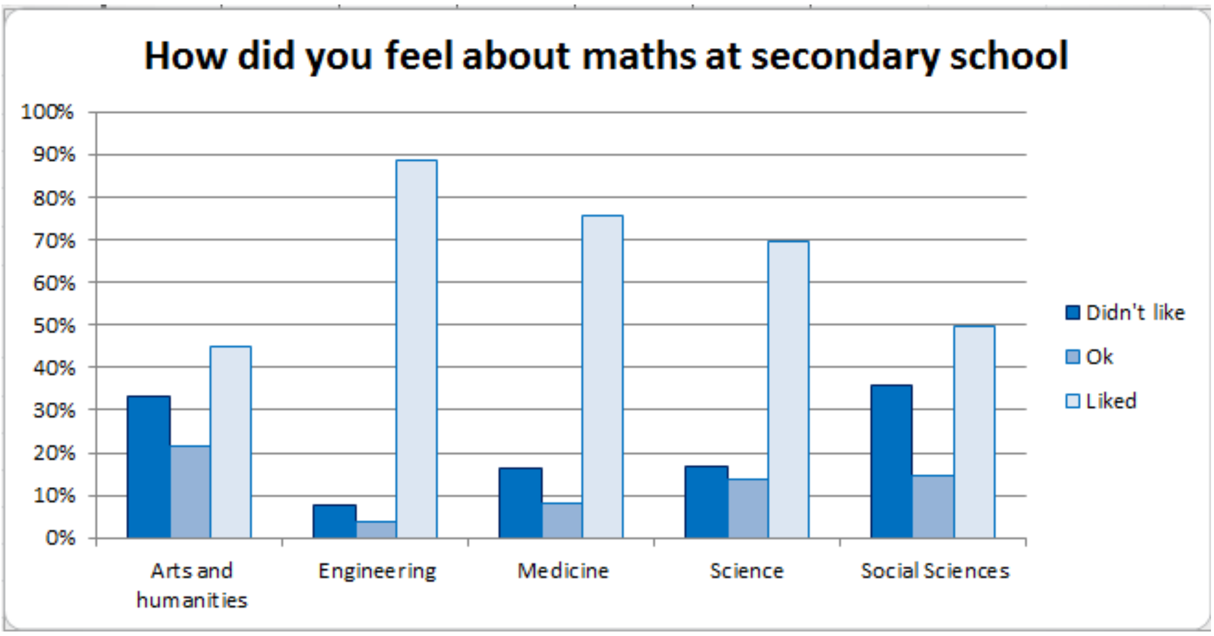

Figure 2. Comparison of attitudes to maths in secondary school by faculty.

It is fairly common for people in the UK to openly admit that they are bad at maths whilst very few admit to being bad at other subjects e.g. English. We used 6-point Likert questions starting with 'I did badly in …' for maths and English in primary and secondary school questions to gauge students' perception of how they did at school. Apart from a slight increase in people agreeing that they did badly in secondary school maths, the other differences were negligible.

3.2 University study and impact

Students were asked if they expected to study maths or statistics as part of their course and 89% said they were. Figure 3 contains a further breakdown of the results.

Expect to study	Number	Percentage
Neither	28	5%
Just maths	158	29%
Just stats	136	25%
Both	196	36%
Don't know	32	6%
Total	550	

Figure 3. Breakdown of subjects students expect to study as part of their course.

It was expected that more students would be studying statistics, but the underrepresentation of Social Sciences in the study is the likely cause. It is also possible that students don't know that they will be using statistics later in their degree so have answered "no" or "don't know". Overall, 48% of students were worried about studying maths or stats. Figure 4 shows the percentage of students within each faculty who said they were worried (either a bit or very). Students in the social sciences are the most concerned about studying maths or statistics with engineers having the lowest levels of concern.

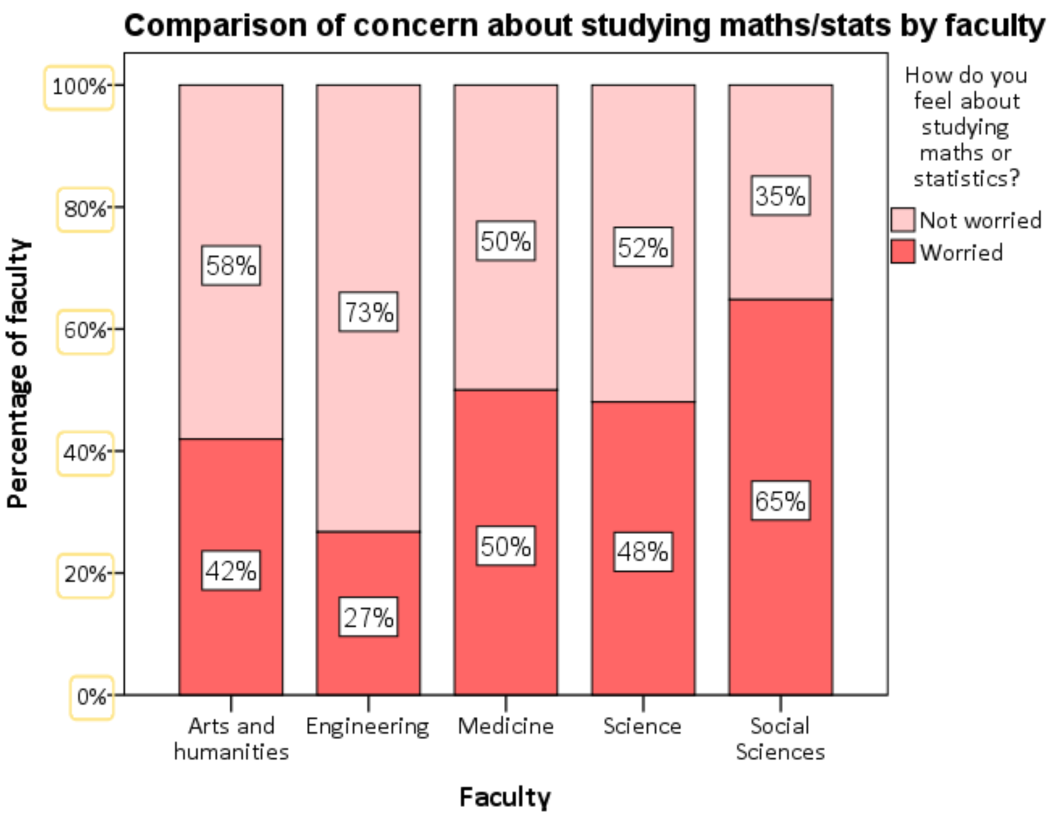

Figure 4. Impact of anxiousness about maths on choices.

Students were asked whether a fear or dislike of maths had influenced choices of A-level, degree, module or job. Overall, 44% of students said that a fear or dislike of maths had influenced at least one of these choices. Figure 5 shows the impact on each choice with A-level choice having the highest percentage of 35%. Choice of A-level limits each of the other choices so it has the biggest impact.

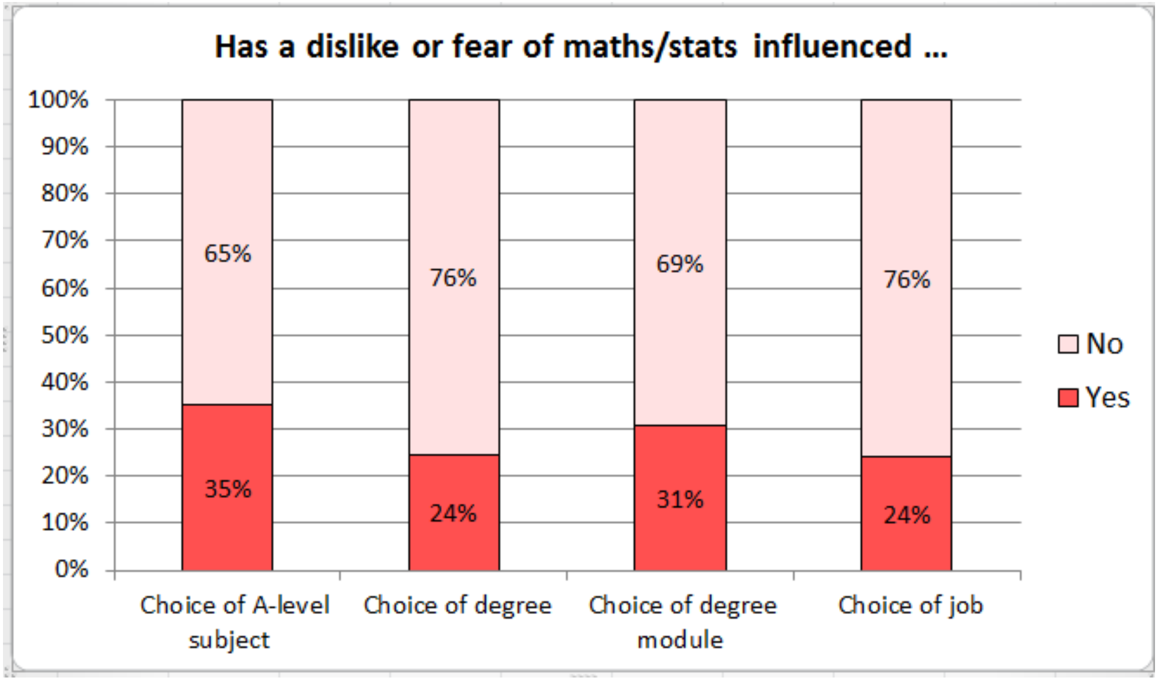

Figure 5. Impact of anxiousness about maths on choices.

3.3 Factors linked to higher maths anxiety

This section makes comparisons between different groups on overall maths anxiety scores from the MAS-UK score. It is hard to say whether some factors led to higher maths anxiety or maths anxiety influenced outcomes or decisions. For example, students without maths qualifications above GCSE have higher maths anxiety. It is difficult, however, to determine whether anxiety prevented them from choosing further maths, or whether they are more anxious now because they do not have further maths. Also, there were strong associations between independent variables; for example, Chi-squared tests showed significant associations between faculty, gender, and further maths. A higher proportion of males have further maths qualifications (66% compared to 41% of females) and Engineering have further maths qualifications (86%) compared to Arts and Humanities (23%) and Social Science (26%).

Univariate analysis was carried out on the variables of interest to help choose variables to be included in the main ANOVA. It was suspected that UK students may have higher maths anxiety compared to others due to the negative maths culture, but when the nationality groups UK, China/Malaysia, India, and Other were compared, Chinese students had a slightly-higher mean maths anxiety score, although no significant differences were found ($F(3,483)=0.162$, $p=0.922$). It was also thought that parental attitude to helping with maths homework at secondary school would impact on maths anxiety, but although those whose parents never helped when asked had a higher mean maths anxiety score, there were no significant differences ($F(3,566)=1.655$, $p=0.176$).

We then ran a Main-Effects-Only Multiple ANOVA model with the eight independent variables shown in Figure 6 as factors, as this summarises the results of the survey.

Independent variable	Categories	Test Statistic F	p-value	Effect size Partial Eta-squared
Gender	Males/females	2.936	0.087	.008
Parents helped with homework	yes/no	1.244	0.265	.003
Dyslexia	Official diagnosis, I think so, No	3.738	0.025	.020
Dyscalculia	Official diagnosis, I think so, No	13.877	0.000	.070
Experience of 1:1 support	Not had 1:1, positive, negative	3.404	0.034	.018
GCSE A*-C at first attempt	yes, no	5.224	0.023	.014
Maths qualification above GCSE	yes, no	41.008	0.000	.100
Faculty	A&H, Eng, Med, Sci, Social Sci.	3.193	0.013	.033
a. R Squared = .382 (Adjusted R Squared = .359)				

Figure 6: Multiple ANOVA results with dependent variable MA score.

As Figure 6 shows, when running the full model, gender, and whether or not parents helped with homework were not significant. Gender was expected to be significant, but part of the difference is explained by gender differences between faculties and having further maths qualifications. Looking at the effect sizes, whether or not students have a maths qualification above GCSE Maths, and dyscalculia status appear to be the strongest predictors of maths anxiety. As expected, students who have or think they have a SpLD have significantly higher maths anxiety scores than those who don't. Figure 7 shows the mean MA scores with confidence intervals for each group. It should be noted that for the group who think they have dyscalculia, they may be confusing maths anxiety with dyscalculia.

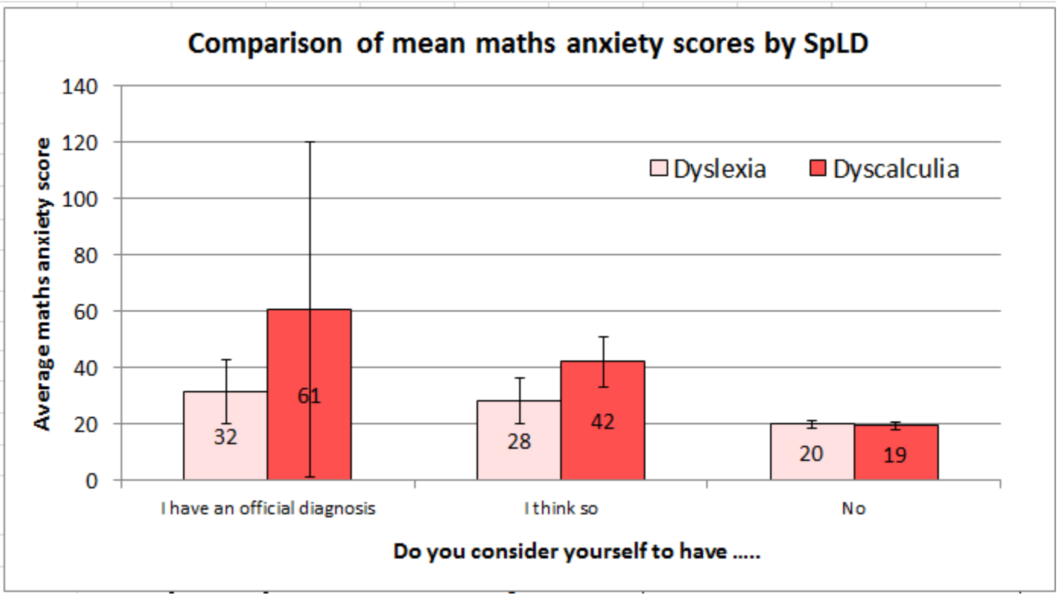

Figure 7. Impact of Specialist Learning Difference on mean MA scores (with confidence intervals).

44% of students had received one-to-one support either at school or home and 80% of those students said it was a positive experience. Students receiving 1:1 support had a range of maths qualifications so as with maths support, tuition was not limited to those likely to fail. Students from China and India were much more likely to have received 1:1 support.

Figure 8 compares the mean maths anxiety score for response to the 1:1 support question grouped by whether or not the student passed GCSE maths the first time. It is clear that the combination of not passing GCSE maths at the first attempt and a negative experience of 1:1 support has the highest maths anxiety score. However, as we don't know the reasons why students did not receive 1:1 support, anxiety levels before 1:1 support or when they received 1:1 support, it is difficult to draw conclusions about the impact of 1:1 support. It may be that students who were more anxious were more likely to receive 1:1 support.

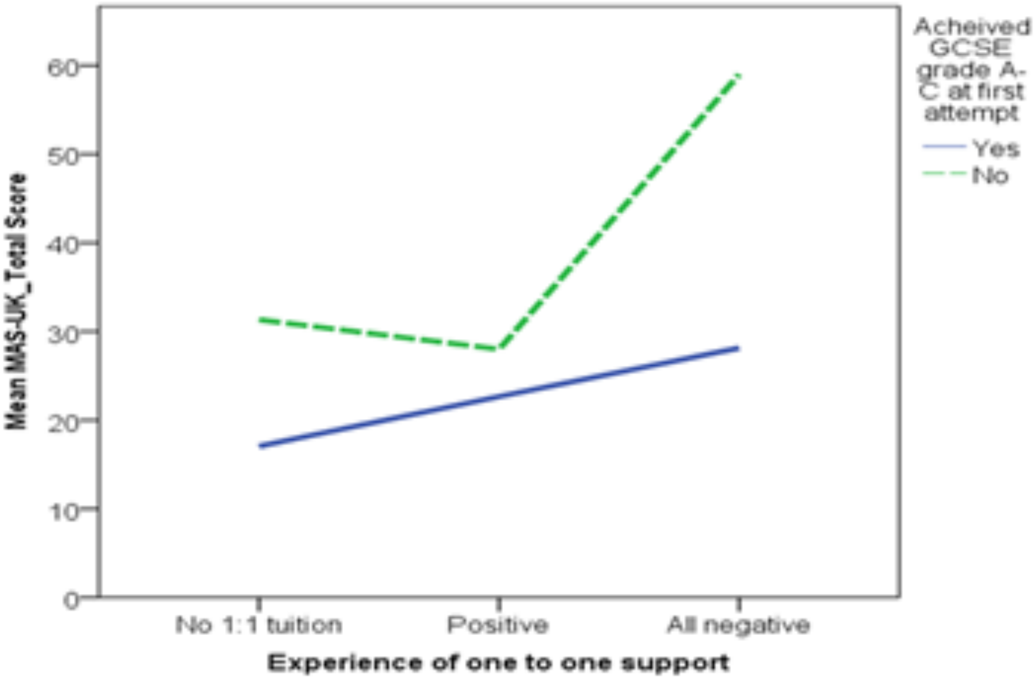

Figure 8. Relationship between passing GCSE maths and 1:1 experience on mean MA score.

There were significant differences between most faculties for maths anxiety scores, which are summarised in the table of post hoc *p*-values (Figure 9).

Tukey pairwise p-values	Arts and humanities	Engineering	Medicine	Science
Engineering	0.008			
Medicine	1.000	0.004		
Science	0.937	0.009	0.941	
Social Sciences	0.009	< 0.001	0.002	< 0.001

Figure 9. p-values from Tukey post hoc tests for MA score and faculty.

When highest maths qualification is taken into account, faculty differences become smaller, which is demonstrated in Figure 10 below.

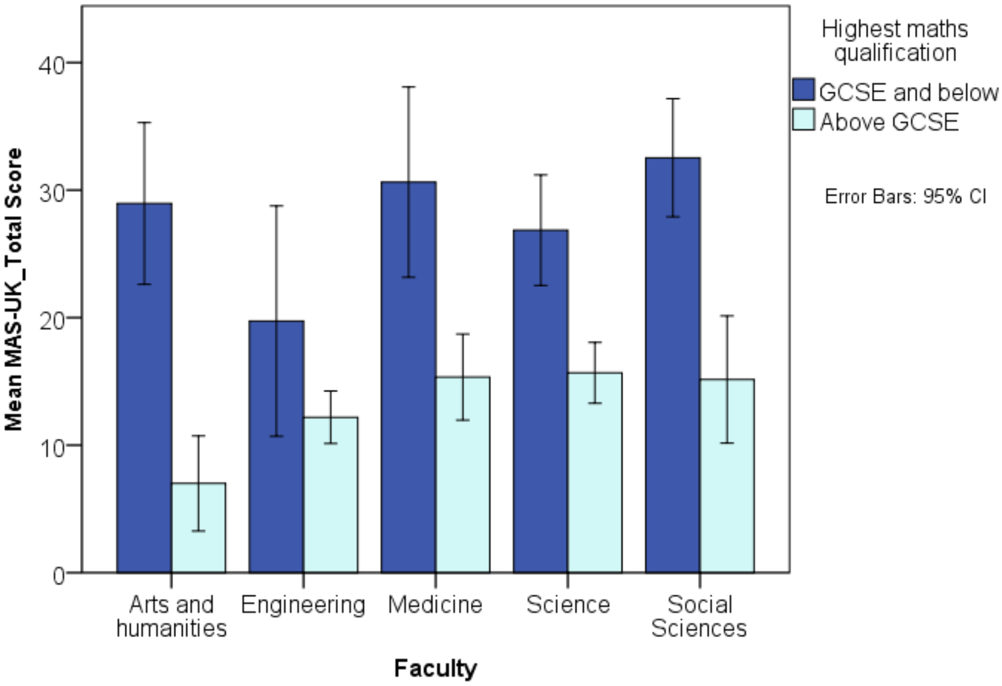

Figure 10. Comparison of mean MA score by faculty and highest maths qualification.

4. Conclusions and further work

In summary, the survey was a good starting point for investigating attitudes and anxiousness about maths, but important information is missing to draw strong conclusions about the causes of maths anxiety. We may consider carrying out a further survey with refined questions and perhaps concentrating on the impact of 1:1 support on maths anxiety.

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Online tutorials in teaching maths courses: do we need to apply different approaches and methods in teaching?

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Abstract

The presence of new opportunities such as online classroom software gives us the opportunity to make significant changes in the delivery of mathematical courses. However, running online tutorials is not a just a simple transfer of face to face classes and requires appropriate changes in methods and approaches to teaching. All online sessions in reality need to be specially prepared with the opportunities to use instant chat, polling, shared applications and recording of sessions in mind.

Many of the Open University (OU) maths courses are now using OU Live (Blackboard Collaborate) in course delivery. This talk will explore the ideas behind the preparation and running of online tutorials for two OU courses. The advantages and difficulties encountered with giving online tutorials are also discussed. We will give evidence which shows that students are very positive with respect to online delivery and support in their studies.

1. Introduction

Online learning or e-learning is nowadays increasingly popular. Many courses are now available only online and a lot of new MOOCs (Massive Open Online Courses) have been created (e. g. FutureLearn free online courses). Furthermore, a report to the European commission *Modernization of Higher Education* (2013) pointed out that "*technology is increasingly offering us the possibility of the virtual faculty, the virtual college*", however "*online delivery is not only a challenge to the classroom. It is a challenge to our entire model of higher education.*"

Online teaching is often based on using conference software such as *Adobe Connect* or *Blackboard Collaborate* (formerly known as *Elluminate*). The author received her first online teaching experience as a student by attending online training sessions run by the company *Wolfram* for a huge group of students around the world. The Wolfram presenters were using *Adobe Connect* software and *Mathematica* presentations during their one hour session. It appeared as though it would not be too difficult to transform OU face-to-face session materials into online presentations. Notes in *LaTeX* or *Mathematica* which had been prepared for face-to-face tutorials seemed at first glance to be suitable (after minimal editing) for use in online sessions without any problems. Unfortunately in reality this is not the case. After the first session of trying this it became clear that materials need to be specially prepared for online tutorials and that sessions must be very carefully planned.

The OU encouraged tutors to run online sessions and also offered extensive support for this by running various training sessions. However, not all of the advice given initially was suitable for maths lecturers, as the moderators who delivered these sessions, did not have a background in mathematics or science and the methods which they recommended were sometimes unsuitable for teaching mathematics. Nevertheless all these sessions helped everyone to get a general understanding of the *Elluminate* software and later about *Blackboard Collaborate*. More recently some training sessions were delivered by maths tutors and these were very useful even for experienced tutors. Either way it is very important to talk to other people who are teaching similar classes.

2. A Completely different teaching environment

2.1. Synchronous online and face-to-face tutorials

It is well-known that online courses can be taught in two different ways, synchronous and asynchronous. Some practical advices and observations about developing and running online courses can be found in (Gleason, 2006; Engelbrecht et al., 2005).

Different types of synchronous tools, such as a virtual whiteboard, chat, audio conferencing and application sharing are integrated within a virtual classroom. There is a participant window that shows the name of everyone attending the session (which can be hidden if necessary, e.g. if session is to be recorded). A set of tools designed for interaction (some comparable to a traditional classroom) such as for raising hands, polling tool or an instant messaging window to send messages to other learners and the moderator is also available. The largest portion of the screen is devoted to the whiteboard, on which the moderator can project slides.

During the session all participants use laptops or tablets. The moderator (or moderators), and ideally students also, should have headphones and microphones.

One of the main differences from face-to-face sessions is that the moderator does not have any 'eye contact' with students. It is easy to underestimate how important and useful the opportunity to see student faces (sometimes 'freezing') during tutorials is. Therefore the moderator must find new ways to get a feel for how their students are doing. For example, using the polling system or emoticons can help to overcome this absence of eye contact.

Also if you are a 'chalk and talk' person, the size of your 'virtual whiteboard' is not the same as in a physical classroom. Another thing which should be taken into account is that there is often a slight delay in the screen updating and it is usually necessary to pause after changing slides. This is not the same as changing slides in the classroom.

An option to record or save the session as a pdf file is available in *Blackboard Collaborate* and this should be considered during preparation the session, e.g. titles on each slide for easy indexing of the recordings.

Finally the moderator must be comfortable using computers and be able to work on technical problems which can occur, not only during the session (which are the most disruptive), but also at any stage of preparation. These could include, but are not limited to interruptions in internet connection, software or devices crashing, or peripherals not working. Ideally, the moderator should have training and/or experience with the software and hardware which is to be used, and be able to troubleshoot it quickly if necessary.

2.2. OU virtual classroom

Synchronous online sessions (the *Blackboard Collaborate* virtual classroom tool referred to as *OULive*) were embedded in the course *MST210* (*Mathematical methods, models and modelling*) and were optional for delivery of the course *M337* (*Complex analysis*) in the most recent presentations. As an alternative option face-to-face classes were also available for both courses and this met student demands for greater choice and flexibility.

In the coming academic year this approach will be revised and changes to tutorial arrangements are being made as the Group Tuition Policy is implemented. According to this new OU strategy all face-to-face learning events must have at least one online tutorial. So the students will have the opportunity to choose the type of sessions and the date which will be more suitable and relevant for them.

All tutorials (face-to-face and online) which were delivered for these courses were synchronous i.e. students and the tutor were online (or obviously in the class!) at the same time and could interact with one another. One of the differences was that a face-to-face tutorial was normally about 2 hours long but the duration of online sessions was usually only 1 hour. This is because it turned out that for effective and productive online teaching the sessions could not be any longer. At the same time this caused some problems in the preparation and planning of the online sessions, as the same amount of material needed to be covered during both types of sessions.

3. Challenges

3.1. Handwritten mathematics

The first problem faced at the preparation stage for the online tutorials was that only *PowerPoint* files can be uploaded and converted into *jpg* format in *Blackboard collaborate*. There is no way to directly use *LaTeX* files or presentations prepared with *LaTeX*, a program popular for maths typing.

There is also an option to use the available virtual whiteboard and to just write the mathematics on it by using the whiteboard tool palette and a touchscreen (with *Windows* 8 or 10) or a digital tablet for writing. Another possibility considered was to use the clip art built-in to *Blackboard Collaborate* for maths symbols. Even after some practice handwritten maths was not ideal, and maths clip art turned out to be inconvenient for use during the sessions and hence alternative approaches needed to be found. It also turned out that the recorded *pdf*s were very poor quality.

After some experimentation two main solutions were chosen. The first was just to use the application sharing option which allows the use of interactive *Mathematica* files, with the ability to perform symbolic manipulations, plot graphs etc. The other approach is to prepare presentations in *LaTeX* and convert them into a set of pictures (*jpg* files) and then to upload these files into *Blackboard collaborate*. The latter was suggested by an OU colleague during the staff development event. The disadvantage of this approach is that the uploaded presentation is a set of pictures which are not interactive without using some workarounds and that the quality of slides becomes worse after conversion.

According to feedback, students found interactive presentations useful and helpful to re-inforce concepts. Using shared software made sessions more interactive and did indeed increase student involvement.

3.2. Technical problems

Obviously, a good, reliable internet connection is required for all participants but is unfortunately not always possible. Occasionally poor internet connections can force students to leave the virtual room and return back later once they have fixed the problem. Even if the participants use the audio setup wizard prior to the session, problems may still occur during the sessions. The quality of headphones and microphones is also important and is crucial for the moderator. All of these technical issues are of course a nuisance since the moderator is also required to be a multi-task person; teaching whilst checking the chat window as well as watching for students to "raise their hand" is not an easy task.

4. Lessons learned

Surprisingly, despite the majority of students being under 40 years old and belonging to the so-called 'press button' generation, students preferred to text chat and not use polling or ask questions by using their microphones (which most of them definitely had). They ignored polling even when answering multiple choice questions and instead chose to type e.g. 'B' as a correct answer in the chat. All attempts to encourage students to use microphones usually failed. Many OU tutors have reported the same problem. Perhaps a short training or revision session prior the course for students, reminding them how to use *Blackboard Collaborate* can help overcome this problem.

It should be noted that only once, during one-to-one exam revision session which I ran a couple years ago, did the student use his microphone during the whole session and ask a lot of questions.

In this situation it makes sense to more effectively use the chat box. Other students can sometimes help you and answer other students' questions.

It was also observed that larger sessions (i.e. 30-40 students) should be carried out by two or more tutors, with one academic controlling the whiteboard and another responsible for the chat box to produce an effective team.

Students also requested to be provided with at least a short version of notes or some materials in advance. They reported that they often had problems making their own notes during the online sessions, because it is necessary to follow the screen with the smaller whiteboard than in a physical classroom, and also keep track of the chat. This means students could manage to make only limited notes during the sessions.

4. Conclusions

Overall students were positive towards online tutorials. Whilst the majority of students were quite happy to attend online sessions there is a sizable group who still prefer face-to-face tutorials. Therefore the model used for teaching these two courses has met student demands and given them some choice and flexibility.

Using different shared software makes sessions interactive, effective and productive and allows the increase of student involvement in the learning process.

It should be also noted that recorded sessions are also a valuable learning resource for students that can be used not only for their studies, but can also help students with revision and exam preparation. Even when not a professional recording the fact that these materials are prepared directly for the course they are studying and cover all of the required topics to the correct depth makes them invaluable.

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Tutoring maths within the context of a degree: Working with undergraduates and postgraduates

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Abstract

The post of Academic Skills Adviser in Maths (0.5 FTE) was established in August 2012 at the University of Aberdeen. This post was a completely new initiative, prior to this date no formal Maths support had been offered at the University. Since the appointment of an Academic Skills Adviser in Maths, advice has been offered to students studying across all degree subjects and at all levels (from access to undergraduates to postgraduates). A variety of different delivery modes have been trialed:

- Bookable one-to-one sessions
- Discipline-specific workshops and drop-in sessions tailored for selected cohorts of students
- Drop-ins at the library during revision weeks
- Online resources in the Virtual Learning Environment (VLE)
- Maths forums using the VLE discussion board facility.

The teaching is delivered using the context and notation of the individual student's degree in order to increase the student's confidence and engagement with Maths topics. Preliminary data shown here indicates that different students access different forms of Maths advice. This suggests that the diversity of delivery modes on offer are responsive to a wide range of learner types.

This paper outlines the history of Maths support at the University of Aberdeen, before discussing the recent development of discipline-specific Maths support for both undergraduate and postgraduate students. In particular, it pinpoints the essential need for collaboration with the University of Aberdeen teaching staff in order to identify the specific needs of different student cohorts. In addition, the wider community of Scottish Maths Advisers in the Scottish Maths Support Network provided a supportive forum to facilitate the discussion of new ideas and the subsequent development of Maths support.

1. First steps of maths support at the University of Aberdeen

The Student Learning Service (SLS), based within the Centre for Academic Development, is comprised of five Academic Skills Advisers: one Adviser for Generic Academic Skills, two Advisers for Academic Writing, one Adviser for Specific Learning Differences and one Adviser for Maths Skills.

As a starting point, Maths support followed a pattern of support similar to that already offered by the rest of SLS:

- Bookable one-to-one appointments
- Bookable workshops
- Online resources located in the VLE.

1.1. One-to-one maths sessions

Students can request an appointment by completing a booking form on the SLS website. Since the creation of the post, in 2012, there have been over 100 appointments per annum made with the Maths Adviser, representing between 30 and 40 % of all Generic, Academic Writing and Maths Skills advice sessions (see Figure 1).

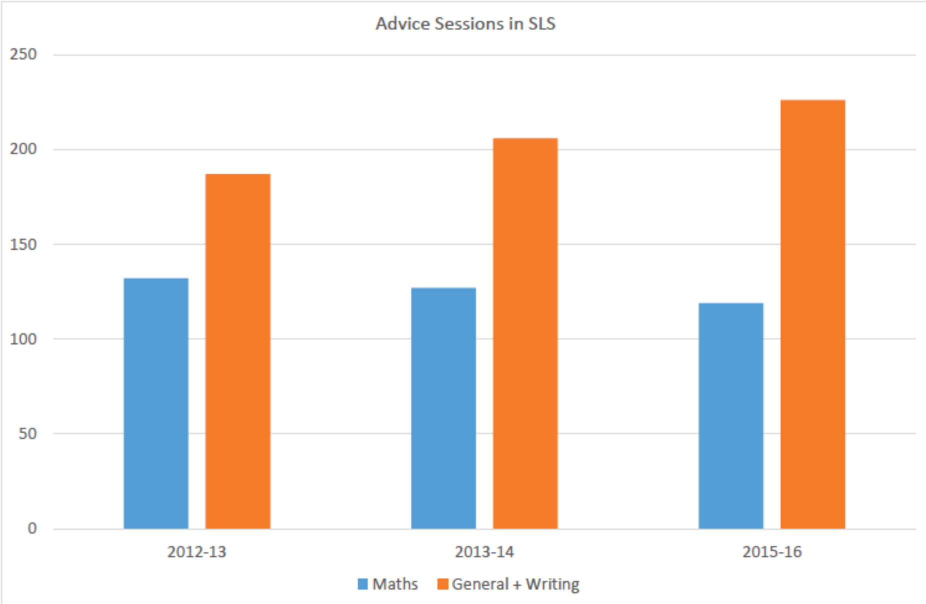

Figure 1: Number of Maths Advice sessions and General or Academic Writing Advice sessions taught in SLS since 2012-2013. Academic year 2014-2015 was ommitted because the Maths Adviser was on maternity leave, resulting in reduced Maths Support offered by SLS.

These results were encouraging and, in academic year 2013-2014, Maths support was extended by introducing drop-in sessions at the main campus library. This was inspired by Dr Kate Durkacz, Maths Adviser at Edinburgh Napier University, who has been running Maths drop-in sessions at their campus library for many years (Evans, 2010). Four sessions of 2 hours each were held during 2013-2014 (two sessions at the end of each semester). A total of 20 students attended these sessions who had never booked an appointment before, 16 of those either came back only within the context of the drop-ins or did not come back at all. This indicated that some students favoured the drop-ins over bookable appointments, and was early evidence that different students may prefer different ways of getting support.

1.2. Online resources

A bank of online Maths resources was created and organised according to the disciplines most frequently encountered: Engineering, Physical Sciences, Life Sciences and Economics and Business Studies. Each discipline collates resources on topics identified as most common for that particular discipline. Resources from **math**centre (Croft, et al., 2016) and the Centre for Innovation in Mathematics Teaching (Burghes et al., 2016), as well as HELM workbooks (Harrison et al., 2007), have been used. Diagnostic tests and contextualised practice questions were also created using the DEWIS e-Assessment system (Hooper et al., 2015) for students in Engineering and students in Economics and Business Studies.

1.3. Maths workshops

Five Maths topics were identified that are covered in both the Advanced Higher Maths curriculum in Scotland and A Level Maths curriculum in England and Wales, that are routinely used in Science & Engineering degrees. These are: Differentiation, Integration, Complex Numbers, Matrices and Ordinary Differential Equations. Even when they are familiar with these topics, new students will often find the style of teaching and expectations at University challenging (Alcock & Simpson 2009). In 2012-13, ninety minutes-long workshops were run on these 5 topics. At the beginning of each semester, workshops were advertised to students across the University through a general email, and published through the SLS workshop booking system. Maths workshops were run again in 2013-2014, and in the first semester of 2015-2016, but were shortened to 60 min to fit the length of lectures (no Maths workshops were run in 2014-2015 because the Maths Adviser was on maternity leave). The attendance at Maths workshops decreased largely from 2013-2014 (see Figure 2).

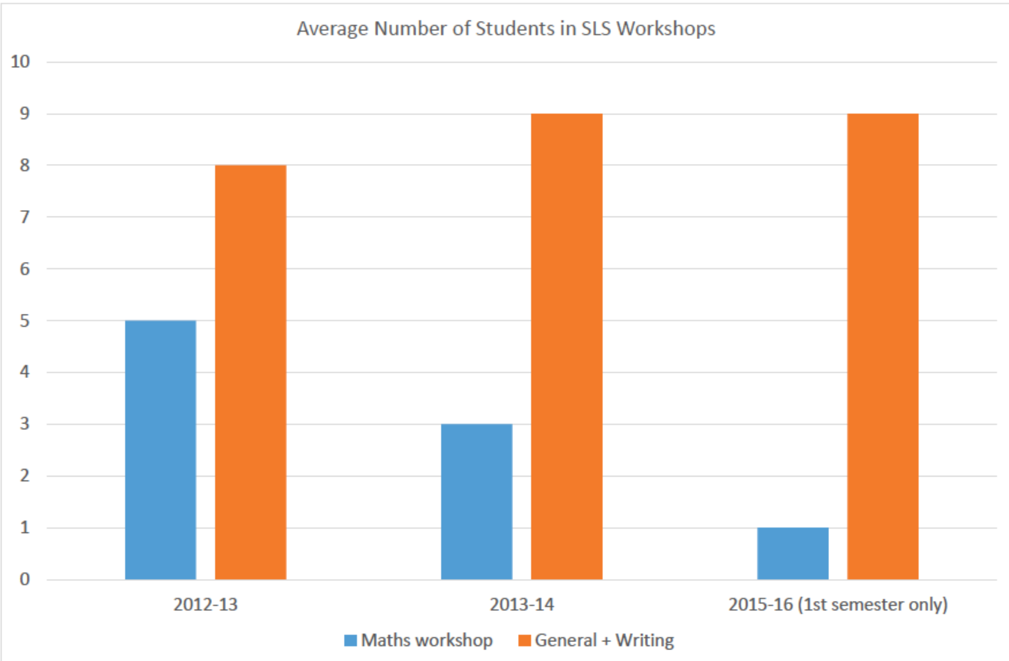

Figure 2: Average number of students attending Maths workshops or other SLS workshops in 2012-2013, 2013-2014 and the first semester of 2015-2016.

Attendance figures at Maths workshops were lower than anticipated (see Figure 2) until a series of two workshops, designed specifically for, and open only to, postgraduate students in the Business School were trialed. These attracted high numbers of students (29 students attended the first workshop). Building upon this, Maths honours students were offered a workshop on LaTeX, which was very successful, over 50% of the class attended. This suggests that Maths workshops were less popular when offered in a general context but worked very well when offered in a specific context.

Consequently, it was decided to offer discipline-specific group support rather than general Maths workshops. Slightly different forms of group support were designed for undergraduate and postgraduate students, whilst maintaining individual sessions, in the form of bookable appointments and drop-ins at the Library, and the online resources.

2. Working with undergraduates

2.1. Group teaching

In 2015-2016, Maths support in the form of group sessions was offered to two cohorts of undergraduates: students taking a Level 1 Chemistry course (Chemistry for Physical Sciences and Chemistry for Life Sciences) and students in Level 1 Engineering. The format of these sessions was designed to:

- Foster pro-activeness in students
- Include practice rather than teaching (the teaching was done by the lecturer in the course)
- Encourage interactions between peers
- Have flexible timing so that the frequency and timing of sessions could be changed according to students' needs.

Consequently, drop-in sessions were opened for students in Chemistry during the 1st semester and for students in Engineering during the 2nd semester. Sessions were initially planned fortnightly and were advertised (as well as the individual one-to-one sessions) through the course VLE. Students could either stay for the whole session or pop in and out as they needed, but were asked to come with questions prepared. For both cohorts, the frequency of sessions increased towards the end of the term on students' request.

The number of students in Chemistry sessions remained low, but some Engineering sessions saw high numbers of students (see Figure 3). Interestingly, only 3 students, 2 Chemists and 1 Engineer, of those who attended the drop-in sessions also requested individual sessions, even though both options were equally advertised through the course VLE. Similarly, most students who booked an individual appointment never attended the drop-in sessions.

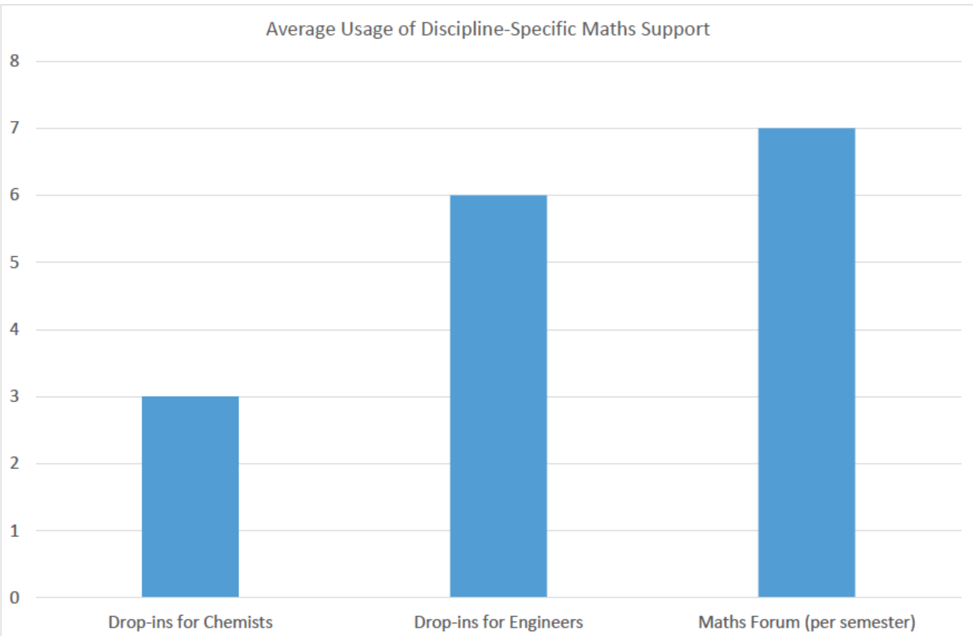

Figure 3: Average number of students attending drop-ins for Chemists, drop-ins for Engineers and participating in the Maths Forum (averaged over the 2 semesters).

2.2. Maths forum

A VLE Maths Forum was opened for students in Level 1 Engineering in the Engineering Maths courses (1st and 2nd semester), using the discussion board facility. The was inspired by the work of Shazia Ahmed, Maths Adviser at the University of Glasgow, who, for the past 5 years, has successfully run Facebook Virtual Peer Assisted Learning groups (Ahmed & Honeychurch 2015). Students post questions on the forum, and these can be answered by the Maths Adviser and the course coordinator, or other students. Students had the possibility to post questions anonymously if they wished to. Almost all of the questions were posted anonymously in the first semester while most students left their names visible in the second semester. The number of forum participants was similar to the number of drop-in participants (see Figure 3). Students who posted questions non-anonymously used no other method of support other than the Maths Forum.

3. Working with postgraduate students

Group Maths support was offered to two cohorts of postgraduate students: in the Business Studies MSc programmes and in the Geosciences MSc programmes. Both programmes bring together students with varying Maths knowledge and abilities, and some found the Maths component of these degrees challenging. In addition, students must complete their MSc in 8 months, so they must gain confidence on the Maths topics they need very early in the year.

A series of Maths workshops were designed specifically for both cohorts and these were delivered in the first week of teaching for the Business School and in Fresher's week for the School of Geosciences. The workshops contained:

- In agreement with the academic staff, teaching of lecture topics and additional foundation topics,
- Practice exercises set in the context of the discipline

The workshops for the School of Geosciences covered: Algebra, Trigonometry and Calculus, and the workshops for the Business School covered: Algebra and Differentiation (functions of 1 and 2 variables), Optimisation, Integration and Matrices. This led to the publication of 4 Facts & Formulae as Maths Centre Community Projects (Richard, 2015).

Workshops were advertised amongst students prior to teaching commencing, or during the first week of teaching, by the academic staff. Students could either attend one workshop or the whole series of workshops. The Maths Adviser worked through an example, and students were encouraged to try and solve subsequent exercises. Both series of workshops attracted high numbers of students (see Figure 4). Following on from this, individual appointments were requested by 20% of the postgraduates in Business Studies and by 13% of the postgraduates in Geosciences. This is clear evidence of the benefits of Maths workshops and individual sessions for the postgraduate community.

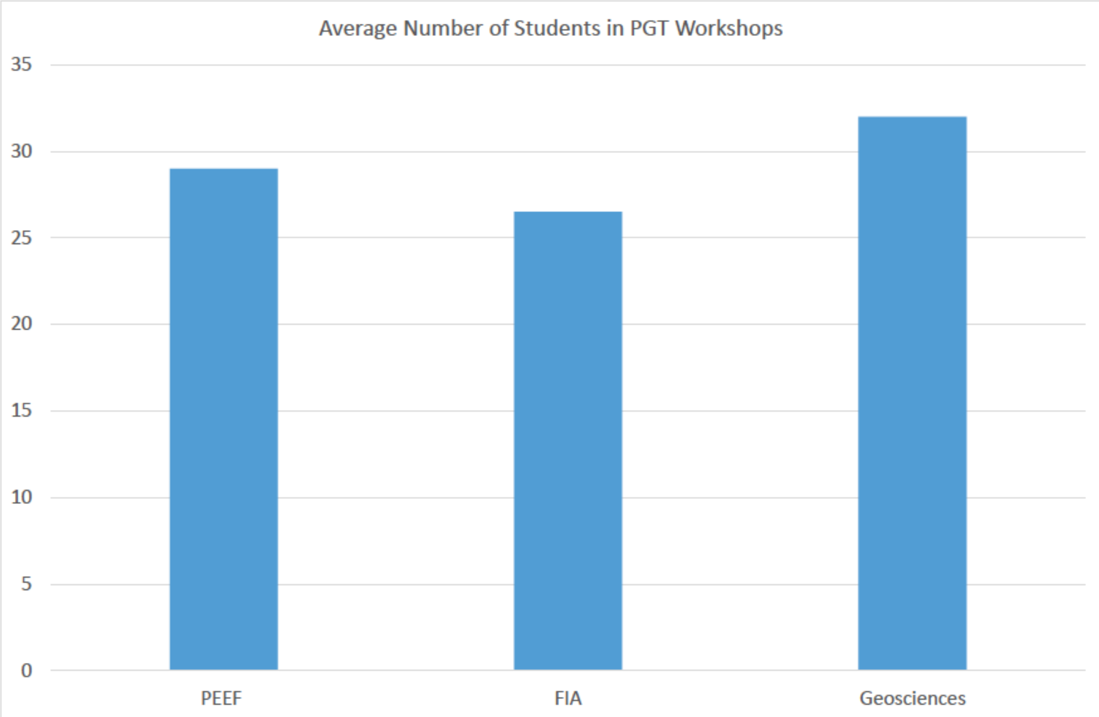

Figure 4: Average number of students per workshop in postgraduate workshops. Students in the Business Studies programmes were divided in two groups: Petroleum Energy Economics & Finance (PEEF), and Finance Investment and Accounting & Finance (FIA).

4. Discussion and conclusion

A difficult task that University Maths Advisers face is the identification of needs in Maths support amongst students who have come to study a wide range of degrees. These degrees use Maths in very different contexts. At University, students often no longer learn Maths topics in a Maths course, but learn specific Maths techniques within one of their degree courses. This is true for many sub-honours and honours students in Life Sciences and Economics and Business Studies, but also for honours and postgraduate students in Physical Sciences. Therefore it is important that Maths support is also delivered in the context of the discipline. This improves students' engagement, as they approach Maths within a known environment, and it makes Maths relevant to them. Maths support can then be envisaged as a meeting between two experts: the Maths Adviser knows the Maths, and the student knows the discipline, rather than a meeting between someone 'who knows' and someone 'who does not know'. This helps build students' confidence.

This is possibly one of the reasons why attendance at Maths workshops gradually dropped. Although they covered topics commonly used across degrees, the workshops did not appear to be related to any particular discipline. Furthermore, undergraduates and postgraduates need, and benefit, from different forms of Maths support at different times of the year.

Postgraduate students must complete their studies within one year. To ensure students address any gap in their Maths knowledge as soon as possible, Maths support has been introduced into two postgraduate programmes (MSc in Business Studies and MSc in Geosciences). Maths support was offered in the form of workshops, and focused on relevant topics. However, contrary to general workshops, the content was discussed with the relevant academic staff, and teaching was delivered using the discipline's notation and context. The sessions in 2015-2016 were very popular and highly interactive.

Maths support provision for undergraduate students started later in the term. This gave students time to experience the Maths in their degree, and appreciate what Maths support, if any, they would benefit from. It was difficult to open regular University-wide Maths drop-ins because there is no dedicated teaching space for Maths support. As a result, it was decided to plan, with the academic staff, discipline-specific drop-in sessions for selected cohorts of students. This setting provided the opportunity for students to work in peer groups, with the Maths Adviser, in an informal and flexible environment. In addition, a Maths Forum was trialed for students in Engineering. It was interesting to observe that different Engineering students used different Maths support methods: individual appointments, discipline drop-ins and Maths Forums.

In conclusion, at the University of Aberdeen, specialised Maths support has been gradually developed, and this has worked better than general Maths support. However, it was only possible when academic staff were willing to establish a collaboration with the Maths Adviser, as this helped to identify relevant Maths topics for various cohorts. Good working relationships with the academic staff also meant that they promoted Maths support as well. In parallel, one-to-one sessions and online resources also continued to be offered. Early evidence indicates that different students access different means of support. The diversity of Maths support in the Institution supports a wider range of learners' styles. One-to-one sessions are perhaps not suitable for all, possibly because some students do not feel comfortable in this type of setting. Some students may enjoy working in face-to-face peer group sessions, while others may prefer interacting via an online discussion board.

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Effects of Early Undergraduate Mathematics: Does It Facilitate MATLAB Learning?

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Abstract
It has been well established that mathematical software packages such as MATLAB have a positive impact on learning mathematics at university. However, the reverse implication (of mathematics on MATLAB learning) has not been widely studied. In this work, we investigate the effects of learning first-year undergraduate mathematics on the learning of MATLAB. In particular, we aim to empirically investigate two questions: 1. Do students with and without mathematics background at university level learn MATLAB differently? 2. How does the students' performance in mathematics modules (such as calculus or linear algebra) correlate with that in MATLAB? We tackled these questions using a combination of questionnaire survey and statistical data analysis. Our work identifies a marked difference between what a mathematics and non-mathematics student considers 'difficult' in MATLAB, and surprisingly points to the modelling-type module which resonates most strongly with MATLAB learning. Our findings can help to refine the pedagogical approach that best facilitates students' learning experience with MATLAB.

1. Introduction
Most undergraduate students in science subjects today are taught at some stage to use mathematical software packages such as MATLAB, Maple or Mathematica. These packages are powerful, easy-to-use, and easily accessible on most computers and mobile devices. The professional capabilities of these packages make them more desirable than module or text-book-specific software packages. Integration of such software packages into learning at an early stage of undergraduate education is becoming a widespread practice (Nyamapfene, 2016).

In particular, MATLAB is a high-level computer 'language' that features a short and steep learning curve (short entry time), using a clear, natural syntax. Its positive impact on learn-ing mathematics is well documented (Abdul Majid et al., 2012; Cretchley et al., 2000; Abdul Majid et al., 2013).

The reverse implication of whether university mathematics affects MATLAB learning is an area where there has been comparatively little research. We ask: do students with different mathematics backgrounds at university have different perceptions on what concepts in MATLAB are difficult or troublesome? In section 2.1, we describe our investigation which compares questionnaire responses from mathematics and psychology students. The results are reported in section 3.

In addition, we investigate how mathematics at university affect the learning of MATLAB. In particular, we seek to identify if there are particular mathematical modules (in first-year mathematics) that resonate strongly with MATLAB. It is not obvious what the answer should be, and the results, presented in Section 3 and discussed in section 4, will be surprising to some.

2. Methods

2.1. Questionnaire surveys

The questionnaire surveys conducted explore the differences towards learning perception of ‘troublesome’ concepts from students reading different subjects, namely, first-year mathematics undergraduates, and first-year psychology postgraduates, together with several early-career psychology researchers.

At the end of the MATLAB course, students were presented with a list of basic programming concepts from the course (for example, vector variable, matrix variable, vector operation, matrix operation, script, function, flow control, loop). They were asked to circle any one that they thought was troublesome and to give a difficulty rating (1 = the least troublesome through 5 = the most troublesome). They were also encouraged to add any other troublesome concepts that were not on the list.

The troublesome aspect of these concepts was intentionally targeted in the question. In addition, another question was included in the questionnaire survey only to psychology participants for a five-level Likert-type response to the statement that the introductory programming module may require a prerequisite of familiarity with introductory undergraduate-level mathematics. Students were encouraged to explain why. This was to collect students’ opinions of whether the learning of basic programming concepts may benefit specifically from certain introductory mathematics skills.

The survey was conducted at the end of the last tutorial class to mathematics students in academic year 2015/16. The surveys to psychology students were gathered for three years since 2013/14 with a small number of students choosing to study the module each year.

2.2. Statistical correlation

Another aim is to quantify the correlation between MATLAB module and other mathematics modules, and to determine any possible relationship in the learning processes among these modules.

The assessment results for the MATLAB module were correlated to other first-year mathematics modules, namely: 1. Linear algebra, 2. Numbers, sequences and series (i.e. introductory analysis), 3. Calculus, 4. Probability and statistics, and 5. Modelling and mechanics. The students’ learning performance is measured by the final module marks. The correlations across pairs of these modules were calculated over three years of data (from 2013 to 2016). All the correlation computations were conducted using IBM SPSS software package.

3. Results

Among the 20 psychology participants, 13 returned their completed questionnaires. From 33 mathematics participants, 17 returned their completed questionnaires (with 1 invalid return).

Table 1 (troublesome-concept ratings) shows concepts that were voted as the most troublesome, showing both the average and total ratings as described above. Mathematics participants found *loop* the most troublesome concept. Based on the limited size of data, *function* was chosen as the most troublesome concept for the psychology participants. *Loop*, *flow control* and *matrix variable* all got high and close average ratings. However, *function* got the highest total rating which means more participants voted it onto the list of highly troublesome concepts.

For the question about familiarity with introductory undergraduate mathematics, the results are with two 'strongly disagree', seven 'disagrees', one 'neither' , two 'agree' and one ' strongly agree'. One student commented: "Whilst more advanced mathematical knowledge may have been useful in some cases (and I'm sure is more crucial for more advanced use of MATLAB), I thought it was possible to get a good basic grasp of MATLAB skills without familiarity with understanding Mathematics (at undergraduate level)." This view is a fair representative of the role of mathematics in MATLAB programming for psychologists in general.

Subject	Concept	Total	Average
Mathematics	*Loop*	49	4.08
	Flow control	26	2.89
	Array	21	3.00
	Plotting a graph	21	3.00
	Matrix operation	20	2.86
	…	…	…
	Function	12	2.40
Psychology	*Function*	33	3.67
	Loop	17	3.40
	Flow control	16	3.20
	Matrix variable	14	3.50
	Logical indexing	14	2.80

Table 1. Troublesome-concept ratings.

Table 2 shows the correlation of the assessment marks for first-year mathematics modules with those of the MATLAB module. Evidently, the correlation between MATLAB module and Modelling and Mechanics module is consistently significant across the three years while, interestingly, the rest of the modules are not.

4. Discussion

The perceptions of troublesome concepts are obviously different for the two subjects with different mathematical background. Unlike the psychology students who found *function* the most troublesome concept, mathematicians would have had plenty of exposure to the mathematical concept of function (as input-output machines) and therefore do not find the concept as difficult.

Mathematics and psychology students learn MATLAB with different learning objectives. Psychology students learn to use MATLAB for designing and running behavioral experiments, and data analysis while mathematics students learn for solving a variety of numerical problems. Both student cohorts learn with lots of practical examples in their subject contexts. The learning materials are then obviously different. However, they both learn basic concepts in MATLAB programming so that only these basic concepts were compared. Other concepts, for example, concepts of experimental development for psychology students and concepts of symbolic computation for mathematics students, were not compared.

In terms of the correlation values in table 2, the lack of consistently significant correlation from all but one of these modules indicate that the learning of the core, classical introductory mathematics does not boost the ability to learn MATLAB in any particular way.

Year	Module	Pearson Correlation	Sig. (2-tailed)	n
2013/14	Linear Algebra	.632	.000	34
	Numbers, Sequences and Series	.654	.000	36
	Calculus	.569	.001	32
	Probability and Statistics	.643	.000	36
	Modelling and Mechanics	.658	.000	35
2014/15	Linear Algebra	.402	.028	30
	Numbers, Sequences and Series	.413	.023	30
	Calculus	.339	.067	30
	Probability and Statistics	.656	.000	30
	Modelling and Mechanics	.516	.004	30
2015/16	Linear Algebra	.299	.091	33
	Numbers, Sequences and Series	.039	.828	33
	Calculus	.109	.544	33
	Probability and Statistics	.264	.138	33
	Modelling and Mechanics	.374	.032	33

Table 2. Correlation of mathematics modules

However, the fact that only one strong, consistent correlation emerges from our analysis (that between MATLAB and the *"modeling and mechanics*" module) is rather surprising. This may indicate, according to Bloom's taxonomy of educational objectives (Mastascusa et al., 2011), the level and the quality of the learning methods within these two modules may be a better match than others.

The *modelling* module is heavily problem based: students learn to construct mathematical equations which predict the outcome of a physical system (with measurable quantities such as speed, distance, time, weight and forces). In this sense, it is a prototypical "applied mathematics" module in which the overlap with "real-world" problems is key. This applied-mathematics nature seems to resonate with the learning of MATLAB as a practical tool to solve "applied" problems. Just like writing a good MATLAB code, the modeling module encourages breaking down a problem into smaller tasks, and addressing individual cases separately. In other words, a good code and a good model share the same basic planning and execution.

In addition, it is well known that MATLAB has a practical nature, in the sense that students would benefit best from hands-on "doing" rather than studying or memorising facts. This is similar to mathematical modelling in which students would gain most from practising with as wide a range of problems as possible.

The learning outcome for the MATLAB module is to offer students a tool for their scientific study within the subject areas. It is not intended to train students to be professional programmer. The learning could be very different between the MATLAB programming for scientific study and the programming for professional software development. In the latter, there could be different troublesome concepts and the effect of mathematics on this type of programming course could be very different.

There is also difference in correlation among different years for a particular module. One of the possible reasons could be due to the fact that assessment method differs slightly from year to year. Narrower mark range or ABCDE based scale could restrict the learning performance correlation as it might suppress nuances in the assessed outcome (in the sense the finer divisions in the marks are lost). This idea requires further investigation using more participants over a longer period.

5. Summary

Our investigation corroborates the fact that students from different subjects find different MATLAB concepts to be troublesome, and therefore MATLAB must be taught differently to different student audience.

We also presented a consistent correlation between MATLAB results and that in the *modelling and mechanics* module (amongst first-year mathematicians). This may imply that a modelling-type module can be learned together with MATLAB module to capitalise on this synergy.

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