

# CETL-MSOR Conference 2011

**Conference** Proceedings



### Edited by Dagmar Waller







## **CETL-MSOR Conference 2011**

Coventry University 5th – 6th September

Conference Proceedings Edited by Dagmar Waller

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## **Editor's Notes**

The sixth CETL-MSOR conference was held on 5-6 September 2011 at the University of Coventry. As in previous years, there were a large number of excellent presentations, some of which are reflected in these Proceedings. Others have been reported and published elsewhere. In particular I would like to draw your attention to MSOR Connections, Volume 11 No 3 Autumn Term 2011. This special edition focuses on projects being undertaken as part of the Mathematical Sciences HE Curriculum Innovation work strand of the National HE STEM Programme, many of which reported at the conference.

This was my first CETL-MSOR Conference and I was impressed by the quality and variety of work demonstrated. A particular high point for me, and for many of the delegates, were the two plenary sessions presented by students involved in **sigma** and MSOR projects. If these students are typical of the calibre of MSOR undergraduates then I believe the future of the discipline is in safe hands.

As in previous years, these Proceedings would not have been possible without the help of all those colleagues who have reviewed submissions, so my thanks to all of you.

#### **Conference Papers in these Proceedings**

**Angelini** reports on University College London's transition programme which includes the allocation of mentors to all students, study skills workshops, information sessions, peer-assisted learning and online support. The paper discusses the evidence for improved retention rates utilising student feedback and progression data.

**Barton, Foster, Levesley and McCabe** report on an ongoing HE STEM Large-scale Curriculum Innovation and Enhancement project set up to enable the consolidation, sharing and joint reflection on the use of e-assessment in mathematics and statistics. This paper outlines interim findings and discusses the work needed to further inform the HE Community on the efficacy and promotion of the use of electronic teaching and assessment methods given the current unstable environment.

**Biehler, Hoppenbrock, Klemm, Liebendörfer and Wassong** introduce the German Centre for Higher Mathematics Education and briefly explain its structure and aims. Two of the Centre's research projects are discussed; a training programme for student teaching assistants and the math-bridge project providing elearning material for mathematical bridging courses and student support centres.

**Bradshaw, George, Lakin, Mann and Ramesh** discuss issues in the development, delivery, assessment and evaluation of a new core course, Mathematical Technology and Thinking, introduced at the University of Greenwich. Part of this course for first year undergraduates involved weekly workshops giving overviews of areas of mathematics not otherwise covered in the curriculum in order to increase awareness of a wider range of mathematics.

**Broughton, Hernandez-Martinez and Robinson** discuss early efforts to understand students' thoughts and actions when they are presented with mathematics-based computer-aided assessment. The paper provides an analysis of the results of two student focus groups and discusses the conflict between students desire to be competent, confident mathematicians and their need to maximise marks.

**Cooper, Gillard, Graham, White, Wilson** together with **Anderson, Bond, Taylor and Kennedy** report on a summer intern programme for students across the south west region. The latter group of authors are four students who took advantage of the programme, based at the Universities of Bath, Cardiff, Exeter and Plymouth. This paper describes the intern programme and the individual experiences of the students involved, and discusses how this could be taken forward in the future.

**Duah and Croft** report on a project to enhance the second year undergraduate mathematics experience and increase student engagement and satisfaction. Four students were recruited as interns to produce teaching and learning resources that could potentially engage future cohorts of second year students. The paper describes the findings of an ethnographic study designed to understand the students' role, experiences, working relationship with staff, and the resources that they were able to produce.

**Graham** reports on a peer assessment scheme that has been used over a number of years on a core second-year module in undergraduate mathematics courses at Plymouth University. The paper outlines how this has been implemented together with benefits and potential issues that other institutions considering introducing similar schemes should be aware of.

**Jordan and Lowe** report on a MSOR project recently undertaken to produce and evaluate the effectiveness of short audio-visual screencasts to support students learning in algebra and calculus. It provides practical suggestions for the production of screencasts and considers their effectiveness for students learning at a distance.

**Kotecha** discusses the outcomes of a small scale study in which students were encouraged to actively contribute to various aspects of their education. First year undergraduate students were encouraged to contribute to course design and provide feedback. It goes on to describe how those initially involved went on to share their experiences and perceived benefits with students in the following year's intake.

**Mac an Bhaird** reports on a mentoring scheme for students who were repeating at least one of their first year mathematics modules. The paper describes the scheme, the mathematical background of the students and focuses on their engagement levels, behaviour and feedback. It briefly discusses impact on further initiatives and interventions run by the Department of Mathematics and Statistics, National University of Ireland Maynooth.

**Oliver** discusses the use of complete worked examples that show how fundamental mathematical and engineering principles relate together within the teaching of Wavelet mathematics. It describes the development of a new realtime example for a previously described Wavelet Toolbox Guided Learning Handbook.

**Dagmar Waller** 

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### Measuring the effects of Peer-Assisted Learning on the development of students in transition to maths-based teaching programs

#### Marco Angelini

University College London

#### **Background and Policy Framework**

The UCL Transition Programme (TP) began in 2005 as a pilot in three undergraduate teaching programs. From 2006/07 it has been rolled out to include all undergraduate teaching areas, and since 2009/10 every first-year student has been allocated a mentor, and has benefited from study skills workshops, information sessions, peer-assisted learning and online support. The TP pilot report provides a comprehensive discussion of how it was developed [1].

Recent government policy on Access and enhancing the student experience in Higher Education (HE) has placed support activities that focus on the student experience at the centre of institutional approaches that tie outreach, admissions and student engagement together. Despite a challenging financial landscape, the TP is strategically placed to maintain and enhance its role in supporting academic and personal development for UCL students. In particular, UCL policy documents have outlined an emphasis on the programme's role in supporting transition into and through the first year of HE, focussing on groups that are under-represented in UCL undergraduate cohorts.

#### Extract from UCL Institutional Learning and Teaching Strategy 2010-2015 [2]

63: UCL recognises that students will have an increasingly varied prior educational experience. The retention rate for UCL is high, but, to enable students successfully to follow its academically rigorous programmes, UCL will continue to sustain and develop its Transition Programme for first-year students as appropriate.

Extracts from UCL Access Agreement 2012/13 [3]

4.8: Over £100,000 of the new additional fee income will be spent on retention, including £14,200 on new activities. Over £80,000 of non-additional fee income is currently spent on retention activities through the UCL Transition Programme and this will continue.

5.19: UCL currently runs a successful Transition Programme that operates in every academic department that has new undergraduate students. This programme has contributed to the steady increase in UCL's retention rate. UCL now plans to develop a series of bespoke events and activities for students from under-represented groups to provide additional support and guidance throughout the first year of study. This will include workshops on study skills to ensure that students have the requisite skills to succeed on their degree programme.

#### **Transition support activities**

The programme recruited 407 Mentors and 52 Senior Mentors to support new first years in all undergraduate teaching areas in the 2010/11 session. In the four maths-based teaching programs that are the focus of this paper (Mathematics, Statistical Science, Economics and Physics) the programme recruited 62 mentors and 6 Senior Mentors, supporting the new first year cohorts in those respective departments, which is to say 560 first year

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students in all. Training and on going feedback and support for mentors is provided by TP staff prior to taking up the role, and this involves: managing groups and personalities, facilitation techniques, diversity and equal opportunities awareness, problem-solving, critical thinking and managing academic discussions.

Senior Mentors co-ordinate activities and feedback in their individual teaching areas through mentor group observations, they assist in developing workshops and study resources as well as providing support to mentors in their departments cascading good practice to their teams. Typically, Mentors each run groups of 8-12 first years, providing support, advice and guidance on the transition to UCL and their course in particular. Mentor groups focus on social activities at the start of the session in order to acclimatise new students to the institution, their course and the city, and typically introduce peer-assisted learning (PAL) to their groups by the third or fourth week of term, so groups effectively become forums for academic discussion and study skills support.

There is variety in the way mentoring is structured throughout UCL, as alternative approaches will suit different departments and teaching areas; content, frequency of meeting and mode of delivery vary in terms of how groups function in different faculties. All Mentors feed back to Senior Mentors on a weekly basis, and the latter then produce summary reports for TP staff who provide feedback and support to Senior Mentors; in some cases, support is given by TP staff to Mentors or first years directly, depending on the seriousness of the issue reported.

A variety of workshop sessions are made available to students covering areas in academic development, employability, networking and personal development. Most workshops are discipline-specific so as to increase the relevance of the material to individual course participants; examples of these kinds of sessions this year are: CV Writing and Interview Techniques, Essay Writing, Academic Writing, Presentation Skills, Managing Groups and Teamwork, How to Succeed at University, Avoiding Plagiarism. These and other sessions have been delivered by TP staff, research students, departmental teaching staff, CALT staff and Senior Mentors throughout UCL teaching areas.

During induction week Information Sessions are held for incoming students, consisting of brief presentations from various support services to let them know how to access opportunities for engagement and the help available from various support units. Academic skills resources and opportunities for wider engagement have been developed in electronic formats and made available through the transition site and two Moodle courses; one of these courses has been designed for use by incoming students in the pre-induction period and includes virtual tours of London and UCL, study skills courses that can be completed wholly online, discussion forums, information on budgeting, student finance and accommodation. This resource is designed to prepare students for the social and academic transition to life and study at UCL. A second course has been designed primarily for use by mentors as a way for them to share resources and good practice, and contains resources to be used in mentor group sessions. In addition, this Moodle site contains resources to stimulate wider development for mentors in terms of professional growth and leadership skills, with opportunities to engage further at UCL and develop their skills in post-UCL contexts. This support for mentor development is intended to enhance UCL strategies on employability and global citizenship, offering pathways for mentors to tie their experience to the kinds of skills and leadership growth that can impact their future personal and professional development.

The transition website [4] is a resource centre for use by students, mentors and external stakeholders; in particular it provides information and tools on academic and personal development for students, and an interface for schools and colleges to engage with transition outreach activities and academic resources designed for preuniversity learners (see below). There is evidence that the transition site is used significantly by external staff and institutions to learn more about the UCL model for transition support and to make use of the resources that are available there. The TP site also includes comprehensive reports on how the programme's activities are implemented and evaluated, including links to all the training and study resources that are used by mentors and staff, as well as student profiles, evaluation data from previous years and links to outreach activities the programme promotes..

#### **Feedback and Evaluation**

Table 1 below shows the percentage rate of UCL first years progressing into year 2 of their degree, where the data refers to first year cohorts in the four maths-based teaching programmes starting their programmes in September of that year; 2002 is the earliest year we have for this data and is followed by the years where the Transition Programme was being rolled-out in the four departments in question, that is, since 2006.

Year cohort begins degree	2002	2003	2004	2005	2006	2007	2008	2009	2010
Progression rate into year 2	85%	86%	87%	87%	87%	88%	90%	89%	90%

Table 1: Percentage rate of UCL first years progressing into year 2 of their degree

Since the TP has been active, there has been an improvement in the progression rate of first years into year two of their degree programmes; more detailed feedback from first years in the yearly questionnaires that have been conducted indicates that attendance in PAL sessions in particular has had a positive impact on the student experience.

Whilst it is too early to discern any long term patterns in the progression figures connected to the programme, the progression data show very encouraging signs that the programme is having a positive impact in supporting first years. Though experience from other institutions that have embedded transitional support suggests that positive patterns are only clearly discernible after five to six years of the embedding process, the feedback from new students in the years in question indicate that the learners who have engaged most with transitional support activities are more likely to report positive development in terms of their academic identities.

The data and comments below are taken from an anonymous online questionnaire completed by first years in the 2010/2011 cohort in the four maths-based teaching programs mentioned above. It was collected at the end of the first term of the students' programmes, between 12 December 2010 and 15 January 2011. Students were asked a variety of questions to map out their experience of making the transition to UCL; 98 (n) 1<sup>st</sup> year students across the four maths-based departments completed the Student Transition Survey:

86% of all respondents attended their initial Meet your Mentor session during induction week.

74% attended at least one PAL session

91% of all respondents would recommend the programme to other first year students.

51% of all respondents intended to continue with PAL throughout the academic year

The tables in the four figures right and overleaf measure responses to key milestones in academic development, broken down by frequency of attendance at PAL sessions during term 1. The Agree and Disagree data have been aggregated from Likert scale options for the intensity of their responses: the scale used has five possible responses, including Neutral.



Four-Six

Seven-Nine

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None

One-Three

Ten



You are able to structure and write good assignments



## You are confident you will achieve good grades for assignments



Measuring the effects of Peer-Assisted Learning on the development of students in transition to maths-based teaching programs – Marco Angelini

#### **Summary Reflections**

Students were asked about their perception of their own confidence and abilities in key areas, having completed their first term at UCL. The feedback shows that where students attended more meetings, they typically responded that they felt more confident in various areas. Responses were grouped by no meetings having been attended through to ten or more meetings, with incremental options for reporting increased attendance. There is good evidence from the questionnaire feedback that students are developing skills as reflective learners and positive self-concepts as members of the UCL learning community, which are key goals of the TP. Establishing the ability to self-regulate the necessary adjustments towards becoming effective learners, reflecting on and adapting their style of academic performance, are all strong evidence that the programme is having a positive impact on learners. There are further indications in this context that the TP is having a positive impact in terms of personal development and wider key skills, particularly in terms of managing their expectations of university life, goal-setting and working effectively with staff and other students.

In summary, the evidence from the student feedback responses, together with the progression data, are highly indicative that the TP as a whole is exerting a positive effect on the experience of students taking the mathsbased courses that have been assessed here. The programme succeeds or fails on its ability to generate strong levels of student engagement, both socially and academically. Though it is very hard to thoroughly dis-entangle the various factors that affect student motivation, resilience and performance, the evidence outlined here would strengthen the case that support programs which improve the quality of student engagement can be effective in improving the student experience as a whole and progression rates in particular.

#### References

- 1. TP Pilot Report http://www.ucl.ac.uk/transition/Transition\_report\_2005.doc
- 2. UCL's Teaching and Learning Strategy http://www.ucl.ac.uk/teaching-learning/strategic\_priorities/ILTS
- 3. UCL's full Access Agreement http://www.ucl.ac.uk/prospective-students/widening-participation/access
- 4. UCL's Transition Website http://www.ucl.ac.uk/transition/

### Barriers in integrating e-assessment into mathematics teaching and learning for first and second year students

#### Sally Barton<sup>1</sup>, Bill Foster<sup>2</sup>, Jeremy Levesley<sup>3</sup> and Michael McCabe<sup>4</sup>

<sup>1</sup>School of Mathematical Sciences, University of Nottingham, <sup>2</sup>School of Mathematics and Statistics, Newcastle University, <sup>3</sup>Department of Mathematics, University of Leicester and <sup>4</sup>Department of Mathematics, University of Portsmouth

#### Abstract

HE institutions have used and are using e-assessment in mathematics and statistics and some have reported benefits in pedagogy, feedback and resource saving especially at the teaching -intensive early stages of degree courses. However, there is at present little sector-wide structured dissemination enabling decisions to be made on implementation. Where implementation has taken place there is often a duplication of effort not only in e-assessment and learning strategies, but also in the writing of questions and the creation of local e-assessment systems. This article reports on an ongoing HE STEM Large-scale Curriculum Innovation and Enhancement project set up to enable the Mathematics and Statistics community to consolidate, share and jointly reflect on these issues and by extension to all STEM disciplines. However it appears that e-assessment and e-learning implementations in the HE sector are in a state of flux reflecting the changes and uncertainty in HE at present. For example, the use of e-assessment is declining in many of the universities visited in the region surveyed so far. As well as the readily identifiable barriers, there are new barriers appearing due to changes in policy at institutional level. This article reports on these interim findings and discusses the work needed to further inform the HE Community on the efficacy and promotion of the use of electronic teaching and assessment methods given this unstable environment.

#### **1. The Project**

This article describes the progress and some of the interim outcomes and observations to date of the project, funded by HE STEM on e-assessment and learning in Mathematics and Statistics, and is an expansion of the talk given at the CETL-MSOR conference held at Coventry University in 2011.

The project has been funded as part of the HE STEM Large-scale Curriculum Innovation and Enhancement call.

The original plans of the project are detailed in the Supplementary Information section 4. Many of the Mathematics and Statistics departments or schools of the institutions we are in contact with appreciate that the use of e-assessment and e-learning can bring resource and pedagogic benefits if properly implemented and with sustainability built into the provision. One important driver in the take up of e-assessment in Mathematics and Statistics schools or departments is the relatively poor showing of feedback provision in the National Student Survey. The use of electronic delivery and feedback is seen as meeting some of these feedback aims given limitations on staff resource.

The workshop held in February 2011 and the forum held afterwards chaired by Prof Cliff Beevers at the University of Nottingham was particularly valuable in establishing parameters for the project and establishing a initial focus for future investigations. See section 4 for more details of the forum discussion. However, as we visited North East Mathematics and Statistics departments and schools afterwards it became clear that despite the many

excellent examples of e-assessment implementations seen in the workshop, the systematic implementation of eassessment was generally reducing even in institutions with a previously strong record of use. The identification of the reasons for this apparent decline became of increasing importance. As well as departmental or school barriers or constraints, it is of particular importance to examine the role of university regulations and policy in regard to formative assessment. This has had a significant effect on the provision of e-assessment in some cases.

The project has two case-studies at Nottingham and Leicester. We report on the Nottingham study to date along with a report from the University of Portsmouth as they demonstrate the problems that arise in the implementation of e-assessment when change is at an institutional level. We also include a short report on the visits to the NE Universities where other important barriers and issues are raised. The other case-study from the University of Leicester Department of Mathematics is looking at the planned increase in the use of e-assessment as part of the project and we will report on this in more detail later.

#### **1.1 Barriers at the School or Department Level**

These were found in all instances of reduction in use in the universities visited, see the report (2.4) below on the North East Universities, and were mainly expressed through the reactions of members of staff. Heads of School/ Departments were in general supportive of the use of e-assessment as they see the benefits but are reluctant to impose this on staff who, for example, see little opportunity for promotion based on this type of work. These barriers can be summarised as follows:

- Distrust through lack of information on performance
- · Past experiences of poorly performing and difficult to manage systems,
- Lack of resource (staff, time, money, infrastructure, training).
- Inertia/tradition as expressed through lecturer autonomy and the reluctance to change assessment methods.
- Sustainability. Staff involved with e-assessment moving to other posts and no back-up available.
- Lack of school/departmental policy on e-assessment.

The report by Dr Sally Barton on the University of Nottingham Case Study highlights some of these issues as does the report on the visits to North-East Universities.

#### 2.2 Barriers at the University or Institutional Level.

Universities are adopting policy strategies on e-assessment and learning and encouraging its use. However this can be a two edged sword. Policy decisions at the institutional level can have major impacts on the quality of the current provision of e-assessment in Mathematics and Statistics in terms of the required functionality. This is particularly true when a university wide e-assessment system is chosen without reference to the needs of STEM disciplines in Mathematics and Statistics. See the reports on Nottingham (2.1) and Portsmouth (2.3) below. It is important that the needs of specialist e-assessment techniques of STEM disciplines are transmitted to decision makers.

Other policy decisions that can have profound and sometimes unforeseen effects include university-wide policy decisions on stopping possible collusion in coursework, even when this is a minor contribution to the overall mark or grade. As a result, York and Northumbria Mathematics departments have drastically cut down on their provision of in-course formative assessment and as a consequence there is very little formative e-assessment offered . Nottingham has also reported restrictions on the use of e-assessment for coursework.

Other universities Mathematics and Statistics departments take a more robust view of this, for example at Sheffield Hallam and Newcastle, the view is that the pedagogical advantages of constantly available practice with good quality feedback and monitoring of students far outweighs the risk and effects of collusion.

#### 2. The Case Studies and Visits to North-Eastern Universities

#### 2.1 Nottingham Case Study.

#### Report by Sally Barton School of Mathematical Sciences.

#### School support

At the school level there is an encouragement to consider e-learning in line with the university policy of promoting the use of electronic teaching methods and its use for assessment and feedback. This encouragement was given a boost with the retirement of the school IT support officer and her replacement by a full time computer applications officer and a part time e-learning co-ordinator. Unfortunately this dedicated support was lost when he moved to a new job and the decision was taken to rely on central IT support. Developments are now dependent on individual lecturers deciding to get involved.

#### **Central provision**

So can the central provision support us? The university wide position is (from my viewpoint) confused. University wide there are excellent initiatives and policies promoting the use of e-assessment. However software decisions seem to be taken on a 'one size fits all' basis. Recently the previous systems such as QMP were replaced by TouchStone, a bespoke system developed by our medical school. It was heralded as having various features which were improvements on QMP and indeed the new system does know the difference between 0 and a blank or 1 and 1.7 but using the new system proved to have difficulties of its own. This resulted in a need for more development work which had to be rationed between competing Schools. Academics were encouraged to use the central workspace to make suggestions and report difficulties but the responses have all been reactive not proactive. There is now an upgraded version with a new name, Rogo, which has some improvements to the question types but there is still no-one on the development team asking for information from the schools. The new system is being developed and mathematics academics are not being encouraged either centrally or from within the school to be involved. Will there be any surprise when e-assessment opportunities are not taken up?

#### E-assessment issues

There are also issues with central assessment policies as e-assessment is given a higher standard to meet than standard coursework. As a result of these requirements outweighing the advantages one module no longer uses e-assessment and has reverted to paper based multiple choice tests.

#### **Moving to Moodle**

WebCT is being phased out and there is a Moodle pilot. There was a risk of no mathematics involvement in this pilot but due to funding from the HE STEM project, I have had time to develop two pilot modules, encourage other staff within my school and network with staff in other STEM areas. My involvement with the HE STEM project has also enabled me to put technical staff at Nottingham in contact with staff elsewhere to enable the adoption of best practice.

#### How can the HE STEM project help?

I am aware of how useful it would be to have a central or web based resource/community where non-specialists like myself and others in the HE community can see what is available and make informed requests. Wider access to information about what is possible and current developments can bring about more improvements more quickly.

#### Back to Nottingham School of Mathematical Sciences:

Within the school there is suspicion and hope - hope that there will be something that can be used but suspicion that it won't work well or will be 'buggy' or will be replaced with something else. This makes issues of transferability and standards key to increasing the take up of e-assessment. If questions can to some extent be independent of the software used then more time will be spent developing them and there will be more options for sharing of resources across institutions. I am not alone in the school in wanting to make improvements. We hope to produce the evidence to bring others on board but the majority of staff still think that e-assessment 'isn't worth the hassle' and more work needs to be done on how to engage them.

#### 2.2 Leicester Case Study

#### **Report by Jeremy Levesley, University of Leicester**

We currently have four undergraduate modules actively using MAPLE TA, first year calculus and linear algebra, second year differential equations, and final year complex analysis. We also have a basic skills test which incoming first year students take to check that they have the requisite calculus, trigonometry and algebraic manipulations skills.

We are seeking to extend the use of computer-aided assessment (recorded in the Learning and Teaching Committee minutes) as part of a strategy of more focused assessment for particular skills. We are targeting good ability in basic skills as the hallmark of a 2ii student. We are hoping that this level can he adequately assessed using CAA. This will free academic time for assessment of higher order skills with more appropriate methodology (oral examination and problem-solving for instance). We are also interested in creating basic skills tests for transition between years (we find that the jump from year 1 to year 2 is bigger than A level to year 1). Such a test would establish a mutually understood baseline for students entering higher years.

The measureable outcomes of the proposed project would be:

- Improvement of basic skills related to large amounts of formative assessment available;
- Saving of staff time on the marking of routine work;
- Changes in assessment practice related to a better articulation of learning outcome and assessment mode;
- Changes in the sort of question asked related to the incorporation of IT into questions;
- · Amount of staff development time directly involved with the project;
- · Level of cooperation across different institutions;
- The level at which institutions are prepared to contribute financially to well-articulated projects with outcomes of high value.

#### 2.3 University of Portsmouth

#### Report by Michael McCabe, Department of Mathematical Sciences.

In 2007 a major report was commissioned by the University of Portsmouth to make recommendations for future e-assessment. At that time the only university-wide tool supported was the quiz element of WebCT (now Blackboard) with fragmented use of QM Perception and MapleTA. Since then QM Perception has been rolled out university-wide and upgraded to V5 over the past year. Use of MapleTA has been limited to within the Department of Mathematics and is supported locally

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Major university policy decisions are creating difficulties in maintaining the provision of e-assessment in maths and stats:

- 1. University-wide revision of the curriculum from semester to year- long units in 2012, known as "Curriculum 2012", is making significant changes to the content and structure of courses. Good e-assessment has a long development time and does not adapt readily to such changes.
- 2. A planned change from the university-wide "Victory" VLE (Blackboard, originally WebCT) to Moodle in 2013 is underway. This will be the major thrust in the development of e-learning resources for the future and could provoke a complete change in the direction of mathematics e-assessment. For example, STACK is probably the tool most appropriate for use in conjunction with Moodle. There is also the question of whether existing Blackboard/WebCT questions will be exportable easily into Moodle.
- 3. The existence of Question-Mark Perception as the main supported e-assessment system leaves 'specialised' tools such as MapleTA to be dealt with locally.

Over the past three years, a different solution to the thorny question of e-assessment has been adopted. The Department of Mathematics has introduced 'pre-packaged' commercial WileyPlus courses as the main source of e-learning into two of its large first-year course units in calculus and linear algebra. With its integrated use of MapleTA as its underlying assessment engine and comprehensive resources, the use of WileyPLUS has both pros and cons. The cost is modest, but the resources are relatively inflexible. Since WileyPLUS is developed externally, its use is independent of the VLE changes and the adoption of Perception. Likewise Maple TA is independent of the university VLE as it has its own server, though it has not always been considered appropriate to keep up with the latest version changes. Despite its underlying MapleTA assessment, it is not currently possible to write in-house questions for WileyPlus in MapleTA. It is hoped that the next release of WileyPlus (V5 expected late 2012/early 2013) will allow questions written in MapleTA to be exported into WileyPlus, although this is by no means a certainty.

QM Perception, was used routinely for mathematics assessment for around 10 years before the introduction of WileyPLUS, but it is unlikely to be re-adopted since it cannot achieve the required level of maths and stats sophistication that is possible with MapleTA and WileyPLUS.

#### 2.4 Visits to North East Universities

#### **Report by Bill Foster, Newcastle University**

The following universities have been visited. More detailed reports will be made available on the eAssessment web-site.

Durham, Leeds, Northumbria, Sheffield Hallam, Sunderland, York and Newcastle

The story is of a generally declining use of e-assessment in Mathematics and Statistics in the NE universities visited and where it is used it is largely dependent upon local enthusiasts. However, even these enthusiasts are thinner on the ground than say 10 years ago as it is clear that spending a large amount of time on installing and maintaining such systems and then writing questions is not viewed as mainstream academic activity and is not generally linked to promotion. Also the systems used in the past have been somewhat unreliable or difficult to use or have not had sufficient sophistication to enable the setting of sufficiently challenging questions.

A case in point is that of AIM, a relatively sophisticated assessment open-source system linked into a computer algebra system, but although challenging questions can be set in Mathematics, the system itself is unreliable and needs upgrading and maintenance for which no resources are presently available. Previous users, Durham, Leeds and York, have more or less ceased using the system.

A powerful commercial system such as Maple TA has been used in four of the North-East universities but once again its use has been limited and dwindling due to perceived difficulties in authoring and in support/installation.

A surprising outcome of these visits has been the effect of some of the stringent application of policies on coursework collusion. This has lead to the more or less abandonment of in-course e-assessment in York and Northumbria Universities.

#### **3. Conclusions**

The use of e-assessment throughout the STEM disciplines varies considerably in the HE community. There is a general perception that formative e-assessment is a 'good thing' but that there is little coherent information in the community which is allowing schools and departments to make informed choices, or even cases internally or to their institutions for resources to sustain any implementation. Policy changes at every level can put even more barriers in place.

The outcomes of this project are planned to give STEM disciplines the information and ammunition to make their case in order to influence decision making and to regain control over the use of electronic learning materials and tools. Otherwise the lack of control as reported in this article will lead possibly to further abandonment of e-assessment and e-learning in Mathematics and Statistics.

#### 4. Supplementary Information

#### **4.1 Project Outcomes**

- Information for all STEM disciplines on present benefits and developments in e-assessment for Mathematics and Statistics in HE. This includes open-source e-assessment systems.
- Sharing of best practice through wide-scale dissemination to all STEM disciplines.
- Understanding barriers to sustainable use of e-assessment in STEM disciplines and to potential future developments in HE.
- Criteria and implementation strategies in terms of pedagogy and resource implications, tested by our casestudies at Nottingham and Leicester, helping departments and schools introduce sustainable e-assessment into their curriculum.
- A web-based e-assessment advisory resource for Mathematics and Statistics in STEM disciplines initially based within the HoDoMS forum.
- Models for staff development in using e-assessment crucial for sustainable use.

To this we added a new outcome as the project unfolded:

• A review of interoperability and the use of standards such as IMS QTI and SCORM

This last point was prompted by the following question which came from the forum discussion held after the first workshop in February 2011 at the University of Nottingham.

'Why hasn't HE with all its embedded technological and pedagogical expertise managed to organise a sustainable community-wide multi-platform system for mathematics and statistics with the required functionality and the concomitant savings and interoperability/dissemination via a database and good authoring system?'

This question was and is the focus of a subgroup within the project which is discussing interoperability in the context of open-source mathematically sophisticated systems which have been developed in several universities. This group has also made bids to JISC centred around these issues.

#### 4.2 Project Workshop

The first day of this workshop/conference for all collaborators involved demonstrating current e-assessment implementations and strategies across the HE sector. There were 15 HE institutions involved as well as 4 commercial vendors. The second day involved a detailed planning of the project between the project participants.

The talks were split into four sections:

- Commercial Vendors
- Local Statistical e-assessment implementations
- Tried and Tested Implementations in HE
- New developments and open-source projects

Presentations can be found in the Resources section of the e-Assessment Association. This first day workshop was followed by a forum with all attendees present.

#### 4.3 Forum: HE STEM e-assessment in Mathematics and Statistics

The discussion brought out the fact that there were many common features in the workshop presentations of current e-assessment. Also that the introduction of these features was driven to a large part by the following mix of aspirations and requirements:

- Creating sufficiently challenging questions for HE Mathematics and Statistics with symbolic input (for example reflective questions).
- Rich question environments e.g. multimedia for formative e-assessment and feedback.
- · Adaptive and timely feedback to students
- Reacting to student input intelligently, for example input of mathematics.
- Monitoring of students progress.
- Student centred more in control of their paths through a course.
- Monitoring of assessment performance and item analysis
- Efficiency savings in staff resource e.g. standard text-based formative assessment and feedback involves a large-scale marking effort. Using formative e-assessment releases more time for lecturers including feedback on higher level skills not at present handled by e-assessment.
- Good and accessible authoring tools for e-assessment questions and tests useable by lecturer or moduleleader and adding to the pool available.
- Secure, stable systems which are scalable. Possible use in large classes for summative assessments.
- Good metadata and shared taxonomy towards interoperability and pooling with the HE STEM community.

There was considerable debate on the reasons why a locally developed system should be chosen as against a commercially available one. This will be reported on later in the project and crucially depends upon a mix of sustainability, control, support and cost and how the above features are dealt with.

### Training of student teaching assistants and e-learning via math-bridge – Two projects at the German Centre for Higher Mathematics Education

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#### Abstract

We introduce the German Centre for Higher Mathematics Education and briefly explain its structure and aims. Then we present two research projects from our Centre: firstly we look at a training programme for student teaching assistants organizing small learning groups as support to large scale lectures. Secondly we refer to the math-bridge project providing e-learning material for mathematical bridging courses and student support centres including tools for assessing mathematical competence.

#### 1. The Centre

The German Centre for Higher Mathematics Education (khdm, www.khdm.de) was founded in late 2010 and was funded after a successful application in a national competition for innovative projects in university education. It is established as a joint institution of the Universities of Kassel, Lüneburg and Paderborn.

The main objectives of the khdm are the development of a scientific foundation for research in higher mathematics education as well as the implementation of teaching innovations and their evaluation corresponding to scientific standards. A further aim is building a network for higher mathematics education both nationally and internationally. In our work, we (especially) focus on bridging courses before the first semester and on the first study year since problems show up very early throughout all programs that have mathematics as content.

On the one hand, our research concentrates on how to understand more deeply students' problems with university level mathematics. We include problems with understanding mathematical concepts, problems with proving and mathematical writing, deficiencies in learning strategies and problem solving strategies as well as with the specificities with the university mathematics culture that is much different from school mathematics. Moreover, we run some intervention projects, where we foster the use of learning strategies and working techniques and where we improve the small group teaching carried out by student teaching assistants, enabling them to give more individual advice and support. The curricula are enhanced by 'interface modules' where the relationships between the new university mathematics and the students' major subjects such as engineering, economy and mathematics teaching are explicitly drawn. We also develop tools for competency diagnostics, teaching evaluations and reusable e-learning modules for blended learning scenarios in bridging courses and in first year university courses.

The research and development projects are organized in four working groups (WGs) referring to different study subjects:

- WG 1: Mathematics for primary/secondary school teachers
- WG 2: Mathematics for bachelor and gymnasium (grammar school) teachers
- WG 3: Mathematics for economics

• WG 4: Mathematics for engineering

These make up the pillars of the Centre (see Figure 1) and are connected via Cross Working Groups (CWGs) dealing with overall issues:

- CWG 1: Methods in empirical teaching/learning research
- CWG 2: Didactical analysis of mathematical content
- CWG 3: Innovations in teaching/learning
- CWG 4: e-learning

The working groups are complemented by a team of associated scientists (e.g. educational psychologists) that support the centre in special research projects (e.g. CWGs). Management of the daily operations and a directorate for the more forward-looking decisions form the head of the centre.



Figure 1: The structure of the centre

In the future, we plan to develop a web portal for information services and exchange of teaching resources and offer courses for professional development for university teachers in mathematics. Community building is also done through organizing annual conferences. The 2011 conference focussed on mathematical bridging courses.

#### 2. A training programme for undergraduate teaching assistants in mathematics

Lectures in university mathematics are often attended by several hundred students. Individual support by the lecturer is impossible. Weekly tutorials given by undergraduate teaching assistants play a central role in directly supporting students' learning. In these tutorials homework assignments and students' questions concerning the lecture are discussed. Moreover, tutorials should offer opportunities for collaborative work in small groups. Teaching assistants are urged to support the learning process on a minimal basis, just intervening when absolutely necessary. Apart from their role as a teacher in the tutorials, teaching assistants are required to do additional tasks: correcting and even grading homework assignments or advising students on mathematical or personal questions.

Obviously, the competences and the beliefs of the teaching assistants have a great influence on the students' learning. Teaching assistants in Germany are usually successful students of mathematics at the end of their studies without further educational qualification or experience. They do not receive any training at all because programmes are seldom available. Some universities offer training programmes for teaching assistants from all faculties [9], [12], however, these do not fit the specific needs of mathematics' lectures. "It is interesting but not applicable for us" is often expressed by the assistants after such workshops. Little effect on teaching habits can be observed. As a result, specific training programmes for teaching assistants of mathematics have been developed in the last years [13]. Compared to the general programmes offered by the faculty of pedagogy, these mathematically orientated programmes focus on specific methods and exercises used in mathematical tutorials. However, most of these mathematical training programmes still focus a lot on the general topics of pedagogy, which often complicates the application of content to actual situations in tutorials. A different approach to training teaching assistants in mathematics can be found in [5]: there a programme is developed that concentrates on the tasks of the teaching assistants and uses simulations to practice typical situations.

Based on this idea, a training programme orientated on the specific needs of mathematical teaching assistants was developed by the Centre's LIMA project (Learning Innovations in Mathematics for pre-service teachers, http://www.lima-pb-ks.de/, [5], [6], [8]). In order to identify the needs of our teaching assistants, we developed a theoretical competence analysis and observed teaching assistants during their work in the tutorials. We analyzed

the feedback on the students' homework assignments given by the teaching assistants. We were able to identify several areas of difficulty: the feedback provided in the tutorials and on the assignments was usually too general and did not apply to the specific difficulties of the students. Presentations of solutions to exercises often did not fit our expectations in form and content, or flaws in time and group management prevented an effective learning atmosphere. Based on these and further information, we defined our list of tasks a teaching assistant should be able to accomplish:

- 1. Pedagogically reflected content knowledge: Certainly, we expect teaching assistants to know the mathematical content and its representation in the lecture. Additionally, they must be informed about the didactical intentions of the lecturer and connect the content of the current lecture to the exercises given to the students.
- 2. Group management: Teaching assistants must create an atmosphere that facilitates learning. Therefore, they should be able to define and encourage rules for the tutorial, moderate discussions and implement social conventions of communication.
- 3. Presenting solutions: By presenting solutions to exercises, teaching assistants should discuss difficult parts of the solution and unfold the problem solving process. Additionally, the solution should be structured and presented in a manner that facilitates students' understanding.
- 4. Organizing collaborative group work: Apart from being able to introduce and end with collaborative group work, teaching assistants should function as moderators having a spectrum of intervention types at their disposal (content-related, strategic, etc.).
- 5. Commenting on students' assignments: Teaching assistants should not only be able to identify mistakes and alternative solutions, but also give constructive feedback which provides insight into the nature of mistakes and ways to overcome them.

Based on these tasks, we developed a specific training programme consisting of a pre-term workshop, in-term assistance & feedback as well as an evaluation meeting at the end of the term. The pre-term workshop lasts two full days for discussing and practicing the tasks described above. Special attention is paid to the specific conditions and requirements of the respective lecture. Exercises, which might become student assignments later in the term, are used as workshop material for practicing the presentation of the solution or the correction of homework. In this way, the participants see the direct connection of the workshop content to their actual work. Furthermore, the trainer gets a first insight into the mathematical knowledge of the teaching assistants and can discuss difficult topics in the workshop if necessary. On the whole, the pre-term workshop aims at unfolding the standards set for the teaching assistants and giving a first feedback on their strengths and weaknesses.

The LIMA training programme pays special focus to the in-term assistance. On the one hand, teaching assistants receive extra material, e.g. planning devices or solutions with didactical and mathematical comments, on the other hand, they get individual feedback. At least once a term, they are observed in their tutorial session by the trainer. The session is videotaped, in order to be able to view and discuss interesting scenes in the feedback session. Additionally, the teaching assistants visit each other in their tutorials and exchange experiences afterwards. Lastly, the teaching assistants meet with the trainer and lecturer every week to talk about the mathematical content and plan the next tutorial together.

After the first term we interviewed the teaching assistants who took part in our programme. We have adjusted and improved specific elements in response to their feedback and repeated the programme with teaching assistants from a different university. The response in further interviews was positive, especially complimenting the in-term assistance. However, teaching assistants were also thankful for the opportunity to better understand what is expected of them and how they can fit these expectations. Comments on the programme such as "it is interesting but not applicable for us" have not yet been recorded, probably due to the close linking of our training concept to the actual setting of their work.

#### 3. Math-Bridge

#### 3.1. The Project

When looking at existing bridging courses all over Europe you will find several problems: most of the projects are not networked either nationally or internationally, most of the content is not multilingual and interoperable, and in addition the content of most projects is not adaptable to the special needs of an individual learner. The project Math-Bridge (http://project.math-bridge.org) tries to give a solution for these problems. The targets of the project are supporting multilingual, European-wide usable content, enhancing the adaptive and adaptable system ActiveMath (http://www.activemath.org) for the special needs of bridging courses and presenting tested bridging course scenarios for the use of the content and the system. One product of the project is the system Math-Bridge, which includes all of the content and the features concerning the needs of bridging courses.

Math-Bridge is founded by the EU within the eContentPlus programme (ECP-2008-EDU-428046-Math-Bridge).

#### 3.2. The Content

#### 3.2.1. Structure of the Content

Several universities from all over Europe (Austria, Finland, France, Germany, Hungary, Spain and The Netherlands) are partners in the project. Most of them have experiences with bridging courses in their countries and also support content for bridging courses. These contents had to be integrated into ActiveMath. For this purpose, the content needs to be sliced into learning objects and annotated with different metadata. This is necessary for the system to choose the right content for the special needs of the individual learner. Moreover, course designers can pre-allocate contents for a course. Currently Math-Bridge provides 9713 learning objects, 1514 of them are examples and 4200 are exercises. This is the largest repository of mathematics related learning objects, at least European-wide.

The learning objects have to be annotated with two different types of metadata: structure metadata and pedagogical metadata.

The **structure metadata** defines the type of the learning object (axiom, definition, theorem, proof, example, exercise, text) and also the content related relationship between the learning objects: on one hand we defined an ontology of topics [1, pp. 22]. These are possible topics in bridging courses, based on the Core Taxonomy for Mathematical Sciences Education (http://people.uncw.edu/hermanr/mathtax/), the experiences of the project-partners and the SEFI-Curriculum [11]. Each learning object is linked to a topic in the ontology. On the other hand, the structure metadata define the connection between different learning objects concerning one topic. For instance, a proof is assigned to a theorem or an example/exercise is a assigned to a corresponding definition. Some learning objects need more information to be displayed in the right context. For instance, there are exercises that can only be solved by knowing a specific example. For these and similar dependencies between learning objects we introduced so-called 'complex learning objects' that combine several learning objects in a predefined order.

For the **pedagogical metadata** we defined a competency model for bridging courses with the following: *technical competency, mathematical problem solving competency, modelling competency* and *communication and reasoning competency*. [10, p 18]. Besides the competencies we also defined three achievement levels for each competency (reproduction, connection, reflection) [1, p. 19] and five levels of difficulty (very easy, easy, medium, difficult, very difficult) [1, p 20].

#### 3.2.2. The Interactive Exercises

One important feature of Math-Bridge is the exercise system. Math-Bridge has a large number of more than 4200 exercises. The Math-Bridge exercise system has a comfortable functionality: The built-in exercise system

supports multistep interactive exercises with an automatic evaluation of the students input, supported by a computer algebra system. Also included are non-interactive exercises with self-evaluation based on a sample solution. Math-Bridge also integrates several external exercise systems, for instance STACK (ttp://www.stack. bham.ac.uk/wiki/index.php/Main\_Page) and domain reasoners like IDEAS (http://ideas.cs.uu.nl/www/).

The integration of different exercise systems increases the opportunities of pedagogical scenarios for the use of exercises, like assessment, diagnosis, learning and practicing with exercises.

Ideas Exercises collection	Assessment Test	8
Learning Material Exercise x	Learning Material Exercise X	
Solving linear inequations Solve the linear inequation $4 \cdot (x - 3) > 3 \cdot (x - 4)$	Inverse function Solve the inverse function of the function	
$4 \cdot x - 12 > 3 \cdot x - 12$ This step is correct. Proceed with your solution	$f(\mathbf{x}) = 8 \mathbf{x} + 8$ Give your answer with the help of the variable x.	
This step is incorrect Try again	$f^{-1}(x) =$ Valdate syntax of your answer	The second s
The current task is : $4 \cdot x - 12 > 3 \cdot x - 12$ The next correct step is : x - 12 > -12 x - 12 > 12	Inverse function Solve the inverse function of the function f(x) = 8x + 8 Give your answer with the help of the variable x.	
This step is incorrect Try again : The current task is : $4 \cdot x - 12 > 3 \cdot x - 12$ x - 12 > -12	$f^{-1}(x) = (x-8)/8$ was interpreted $\frac{x-8}{8}$ Check your answer Edit your answer	
This step is correct. Proceed with your solution	Inverse function	
✓ x > 0	Solve the inverse function of the function f(x) = 8x + 8	
Correct: Well done! Your exercise is over, please close the tab.	Give your answer with the help of the variable x. $f^{-1}(X) = (x-8)/8$ was interpreted $\frac{x-8}{8}$ Correct answer	wer

Figure 2: IDEAS exercise (left) and STACK exercise (right)

Another important aspect of the exercise system is the recording of degree of correctness of the learners' answers. The system uses the scoring to estimate the competency of the learner against the competency model of Math-Bridge [7].

#### 3.2.3. The Remedial Scenarios

Math-Bridge provides the possibility to create automatic generated books that fit learners' individual needs. The system uses the learner's estimated competencies to select the adequate learning objects.

The learner first has to choose her/his type of book, the so-called remedial scenarios: *Improving your knowledge*, *Exploring new topics*, *Training a Competency*, *Taking an Exam* and *Using pre-structured Courses* [2, 3]. In a second step the learner has to choose the topic she/he wants to learn about.

The remedial scenarios are based on a scheme of orchestrating different learning objects. The system uses this abstract scheme to create the book and choose the learning objects, the exercises and examples based on estimated competencies.



Figure 3: Steps to create an individual automatic generated book

#### 3.3. The Use of the Content

#### 3.3.1. The Composition of the Content

For the bridging courses in Kassel and Paderborn, where we used Math-Bridge in 2011 for the first time, we started with our content from the project VEMA [4] that we provided for Math-Bridge with one pre-recorded book for each topic. We analysed the content based on this from the other partners and enriched our content with several learning objects. In doing so we increased our number of interactive exercises and added some visualisations to increase our students' understanding of the topics. We added a large number of IDEAS-exercises in order to support the technical competencies of our learners.

#### 3.3.2. The Use of the Content in the Lecture

During the bridging courses in Kassel and Paderborn we used the learning management system moodle as main platform to structure the content and to communicate with our learners. The moodle course for the bridging course provides opportunities for synchronous (chats) and asynchronous (mail, forum) communication, diagnostic tests for each topic, a link to the dialog for automatically generated books and links to the different pre-defined books.

The bridging courses consisted of three days of attendance a week and two days for individual learning. The days of attendance are structured with three hours of lecture in the morning and two hours of tutorials in the afternoon.

During the lecture the lecturer included at some points several learning objects, mainly (interactive) visualizations. For individual learning, the lecturer assigned tasks to the learners to structure their learning. Examples are tasks for individual learning of specific topics, the use of IDEAS-exercises for training in technical competencies and the use of the remedial scenario for specific purposes.

#### 3.4. Evaluation

An important part of the use of Math-Bridge for the bridging courses in Kassel and Paderborn was an evaluation with more than 1900 learners. The evaluation contains pre and post tests to measure learning gains and pre and post questionnaires to measure the usability for learners and their attitudes towards mathematics. The analysis of the data is currently in progress and will be published in further publications.

#### 4. Future perspectives

The training programme for student assistant teachers will be used and adapted for the courses accompanied by all other working groups of the centre. Moreover it will become the object of a research study where we will empirically observe and analyze the emerging competencies of our student tutors. Math-Bridge and our VEMA material will be extended and integrated for use not only in bridging courses but also in the first year study programmes for remedial purposes.

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## Breadth versus depth: a new first year module providing an introduction to the range of mathematics

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#### Abstract

Most mathematics graduates have studied some parts of the subject in considerable depth, but they may have little, if any, knowledge of those branches of mathematics which were covered in the options they did not choose or which were not available to them. This limited view of the subject may in practice restrict their awareness of options for further study.

The authors introduced a new core course, Mathematical Technology and Thinking, for first year mathematics undergraduates at the University of Greenwich. Part of this course involved weekly workshops giving overviews of areas of mathematics not otherwise covered in the curriculum. This paper will discuss issues in the development, delivery, assessment and evaluation of this part of the course over the last three years.

#### 1. Context

The University of Greenwich's Department of Mathematical Sciences has a small teaching staff (although it also contains some highly successful research groups). At the time of its quinquennial review of undergraduate programmes in 2007/2008, its annual intake was around 70 students. With the relatively small numbers, staff know students well: the department performs well in the National Student Survey and in league tables, with excellent student achievement. The students come largely from non-traditional academic backgrounds. A lively student-led Mathematics Society ('MathSoc') provides varied activities with which many students engage, and a popular 'Maths Arcade' provides opportunities for enrichment activities and support [1].

While these student numbers help staff forge strong relationships with students and provide personal support, another consequence is a limited choice of final year modules. Those offered focus on industrial and business mathematics to help students' employability. Larger departments are able to offer more options covering different areas of mathematics, statistics and operational research, with more coverage of abstract pure mathematics. Staff had concerns that as a result Greenwich graduates had limited knowledge of the range of contemporary mathematics and might miss further study opportunities in subject areas of which they were not aware.

A typical mathematics module delves deep into the technical details of the topic. In Freeman Dyson's classification [2], students are trained to be frogs rather than birds: birds have an overview of the topic while frogs have detailed knowledge of a small area. Textbooks like John B. Conway's recent "Capstone course" [3] are unusual. This narrow focus is perhaps an inevitable consequence of the structure of mathematics degree programmes and the nature of assessment.

A further concern was that today's focus on individual coursework deters students from working together. Seminal work by Treisman thirty years ago showed that value of collaborative learning, especially amongst ethnic minority students (like many mathematics students at Greenwich) [4],[5], while Swan's recent book argues strongly for the importance of collaborative learning [6].

The review of undergraduate mathematics provision for delivery from academic year 2008/09, led by one of the authors (Ramesh), provided an opportunity to address these issues.

#### 2. Development

In the redesign of undergraduate programmes a new core first year, 30-credit course was created. ('Course' is the Greenwich terminology for a module.) The name 'Mathematical Technology and Thinking' was chosen after discussion with students, who liked the abbreviation 'MaTT'. This course was designed with three components.

Firstly, it contains the Personal Development Planning (PDP) element of the first year. In line with a wider School policy, the first year PDP curriculum focuses on study skills and is integrated into a core course.

Secondly, it includes the delivery and assessment of computing skills for mathematics. This element was designed to support students' other courses, by teaching the use of Matlab and Excel to carry out matrix operations, perform numerical algorithms, present data graphically, and transfer data between different software packages. It also provides an introduction to programming, which is built on in a second year numerical mathematics course.

Thirdly, the bulk of the course consists of workshops on widely different mathematical topics, aiming to give an overview of the range and power of mathematics, and hoping to inspire and excite students without losing their enthusiasm in a mass of detail. We feel that students sometimes get bogged down in the slog of tutorials and coursework and lose their excitement in new mathematical ideas: they forget how much fun maths is!

Additionally, the first week of the academic year for mathematics students is devoted to a group mathematical modeling activity which, while technically part of MaTT, is intended primarily to help students settle into the university environment and local area, to help them make friends and to motivate their mathematical studies.

Since its inception the course has been delivered by the first four authors.

The PDP element is delivered by one of the personal tutors for first year students, to reinforce students' bonding with their tutor. It was initially designed by Bradshaw and in 2011/12 is delivered by Lakin. The tutor takes regular slots during timetabled classes addressing topics like learning skills, reflection on induction and on the department's mentoring scheme for new students, exam preparation, coursework and plagiarism. Much of the material was originally based on Phil Race's book [8]. Particular efforts have been made to make these sessions highly interactive, for example with students doing exercises in pairs and completing self-assessment questionnaires. Attention has been taken to relate these sessions to immediate student concerns, so sessions on coursework, using library resources and so on are carefully timed to fit with assignments in this and other courses. While students often resent time spent on PDP, the care taken to make this material immediately relevant to their studies, and to stress this relevance at every opportunity, has helped students see the value of reflection on their learning.

This element is assessed through the writing of short regular reflective comments, encouraging students to think about their learning. They are asked to comment on a variety of experiences, including extra-curricular activities such as MathSoc events, to encourage engagement. The most substantial assessment component is a book review: students write about a popular mathematics book (or textbook) of their choice, which encourages them to read around the subject and increases awareness of the resources available in the library. This assignment challenged and changed some student attitudes: *"To be honest, I wasn't really excited to read a book, especially a maths book. I cannot remember the last time I read one. However, this book was surely going to change my attitude."* [7]

The computing element was designed and initially delivered by Bradshaw and Mann and subsequently delivered by George. The programming element has been strengthened. Again it is felt that timing is important so that

students can see the software they are using is helpful in other courses, and so this element of MaTT helps to integrate the first year curriculum.

The third element was initially delivered by Mann with some contributions from Bradshaw. In 2010/11, when rooming constraints required that the workshops be delivered twice, George and Lakin were also involved. This element comprises workshops on topics not covered in detail elsewhere in the curriculum, such as Newtonian mechanics, relativity, quantum theory, number theory, group theory, topology, Godel's Theorems, and the philosophy of mathematics. It gives students the opportunity to learn about subjects which might be in the news, and aims to promote collaborative discussion.

#### 3. Issues

The remainder of this article will focus on this third element of the course which seeks to explore 'the range of mathematics'. While the other elements build on existing practice, this element is new.

During the course design we anticipated that preparing this element would be time-consuming. Each workshop covers a different branch of mathematics, and many of these were relatively unfamiliar to the tutor. As a result preparing the workshops involved a lot of reading (of literature in unfamiliar fields), and during the first year the course ran, the preparation workload was very substantial. Wikipedia [9] proved invaluable as a starting point: the tutor's confidence in this source was reinforced when Timothy Gowers in his plenary talk at the British Mathematical Colloquium praised Wikipedia as a great enabling factor for mathematics and noted the high quality of its mathematical articles [10].

Of course, in subsequent years material can be re-used, although MaTT remains demanding in terms of preparation time because the content is so varied. There is also a potential issue in the tutors keeping up with developments in diverse fields; for example, a new result from the Large Hadron Collider might have drastic implications for the contents of one workshop. Keeping up with developments in many different areas remains an issue.

The delivery of the workshops is a challenge. It proved difficult to produce worthwhile tutorial exercises that helped students understand the concepts being discussed without side-tracking them into detailed calculation that obscured the big ideas. Traditional mathematics tutorial exercises are for Dyson's frogs: it was sometimes hard to find suitable exercises for birds' perspective. The workshops are intended to be as interactive as possible. They are copiously illustrated with video clips, demonstrations and magic tricks which are intended to elucidate the ideas, but are sometimes still dominated by the tutor talking.

Assessment is similarly problematic. Most mathematics assessment is for frogs – there was no obvious way to test a bird's overview of many different areas of difficult mathematics. The initial course design envisaged a group assignment where students prepared a presentation and report on a mathematical topic of their choice. In addition to developing students' research and communication skills, this would also ensure exposure to a wider range of topics than those planned by the tutors. This worked very well in terms of these objectives but some students felt they could complete the assignment without engaging with the taught classes.

At the suggestion of the second cohort of students, a small multiple-choice examination was added in 2010 to assess this part of the course. This contains two or three questions on each topic, testing understanding of the big ideas rather than the detail. This succeeded in improving engagement. However the decision to deduct marks for incorrect answers intimidated some students and the results in May 2011 did not fully reflect student understanding of the content. After consultation with the students, the examination is being 'tweaked' to address this issue.

Staff at the time of the 2008 programme review expressed the concern that the introduction of MaTT would limit first year coverage of core mathematics needed in future years. While this remains to some extent a valid concern,

the course designers hoped that this would be mitigated by the wider mathematical understanding gained by students and the enthusiasm some topics might generate.

#### 4. Reception

Largely the course has been well received by students. In the Department's most recent survey 97% of students taking the course said they were satisfied with the its quality, the second-best result of the four first year courses, and in each year the course has gained better student feedback than in the previous year.

Students have found that the course broadened their mathematical horizons:

"To me mathematics was all to do with numbers and applying it to the real world. But during the MaTT course I have seen how it is also applied elsewhere, rather than just in finance."

#### "This course has changed my personal approach to mathematics"

Attendance during the main part of the course is variable: students are very focused on coursework assignments and attendance fluctuates according to deadlines. Due to rooming constraints, the course has a 9am start. This can be problematic for the many students who travel across London by public transport. In a course where the topic is new every week, missing the first few minutes of class may make the rest difficult to follow (although teaching staff are aware of this issue and try to mitigate it).

Some students prefer traditional courses where they know what to expect and can work through routine tutorial problems which clearly relate to a forthcoming examination. The A-level system has encouraged students to focus on assessment and some students feel puzzled that they are being introduced to topics to promote curiosity rather than to prepare for an examination. On the other hand, some students are very enthusiastic about this aspect of the course and ask searching questions suggesting that they are inspired by the material and are reading independently about it.

"MaTT has helped me think about maths from a different perspective and not just how I was taught at A level."

"MaTT this year has offered me the opportunity to explore mathematics in a way I haven't done before, being able to look into the when, who and why behind the mathematics made a nice change from just being taught an idea or method and how to apply it."

"The material which we study in MaTT consists of stuff that I never thought I would be studying at university. I assumed we would be doing hands on maths, similar to what I had studied throughout my two years in college. MaTT is a subject that not only do I find relatively enjoyable to study but I also find it interesting as it represents maths in a way that I have never seen before."

## "For me personally, MaTT has been a very rewarding, challenging and mathematically stimulating course. I have relished learning about all the different areas of mathematics and all of its applications"

It had been hoped that this course would stimulate students to choose a wider range of topics for their final year projects. Previously students who suggested their own topic typically took ideas from the courses they had studied, resulting in a very limited range. In this objective MaTT has been successful. In particular, several students have done projects relating to relativity and other topics introduced in MaTT. As a result, some students have progressed to study at Masters level in areas of mathematics that they would not previously have encountered in the curriculum at Greenwich.

Some topics have proved particularly successful. For example, when Grigori Perelman was awarded the Clay Millennium Prize for proving the Poincaré Conjecture, we presented a workshop a few days later which introduced topology and tried to explain what Perelman had achieved. The combination of fascinating

Breadth versus depth: a new first year module providing an introduction to the range of mathematics – Noel-Ann Bradshaw, E. George, Steve Lakin, Tony Mann and N.I. Ramesh

mathematics and the human interest story of Perelman's declining the Fields Medal and prize money caught the imagination of the class. As one student said, this workshop made him aware that "I want to do maths because I am inspired by knowing about the people behind it".

Some students have reported that the course has boosted their enthusiasm for mathematics:

"It has only served to reinforce my fervor for the subject."

"MaTT has been a fun topic to study ... I think the insight into further, different areas of mathematics was a great idea."

#### 5. Reflections

MaTT has been in many respects successful. It provides something different to the rest of the curriculum, and has succeeded in inspiring some students and in stretching some of the strongest students. Some students have been influenced and motivated by MaTT workshops in their future study choices, either in final year projects or at Masters level. However some students have engaged less, preferring more traditional courses with a clearer focus on assessment and examination.

Many students have provided very positive feedback. A particularly encouraging point has been that the course has encouraged students to reflect on their interest in mathematics and has helped them understand their own motivation in choosing this discipline. This should help their future studies and lead to improved attainment.

MaTT is a demanding course to deliver; preparation is time-consuming and there is limited topic continuity from week to week. Whether the benefits are worth the resources committed will undoubtedly be a major topic for discussion in the forthcoming programme review.

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## Building a profile of how students engage with CAA in mathematics modules

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#### Abstract

Most computer-aided assessment (CAA) systems incorporate practice tests. Students welcome this opportunity to refine their methods and correct errors before attempting a summative assessment. Lecturers employ CAA to give their students the opportunity for regular practice and to help their students identify their learning gaps. This paper discusses our early efforts to understand students' thoughts and actions when they are presented with mathematics-based computer-aided assessment.

First year mathematics undergraduates were invited to attend focus groups. They were presented with questions relating to their views on assessment generally; their approach to tackling CAA tasks; how they view and use the feedback; and their evaluations and suggestions for improvement. It is evident that students in the focus groups find themselves in a conflict between their desires to be competent, confident mathematicians and their need to maximise their marks. They acknowledge that ideally they would be excellent mathematicians and accomplish high scores as a result of this pursuit.

This observation exemplifies the necessary internal debates that are a feature of Activity Theory. That students have shared such views suggests much further study is to be done and many questions are to be answered. Are these feelings unique to mathematics students? What bearing do these feelings have on how students approach CAA activities? Through this project we aim to deliver a student-centric evaluation of CAA and, in turn, to be able to make informed suggestions for improvement. Further study could examine the feasibility and effectiveness in implementing such changes.

#### 1. Background

The aim of this project is to evaluate the feedback provided by computer-aided assessment (CAA) in mathematics modules. While there is a growing body of literature that examines the development of questions and the feedback that can be provided through CAA (for example, by Sangwin [1], Greenhow and Gill [2], and the HELM project [3]), there is a lack of empirical research into the effects of mathematics-based computer-aided assessment on the learning and development of undergraduates studying mathematics modules.

While many studies examine the introduction of innovative assessment forms, work on identifying students' and lecturers' perceptions of different assessment forms are much less prevalent. This presents a problem, since we have no direct reference or benchmark with which to compare CAA.

We compare CAA with theories of assessment and feedback without a mathematical focus. In particular, we discuss the definition of formative assessment proposed by Black and Wiliam [4], from their studies at school level, and seven principles of good feedback practice suggested by Nicol and Macfarlane Dick [5].

Black and Wiliam [4] define formative assessment with five common practices:

- 1. Clarifying and sharing learning intentions and criteria for success.
- 2. Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding.
- 3. Providing feedback that moves learners forward.
- 4. Activating students as instructional resources for one another.
- 5. Activating students as the owners of their own learning.

To consider CAA 'formative assessment', it ought to have these qualities. As we are interested in feedback, point '3' is the most pertinent to our study. This definition does not suggest what "[moving] learners forward" means; however, it does suggest that student improvement is necessary.

The seven principles of good feedback practice, proposed by Nicol and Macfarlane Dick [5] are:

- 1. Share the criteria for good performance.
- 2. Encourage self-assessment and reflection.
- 3. Deliver high quality information to students about their learning.
- 4. Encourage dialogue with peers and teachers.
- 5. Foster self-esteem and positive motivation.
- 6. Provide opportunities to close the gap between current and desired performance.
- 7. Provides teachers with the information required to shape teaching.

These principles present similar qualities as the Black and Wiliam [4] definition of formative assessment, but they apply to feedback rather than assessment. It is more evident still that the actions of both lecturer and student are important to the success of the feedback process.

That such actions and interactions are so important lends well to the use of activity theory as a theoretical framework to aid in the modelling of the learning activity. It presents us with the need to examine actions and interactions more closely and develop a profile of students and lecturers.

#### 2. Methods

An open method of acquiring data was required as the lack of student-centric literature in CAA and assessment made it difficult to generate hypotheses. By using focus groups, we could pursue students' views and identify areas where conflicts might arise between students' and lecturers' aims and uses of CAA.

We invited students from a group of 237 registered first year calculus students to volunteer and select from a list of available time slots. They had experienced CAA in mathematics modules during their first year at Loughborough University. Nineteen students volunteered, from which twelve were invited to attend the two most selected time slots. Of the seven invited to the first group, six attended; in the second group, five were invited and two attended. Convenience payments were not offered.

The two focus groups convened for 45 minutes, in which the first author directed the discussion by asking prepared questions and a postgraduate student attended to make notes. Transcriptions were made from these notes and two audio recordings.

In these two focus groups, we examined four variables:
- 1. Attitudes and motives in assessment how students feel towards assessment and how much importance is placed upon assessment outcomes.
- 2. Attitudes and motives in CAA how students feel towards CAA and whether it helps them to achieve their goals.
- 3. Behaviours with regard to CAA how students use CAA and react to feedback.
- 4. Lecturers' aims and actions students' perceptions of how lecturers deliver CAA to students and the support they offer.

The data were coded according to these variables, so chosen to address our initial research questions and to develop a profile of student members of the learning community. Elements of the transcripts were collated under headings for each variable to generate a list of quotes that reference each variable. We developed student profiles from the resulting documents.

## 3. Analysis

On analysing the data we identified six points of interest that help describe how our students participate in the activity of CAA.

### 3.1 Students use CAA to identify learning gaps

The students in these focus groups identified that the CAA practice tests enabled them to identify weak areas in their knowledge. The practice facility allows students to make mistakes: "you make a point to learn from your own mistake so generally you remember that point much better" (Focus group 2 Participant 8). Indeed, identifying errors before the summative test gives the student the opportunity to learn from the error: "you can fix your mistakes *during* learning" (F2 P7, emphasis added).

#### 3.2 CAA allows students to focus on smaller aspects of the module syllabus

The administration and immediate marking of CAA tests allow students to be tested quickly and more frequently without increasing the human-time required to mark the tests. These students appreciate that this also enables them to identify more of their weaknesses: "assessments bring stuff up that maybe you're struggling with" (F1 P2). He continued, comparing traditional assessment ("you revise half the material and hope that half of it comes up") to his experiences with CAA ("you know which bits are going to come up so you can focus on them"), adding, "it might be a better way of learning than if you're trying to revise a whole lot and just do focus on a little bit".

#### 3.3 CAA is not as good as traditional assessment for testing conceptual understanding

The students were asked whether they preferred traditional assessment or CAA. All of the participants suggested they preferred CAA. Some admitted that it was a "lazy" choice (F1 P4) or the "easy" option (F1 P3, F1 P4, F2 P8). One added: "if you want to make your life easy, then everyone will go for computer assessment. If you want to learn something and gain something out of the subject, the traditional assessment is better" (F1 P4).

This suggests students know their conceptual understanding is not tested so much with CAA as it might be with traditional assessment methods. One student complained that, despite regularly scoring highly in the summative tests, "generally if I don't understand something going into it, I don't really understand when I come out" (F1 P5).

## 3.4 Students' marks improve when they use practice tests

When the participants were asked to rate the feedback they receive from CAA, their responses were markedly different. While some students described the feedback as "really good" (F2 P7), others' responses echoed the sentiment "not that highly, really" (F1 P5). While they agreed that a demonstration of how to solve a problem allows them to correct their mistakes, there was dispute when trying to establish whether this feedback technique is the most helpful.

This conflict is explained, in part, by the contrasting views on the importance of marks. When asked whether they value marks over maximising learning gains, the students broadly agreed that marks were more important to them. One explained: "I like going into the final exam knowing I've got a little cushion in case I mess up on something... I would still like to learn something as well" (F1 P5).

These students expressed that marks were not their only aim, and that understanding the material is important. However, one student remarked, "in theory, I would like to be comfortable with the material and then as a result get good marks" (F1 P2). The tone and context suggested that this participant did not believe this was a realistic approach and this directed his current approach.

Another student offered his approach to CAA: "I normally start by going through the practice tests a couple of times and trying to work it out; and then if there is a question I can't do I generally have a look at the worked example and see what they've done and then just go back through until I can get 100% on the practice test" (F1 P5). Other members of the group concurred, with (F1 P2) adding, "I'm the same, but I always make sure I have my lecture notes with me because I like to look through them as I do them."

These accounts suggest that obtaining full marks is a realistic outcome. Indeed, one student said, "if people aren't getting 100% it just shows they haven't practised it" (F2 P8). We might postulate this CAA system is effective at improving students' scores, but we cannot conclude from the transcripts alone that students gain a desirable improvement in their conceptual knowledge and understanding.

It is apparent, however, that a student's procedural capability improves quickly through this CAA testing. One student suggested, "the information in the practice tests is possibly in such a way that anybody without having attended any of the lectures... could probably answer and do fairly well in the actual test" (F1 P4). This might indicate that the feedback is too prescriptive, allowing students to methodically progress through questions without needing to call upon their ability to recall procedures.

# 3.5 Students adapt to CAA testing

The emergence of a common approach towards completing CAA tests suggests that students have adapted to this way of testing. While these students described their choice for CAA over traditional assessment as "lazy" and "easy", they exhibit desirable effort. One participant elaborated: "you could just do the practice test twenty times, twenty-five times, until you can write down the answer without thinking about what you're doing" (F1 P1). Although he concedes, "you're not actually learning any good skills about how to solve questions which you can take into the exam", these students appear motivated to persevere with the practice tests until they have reached a satisfactory score.

This motivation and the reassurance that good marks are achievable help students that are struggling with confidence. One student believed that CAA had helped restore confidence when it had been shaken: "I have failed several [pieces of written coursework] and after that I have put much more effort on computer-based [assessment] and get a good mark... and I feel like a bit more relieved" (F2 P7).

## 3.6 Students prefer to seek support in groups but they are wary of accusations of plagiarism

These students were reluctant to approach their lecturers for support, particularly with regard to CAA problems. One student elaborated: "I would never go up to a lecturer and ask, but sometimes students do go up to a lecturer and say they've had a problem... and quickly go over it... but that's only happened once or twice" (F1 P2) and this did not happen in relation to a CAA problem.

They suggest that when they have difficulties with assessments, they turn to each other for support: "I'd much rather go and ask my friends about it rather than ask the lecturers, and try and understand from other people" (F1 P2). They concede this is an obstacle for the lecturer that tries to identify where students have the most problems: "if students aren't asking the lecturer for help with a question they got stuck on, the lecturer can't be expected to know that was a particularly tricky question" (F1 P1).

Though they discussed group work as a means to solve harder problems, the participants were not certain of the policy on group work in the summative test and were concerned about plagiarism. One student noted, "there is a lot of merit in working as a group of people throwing ideas around a table. I think that's a good way of learning maths. But whether or not that is an intention of the department, I don't know" (F1 P4).

The lack of awareness of the department's policy led to the participants suggesting ways in which it might be possible to cheat in a CAA test: "you could do the test theoretically with anybody you like there... It becomes a question whether... that person is providing something constructive... or whether they're just sort of mindlessly doing the test for you... in which case your assessment isn't actually assessing you, which would be a terrible thing" (F1 P1).

## 4. Discussion

These students have suggested that they have improved by means of CAA. They do not merely believe that full marks in CAA tests are realistically achievable: they believe it is the only satisfactory outcome; and it simply requires adjusting to the demonstrated method and sufficient practice.

CAA provides students with the focus and motivation to develop their procedural skills in line with course content and away from the lecture theatre. It also offers an opportunity for students to develop their confidence and self-esteem in a low-pressure testing environment.

There are some caveats. The definition of 'improvement', particularly with regard to learning mathematics, is not well defined. Indeed, one might accept any measure of improvement sufficient to regard an assessment as "moving learners forward" [4] or feedback as "closing the gap between current and desired performance" [5].

Some students feel that the improvement they gain through CAA is not the improvement they seek. They believe that CAA does not examine and extend their understanding of underlying concepts. Though they believe that earning full marks demonstrates an awareness of the mathematics involved, some of the participants feel that the scores do not truly reflect the extent to which they understand the mathematics.

For other students, there may be a danger that gaining full marks suggests that there is no further improvement that can be made. Such students may develop confidence and self-esteem on the belief that CAA tests represent what is expected of them. Consequently, students might prepare inadequately for exams.

# 5. Future work

We must further develop the student profile within this learning community. These volunteers may represent only a small section of the larger group of mathematics undergraduates and we seek the views of engineering undergraduates that study mathematics modules here at Loughborough University. We are submitting questionnaires to these students over this semester to collect their preconceptions of CAA and gather their changing perceptions of CAA over the course of their first year here.

Lecturers have a vital role in this learning community and we must understand the aims and intentions behind the use of CAA in their modules. For example, we noted that students did not believe that CAA tested their conceptual understanding, but it helped them develop their procedural knowledge. We might hypothesise it is not the lecturer's intention to test conceptual understanding by means of CAA, but it may be tested elsewhere. We are currently designing a questionnaire to develop the lecturer profile.

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# Summer internships in sigma-sw

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### Abstract

With evidence of the potential for undergraduate students to work as research assistants in mathematics and statistics support centres and with a keen desire to develop explicit collaborations between member institutions within the hub, **sigma-sw** made a successful bid to the HESTEM programme to pilot a summer intern programme for students across the region. Four students took advantage of the programme, based at the Universities of Bath, Cardiff, Exeter and Plymouth; this article describes the intern programme and after reflecting on various aspects of the pilot, discusses how to move forward to develop a vibrant and sustainable student internship programme.

### Background to sigma-sw

**sigma-sw** (http://www.bath.ac.uk/study/sigma-sw) held its first meeting in summer 2008 as a pilot hub for **sigma** activites in the South-West and South Wales. Over the next two years, the focus for the activities was two themed meeting days hosted by different institutions across the region and an annual forum at the University of Bath to reflect on activites and to plan for the coming year. The hub evolved with core membership involving 7 regional institutions (Bath, Cardiff, Exeter, Gloucestershire, Portsmouth, Plymouth, UWE) but with meetings often attended by colleagues from other institutions. Following the success of the pilot for regional hubs, **sigma** used HE STEM funding to extend the idea of regional hubs to a national level and there are now 6 regional hubs in England and Wales each offering a forum for discussion, development and collaboration at a local level. As a result, membership to **sigma-sw** was formalised; this has had some impact already and we look forward to greater diversity of participation in the future.

Every year during discussions at the annual forum, members of **sigma-sw** discussed mechanisms by which we could exploit the hub structure to develop collaborations, carry out comparative studies and share good practice. The idea of student interns evolved from these discussions.

## **Rationale for internship programme**

The Nuffield Foundation has a well-established bursary programme aimed at providing undergraduates with an opportunity to gain research experience during their degree programmes. This, together with individual experiences of employing students using institutional funding, provided us with evidence that a summer intern programme within the hub would be a worthwhile exercise. Our goal, however, was somewhat ambitious, since we wanted to exploit the hub structure to create a regional flavour to our internships. The purpose here was to use the summer interns to develop research collaborations within **sigma-sw**.

The aims of the programme were:

- To provide undergraduates with an opportunity to engage in research activity linked to principles of mathematics and statistics support in HEIs;
- To develop effective, working collaborations between colleagues in **sigma-sw** initiated by the work carried out by students during the summer internship and leading to a research portfolio within **sigma-sw**.

## Structure

Despite initial concerns about the administrative complexities of running an internship programme across 4 HEI, the process ran smoothly. Funding was obtained from the Mathematics Curriculum Innovation strand of the HE STEM programme, from **sigma-sw** funded through the mathematics support strand of the HE STEM programme and with contributions from individual institutions (Plymouth & Bath). Student stipends were agreed within each institution, each worth approximately £2000; travel and conference fees were also covered by the funding.

Each institution took charge of its own project design and student recruitment during Spring 2011 resulting in the following 4 project teams:

- Measuring the effectiveness of mathematics support services; Matthew Taylor, Cardiff University with supervisors Jonathan Gillard & Rob Wilson
- Creating a community of practice for Maths and stats support staff and an online resource for students; Oliver Bond, University of Exeter with supervisor Barrie Cooper
- What do drop-in usage statistics tell us?; Callum Anderson, Plymouth University with supervisor Dave Graham
- Helping students learn how to learn mathematics at university; Andrew Kennedy, University of Bath with supervisors Jane White & Emma Cliffe

Whilst individual students were based in designated HEIs with specified supervisors and projects relevant to their HEI, they were expected to liaise with students in the other HEIs, to test materials and to provide data etc. To facilitate this, we arranged a meeting in Bath around 3 weeks into the internship programmes; at this meeting, each student gave a 10 minute presentation about their project highlighting what they wanted to achieve, the methodology they intended to employ and aspects in which they would seek collaboration with fellow interns. The students created a facebook group following this meeting and used it for the remainder of the summer as their main communication tool. They arranged two further meetings, one in Exeter and one in Plymouth, to discuss their projects using the internship as an opportunity to visit other HEIs. These meetings were also used to format the CETL-MSOR plenary lecture. Each internship resulted in an output of some form; each will be trialled in **sigma-sw** during the coming academic year. In addition, the students were required to write a short reflective piece about their internships – these can be read below.

## Reflections

To reflect on the programme, we first look back to its aims and determine the extent to which they were achieved. The first aim 'To provide undergraduates with an opportunity to engage in research activity linked to principles of mathematics and statistics support in HEIs; was certainly achieved to a good degree. Each student spent time researching the background to, and contextualising, their project. Each project involved the development of a resource and/or analysis of mathematics support data; this process was enhanced using the hub structure to receive and respond to constructive criticism from academics and the intern peers.

Finally, the interns delivered a plenary lecture at the 2011 CETL-MSOR conference, after which Duncan Lawson, Director of **sigma** and MSOR Network, commented:

"In the introduction to the CETL-MSOR conference, the NSS results were discussed and a break-down of the results by subject was present. These showed that mathematical sciences came bottom in response to the statement "My course has helped me present myself with confidence". The presentations given by the **sigma-sw** interns stood in stark contrast to this statement - they were of the highest quality. The interns had achieved a considerable amount in a short space of time, gave clear accounts of their work backed up by good visual materials reporting good co-operation between the interns. This activity was clearly a huge success..."

The second aim was 'To develop effective, working collaborations between colleagues in sigma-sw initiated by the work carried out by students during the summer internship and leading to a research portfolio within **sigma-sw**'. This long term aim has certainly been facilitated by the summer intern programme. It is now our responsibility to move forward first by trialling materials developed by the interns across the region; then by using this as a platform to create further collaborative research projects.

Reflective comments from our student interns provide us with useful ideas to enhance the programme. Most notably, we acknowledge that a preliminary meeting, prior to the start of all projects, would be hugely beneficial to initiate and subsequently facilitate research support by the student community. The other issue that we should consider is placing more than one student in any participating HEI whilst maintaining a minimum of 4 participating HEIs.

Reflection on individual projects also provides insight into the intern programme.

### Measuring the effectiveness of mathematics support services

#### Jonathan Gillard & Rob Wilson, Cardiff University

Since 2006-07, Mathematics Support has been available to all students of Cardiff University. Such support is now commonplace across H.E. Institutions. However, providing concrete evidence to show its effectiveness continues to be very difficult. In Cardiff, the quantitative data that has been gathered has been extremely positive, indicating that students very much appreciate the support for mathematics that is available. Further qualitative data has also been recorded although (until recently) this data has not been related to individual students and therefore it has been impossible to do even a simple comparison, for example, of attendance at maths support sessions with end of module grades.

We used the internship programme to offer the student a research project which would allow them to develop their statistical skills whilst carrying out exploratory analyses on our support usage data. What emerged from the project was a simulation model, parameterised using data predominantly from Cardiff, that we hope to develop into a functional and informative tool for evaluating the effectiveness of mathematics support services.

#### Creating a community of practice for Maths and Stats support staff and an online resource for students

#### **Barrie Cooper, University of Exeter**

This project began with a rather ambitious brief to build an online resource for students to help each other with maths and stats support and for staff to share best practice. It quickly became clear, however, that incorporating both aspects into a single site would be likely to dilute the effectiveness of each, so we concentrated primarily on building the online resources for students.

Our aim was not to replicate the existing panorama of online resources for maths and stats, but to validate them through student review and build a framework for a sustainable student support community. The new site (http://labspace.open.ac.uk/course/view.php?id=7405) will become the online hub for our maths and stats support at Exeter and through regular student and staff use, should evolve into a valuable and effective site that is freely accessible to all.

Summer internships in **sigma-sw** – Barrie Cooper, Jonathan Gillard, Dave Graham, Jane White and Rob Wilson

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The student intern programme has given us the opportunity to develop something that is likely to have otherwise evolved in a piecemeal fashion, and, most crucially, to make it openly accessible to the international community instead of developing it within a closed community institutional VLE. Having regular contact and feedback with interns from other HEIs has ensured that the final output is of value to the wider student community and not only students at the University of Exeter.

## What do drop-in usage statistics tell us?

#### **Dave Graham, Plymouth University**

Since September 2002, SUM:UP (Support for Undergraduate Mathematics at the University of Plymouth) has provided diagnostic tests, support materials and one-to-one help to thousands of students across most Faculties in the University of Plymouth. Such support is now commonplace across UK universities. Students always appreciate the help given and feedback for maths support centres is overwhelmingly positive. However, each university has a different model for this support and the extent to which usage patterns vary between institutions has not really been investigated in detail.

One aim of our project was to analyse usage statistics and feedback, including identification of the main areas of demand and patterns of behaviour in students (e.g. incidences of return visits; do students have favourite tutors?; time spent, etc). This analysis has been immensely valuable for the SUM:UP service. An equally important aim has been to compare such statistics for different institutions to identify common or distinctive features. This has highlighted several issues in performing such comparisons across different models of provision and using varied means of recording participation.

## Helping students learn how to learn mathematics at university

## Jane White & Emma Cliffe, University of Bath

It is fairly uncommon for students entering a mathematics degree programme to consider, in any great depth, how they learn effectively. By contrast, experience of teaching in HE suggests that developing a range of approaches to tackle unfamiliar problems can help students maintain interest and enthusiasm for mathematics at a higher level.

The opportunity to use a summer intern position to initiate this work has been invaluable to us. We are increasingly keen to get students thinking about their learning, to find ways for them to develop independent study skills which are effective in the long-term, not just at examination time. The online resource developed during the internship will form one component of study skills sessions that will be offered in the mathematics support centre in Bath in 2011/12.

## The future

We were fortunate to be able to pilot the intern programme using funds derived from the HE STEM programme; our subsequent misfortune is that funding will not be available through this route for much longer. However, the success of our pilot strengthens the resolve to continue to develop the intern programme to create a community of students involved in the development of mathematics and statistics support nationally, to provide opportunities for students to engage in research into mathematics and statistics support in HEI and to develop and strengthen research collaborations in mathematics and statistics support within and between regional hubs.

To achieve this, we must ensure that an initial meeting of the student interns takes place before any research activity is undertaken. This could be made possible by hosting a student conference to expose undergraduates to a range of concepts and research questions in mathematics and statistics support. Following on from this, students could be asked to formulate a research project to undertake during the early summer, using a combination of local and distance supervision (depending on the project), reporting back at a 1 day meeting. Such undergraduate research conferences are commonplace in the USA; the hub structure put in place by **sigma** facilitates implementation on this side of the pond.

## Student reflection on their summer internship

### Using Simul8 to Simulate a Mathematics Support Centre

### Matthew Taylor, Cardiff University

This past summer I spent 8 weeks working with the Cardiff University School of Mathematics undertaking a research project measuring the efficiency of Mathematics Support Centres. This was achieved by using a computer simulation to model a Mathematics Support Centre and observe various performance parameters such as: 'time spent in the centre', 'average queuing time' and 'the number of students who successfully exit the system having received a desired amount of support'. A subsidiary aim of the project was to produce a user-friendly online resource, which could be used by tutors involved in the running of a Maths Support Centre or interested in setting up such a service. The idea being that a tutor could access various simulation models, input any data or predicted data they may have relating to student arrival rates, number of tutors available and mean consultation times. The tutor would then be presented with an accurate estimation of how efficiently a particular model would suit their needs.

My first few days working on the project largely involved studying existing research into this area. I found that the majority of previous studies into the effectiveness of Mathematics Support Centres were student-centric, focussing on what impact the centre had on a student's learning and confidence. This project aimed to shift the focus of study towards the centre and how it operates, working under the rationale that a highly effective centre must also be highly efficient. As such, learning impact was not directly taken into consideration.

The software package chosen for this project, Simul8, processes systems using discrete simulation, making it a useful tool for modelling real-life systems. It possesses many advantages for this kind of research, providing hard output data to back up any conclusions and also allowing for real-life limiting factors such as failure rates and capacities.

The experiment itself was conducted in three stages. Firstly the conceptual model had to be constructed, making sure that the underlying algorithm captured the fundamental features of a Mathematics Support Centre. It was then important to scrutinize the validity of the model, in order to determine if the simulation was an accurate representation of the real-life system. Finally the output data collected over a suitably large number of trials could be analysed and its significance with regards to efficiency assessed.

The majority of trials were based upon the model used by Cardiff University, as accurate and appropriate data was readily available to me over the summer. One interesting result showed that increasing the number of tutors to 3 or 4, whilst producing expected results such as lower queuing times, actually increased the maximum time spent in the system on average. This may be due to students who wish to consult 3 or more times with a tutor being able to receive an extra consultation and then leave the system successfully within the set time limit.

Another interesting result from the simulations was the benefit of providing separate support in statistics or in other problem areas. However this result was obtained using purely hypothetical input data and so holds no real validity but I feel it would be an interesting area to explore further, if accurate data could be collected.

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Finally, the research demonstrated the benefits of separate rooms to deal with problems such as flooding, whereby a large group of students turn up together, perhaps the day before an assessed homework is due, all with the same problem. As many batch students will have the same questions, it was also found that it was possible to encourage discussion and promote independent learning with minimal, negative effect on the efficiency, through the imposition of a minimum queuing time.

The simulation models have been made available via the YouSimul8 website. The website does not require any simulation software to be installed and so can be accessed by anyone with an up-to-date web browser.

The project provided some very valuable insight into the efficiency of Mathematics Support Centres but in order to further the research it is vital that more rigorous data is collected and recorded universally among other universities. Essential to running a simulation of this kind is information on length of visit, what topic the student wishes to receive support with, the number of times a student consults with the tutor and the length of each consultation.

More dialogue between universities will also allow for more accurate models to be developed of existing Mathematics Support Centres at other Higher Education Institutions.

I thoroughly enjoyed my work on the project as it allowed me to experience what mathematical research is like on a day-to-day basis. It allowed me to explore a practical application of my mathematical knowledge and to network with other students on the same course across the United Kingdom. I feel my confidence in my ability to work independently and trust my own instincts and judgements has also benefited greatly from participating in this research project. As an added bonus, I found the CETL-MSOR conference a great insight into how the teaching of Mathematics at undergraduate level can move forward.

### Creating a community of practice for Maths and stats support staff and an online resource for students

## **Ollie Bond, University of Exeter**

My project work involved investigating the online presence of mathematics and statistics support. A very common problem encountered by a lot of mathematics students is that a lot of online mathematics resources are not pitched at the right level for them, and the good resources are somewhat scattered across the Internet and not all in one place. My project aimed to help eradicate this problem, and I expressed interest in it as I have experience of providing online resources for other students on my course.

In order to get the project started, I had several meetings with Dr Barrie Cooper (my supervisor) regarding the steps to take with the project and to review my progress. We both shared ideas on how to contribute to the main page and what sorts of tasks should be carried out. We also communicated with each other through email, and a blog was set up for me to update my progress, which can be accessed at http://blogs.exeter.ac.uk/sigma/. Barrie registered for an area on the Open University's LabSpace (http://labspace.open.ac.uk) on which all the content would be delivered. I was given administrative rights to this area and this meant that I was free to experiment with different VLE (Virtual Learning Environment) components.

Finding the online resources involved looking at syllabi for the first year Exeter mathematics course and exhaustively finding resources in order to cover them. Some entries span more than one topic, and some of them come from the same resource website (e.g. Math Centre, or Wolfram MathWorld). There was a lot of searching Google and YouTube involved with this part of the project, and my objective was to look through the entries that came up and to selectively choose resources which I felt were of at least quite good quality.

Outputs: Firstly, the main page can be accessed at http://tinyurl.com/sigmaproject. This contains numerous links and graphics. One main aspect of the project was collating a lot of online resources spanning a typical first year course, including topics such as complex numbers, linear algebra, calculus, probability and an introduction to statistics. I collected over 200 resources in the end, although I had to look through many more than that in order

to determine which resources were suitable for students. These were then put in an online database, which includes categorised topics, a search facility, and my opinions on the navigability, effectiveness and presentation of all the resources. I gave each resource a score out of 5 for each of these criteria.

Another main output was the mathematical wiki, to which students can freely contribute after registering for free on the website. The complex numbers section has a fair number of resources, including clear LaTeX typeset derivations, a highly readable 'start-to-finish' style, and also several GeoGebra applets where students can play with the mathematics. This is yet to be fully implemented on the other pages, but contributions from other students at the University of Exeter will soon be encouraged.

Other smaller components included a survey which was sent out to a very large number of students, in order to pinpoint some excellent resources. The main recommendation from students was Wolfram Alpha. Also, a forum was added to the LabSpace area in order for students to discuss non-assessed mathematical problems.

Once more people are made aware of our LabSpace area and what it contains, contribution from students and staff can be encouraged. This will help to increase the awareness of the website, meaning that the repository of online resources can be expanded by incoming and current students and staff, and the discussion and overall interactivity on the website can be made much more hands-on.

I benefited a lot from this project and am very glad I participated. I gained some more ideas about what working from home involves and academic research, whilst my teamwork and organisational skills were enhanced. As a group we were able to set up meetings to collaboratively get work done, and we actively shared a lot of ideas.

### What do drop-in usage statistics tell us?

#### **Callum Anderson, Plymouth University**

The project entitled 'What Do Drop-In Usage Statistics Tell Us?' was focused on examining the data collected by various institutions regarding their respective mathematical and statistical drop-in centres. It should build on the work already done at University of Limerick by Olivia Gill and John O'Donoghue [1] and of Dónal Dowling and Brien Nolan for Dublin City University [2]. The aims of the project were:

- To set-up a student network with students from the partner institutions to discuss, share and develop ideas concerning their respective projects.
- To investigate the usage of mathematics support in (a very small number of) universities, to compare and contrast the patterns at different institutions and to identify particular features that could be introduced at University of Plymouth.
- To conduct suitable exploratory statistical analyses on these data
- To present the work at a national conference.

The project began after an initial briefing meeting with my supervisor, Dr David Graham, who gave me the report cards from the University of Plymouth drop-in centre, SUM:UP (Support for Undergraduate Mathematics at the University of Plymouth). The first step of my project was to input this data into a spreadsheet which resulted in a comprehensive database of drop-in centre usage statistics. During this period of the project I attended the first meeting of the students and supervisors participating in this **sigma-sw** scheme where I presented the title of my project and the progress that I had made so far; compiling the data from the 2010/11 academic year along with some basic summary statistics. Feedback on my work was positive and encouraging and included some ideas of where to look next and aspects of drop-in centres that other institutions would find interesting to investigate and to compare with data that they had. Also at this initial meeting I asked if the other institutions would consent to

sharing some of their drop-in centre data to further the project. The universities from Bath, Cardiff and the West of England consented to my request and supplied me with data via email over the next few weeks.

Initially I compiled and investigated the data from Plymouth for three academic years (2008/09, 2009/10 and 2010/11). The next step was to start looking in greater detail at both the Plymouth data and that which was sent to me from the other universities and to compare the findings. This process was helped by two further meetings with the other students participating in the **sigma-sw** internship scheme in which we shared further feedback and critiquing.

Two of the most interesting findings were concerning repeat visits and the correlation between coursework deadlines and drop-in centre attendance.

Fig 1 illustrates the details of the number of repeat visitors from each of the four institutions and the number of visits each visiting student makes on average. It is worth noting that at Plymouth roughly, the top 100 users account for around 50% of the visits, hence 10% of the students who use the service account for 50% of the visits.

Fig 2 demonstrates the correlation between coursework deadlines and SUM:UP attendance figures during Autumn 2010. Please note that there is a disclaimer in the SUM:UP centre stating that it should not be used for coursework questions directly, but questions may be indirectly asked; so tutors are not answering students coursework questions.

Finally after fully exploring the data from the University of Plymouth and comparing this with the data from three other universities the findings were written into a report and presented at the CETL-MSOR Conference 2011.

Autumn 2008 - Summer 2011		Autumn 2009 - Summer 2010	
Plymouth		Cardiff	
3600	Visits	2215	Visits
1126	Different Students	490	Different Students
3.20	Visits per student on average	4.52	Visits per student on average
Bath		UWE	
2624	Visits	309	Visits
580	Different Students	173	Different Students
4.52	Visits per student on average	1.79	Visits per student on average



Fig 1 – Details about the number of repeat visits from the four institutions

Fig 2 – Graph of the number of visits from a particularly popular module and when the coursework was set for this module, denoted by circles

Summer internships in **sigma-sw** – Barrie Cooper, Jonathan Gillard, Dave Graham, Jane White and Rob Wilson I feel there are a few key areas in which this project can be moved forward and further investigated. First and foremost there should be common criteria collected by all universities about their particular drop-in centre, this would allow for a much more complete and in-depth comparison between institutions to be accomplished since one of the main areas in difficulty in this project was comparing the data from multiple universities. Secondly, it would be worth investigating what type of student uses the drop-in centres; is it the high achievers looking to ascertain the maximum possible grade or is it struggling students trying to understand and retain subject knowledge? Thirdly, a more extensive exploration into the effect of drop-in centres on students' performance in their subject. Finally, a student survey (potentially nationwide by any universities who wish to participate) on how effective they feel drop-in centres are.

I have thoroughly enjoyed working on this project and feel that I have gained a great deal out of it. It has been a first and brief introduction into academic research and into working within a network of institutes. It has also increased my abilities to work independently and as part of a team, provide feedback on others work, write reports and meet self-set deadlines. Overall it has been a very valuable experience and I would strongly advise students to take a similar opportunity if it is presented to them.

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#### Helping students learn how to learn mathematics

#### Andrew Kennedy, University of Bath.

There has been much research into learning styles ([1] - [3]) and a number of websites have translated this into advice for students on how to learn ([4], [5]). There are also many other websites offering study advice to students, but few designed to help students think about how they should learn mathematics. The aim of this project was therefore to use learning styles to encourage students to think about how they learn, and to provide practical advice and examples of how they can incorporate new and varied techniques into their individual learning.

The project uses two types of learning styles, learning modes and thinking styles, to help students understand how they approach learning. Each has its own section in a microsite, accessed from the Bath MASH webpage, with a description of each learner category in the section, an online test to encourage students to think about how they prefer to learn in various scenarios and an advice section giving suggestions of how students can use this information to improve their learning.

The learning modes section focuses on whether students prefer information to be presented in words and formulae (reading/writing), charts and diagrams (visual), verbally in lectures or discussions with other students (auditory) or whether they like a hands-on approach with practical examples and, where possible, physical models (kinaesthetic). The test for this section was written for this resource based on various other public domain and free to adapt tests, with an emphasis on putting students into different scenarios where they are forced to choose between two or more ways of receiving or presenting information. This encourages students to think about how they like information to be presented in a variety of scenarios rather than focusing only on the last time they remember learning something. Students are given advice and examples of how to use each of the learning modes for both learning new mathematical concepts and approaching the problem sheets provided by lecturers.

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The thinking styles section uses the four pairs of thinking styles proposed by Felder and Silverman [6], and uses the test available from Felder and Soloman [7]. The advice given in this section is structured to give students ways to use their prevalent method of thinking to their advantage, and to provide ideas on how to avoid pitfalls written in such a way as to try to appeal to their way of thinking. The advice is based mainly on a document written by the authors of the test, though it has been restructured and rewritten to focus on learning mathematics rather than engineering. The advice for the visual/non-visual category also uses some ideas taken from research by Alcock and Simpson ([8], [9]).

The microsite (http://www.bath.ac.uk/study/mash/learnmaths) is designed to be pleasant and easy for students to read and navigate. Test results are presented in both graphics and text and advice is split into small chunks with clear headings. Advice can be accessed with or without taking the test in the relevant section. For students who want to find out more about the research into learning styles or to look at other tests and advice available online, a further reading section is included.

[Other universities wishing to use the Felder-Soloman Index of Learning Styles will need to request permission through the automated system at http://www4.ncsu.edu/unity/lockers/users/f/felder/public/ILSdir/ILS-certification.html]

The first aim in the future is to expand the range of examples available on the microsite. Currently the examples given all relate to convergence of sequences. While mathematics students at Bath meet this topic in the first couple of weeks, adding examples from other subjects will allow students from other disciplines to make better use of the site. The other aim is to capture data from the website on the answers given in the tests. Particularly for the learning modes questionnaire it will be important to see which questions are good indicators of preferred learning mode and which will need to be refined to make the test less biased.

I have really enjoyed being involved in this project. Not only have I found out more about how I learn, but I have had a chance to develop my skills in a way which will hopefully aid other students in their learning. Throughout the project the staff and students from the four universities have provided valuable input which has helped shape the structure of the final site. Special thanks are due to my supervisor, Dr Jane White, and to Dr Emma Cliffe of the University of Bath, whose support and advice made the project possible.

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# **Students as Partners in Mathematics Course Design**

# **Francis Duah and Tony Croft**

Mathematics Education Centre, Loughborough University

In the 2010-2011 academic year, the Department of Mathematical Sciences at Loughborough University secured HE-STEM funding to redesign two of its historically problematic modules, Vector Spaces and Complex Variables. The aim of the project was to enhance the second year undergraduate mathematics experience, and increase student engagement and satisfaction with mathematics so that students leave the second year reporting increased satisfaction with their learning experience. The project was a collaboration between staff and second-year students and a unique feature was the active participation of four second-year undergraduate mathematicians in the course design process. The four students were recruited as interns to produce teaching and learning resources that could potentially engage future cohorts of second year students. An ethnographic study was designed to understand the students' role, experiences, working relationship with staff, and the resources that they were able to produce. Data on the students' experiences were collected via diaries kept by the students, self-reflection and evaluation reports produced by the students, participant observation, and fieldnotes. Staff were also interviewed individually in order to collect data to triangulate the students' accounts so as to increase the validity and reliability of the findings. In this paper we report on the data collected from the students. Findings from the study showed that the four students were socialised and drawn from the margins of 'legitimate peripheral participation' in academic practice into full participation of a community of practising mathematicians. The four student interns were able to play an important role as mathematics course designers, and gained a deeper understanding of the mathematics they worked on.

## 1. Introduction

## 1.1. Study Background

The Student Experiences of Undergraduate Mathematics [1] study conducted in the UK has shown that beyond the school-university transition year, some students become disengaged and disillusioned with their studies because of poor performance. For some of these students, the difficulties they experience with their studies may be attributed to the on-or-off campus activities that they engage in such as employment, which may leave them with little time to devote to their studies. For others, their lack of success and progression may be attributed to the very nature of undergraduate mathematics which is different from school mathematics, where solutions to mathematics problems are often routine and predictable. Aspects of the design and the delivery of an undergraduate mathematics course could also impact on student engagement with their study of the course and hence on performance. In this paper, the term 'course' is used to describe a course unit that lasts a whole academic year or a module that lasts for one semester. Whatever the attribution of students' underperformance, students will become dissatisfied with their study of mathematics if they persistently underachieve and consequently this may lead to student attrition. Enhancing the student learning experience and increasing student engagement are now hot topics in higher education discourse, as they are believed to improve performance.

In recent years, there have been calls to the higher education community to involve students in the planning and design of courses [2-3]. For example, the 1994 Group of Universities in the UK noted in its policy report entitled

'Enhancing the Student Experience' that member institutions should involve students in the planning and design of courses because students "know how they want to be taught and have ideas about how teaching techniques could be improved." [3 p.12].

## 1.2. Research Questions.

In the 2010-2011 academic year, in an effort to enhance the second year mathematics experience so that student engagement and achievement can be increased in two historically problematic second year mathematics courses, the Department of Mathematical Sciences, Loughborough University, UK, embarked on a curriculum development project funded by the Higher Education Science, Technology, Engineering and Mathematics (HE-STEM) Programme. The two courses were *Vector Spaces and Complex Variables*. A unique feature of the curriculum development project now called SYMBoL (http:/sym.lboro.ac.uk), is the recruitment of four undergraduate mathematicians as paid summer interns to collaborate with staff to redesign the two courses by producing engaging teaching and learning resources for students. We designed an ethnographic study to understand the experiences of staff and in particular the four undergraduate mathematicians. Among a number of research questions the study aimed to answer were:

- 1. What role are the four student interns able to play?
- 2. What resources are the four student interns able to produce?
- 3. What are the outcomes for the four student interns?

### 2. Related Research and Theoretical Framework

Between March and August 2011, the first author conducted literature searches on direct student involvement in course design and found some examples where students have been involved in the design of non-mathematical sciences courses. However, to the best of our knowledge, there is a dearth of examples where undergraduate mathematicians have been involved in the design of mathematics courses. In a literature review on student involvement in course design, Bovill, Bulley and Morss [4] found limited examples of direct student participation in the design of Geography, Education and Environmental Justice courses. In further work on evaluating these examples, Bovill, Cook-Sather, and Felten [5] note that staff and students stand to benefit from a collaborative approach to course design. Similarly, Hess [6] provides an account of his own approach to collaborative course design in a graduate law course but his account may be viewed as anecdotal. For the mathematical sciences community, empirical evidence that supports the potential benefits for staff and students in collaborative course design would be informative and increase our knowledge base on tertiary mathematics course design and delivery.

*Community of Practice* [7] was used as an analytical lens to explore the relationship and interactions between staff and the four student interns. *Community of Practice* is defined as a group of "people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an on-going basis" [7 p. 4]. For a group of people to constitute a *Community of Practice*, the group must have a joint enterprise or domain, mutual engagement or community, and shared repertoire of resources or practice. These defining characteristics, according to Wenger, McDermott and Snyder [7], foster learning and knowledge creation. We also drew on themes from the literature on student participation in course design in non-mathematical sciences disciplines [4, 5] to explore the benefits that accrued to the student interns and their relationship with staff.

## 3. Methodology

In March 2001, all second year undergraduate mathematicians who had enrolled on and studied Vector Spaces and Complex Variables were invited to apply for four positions as student interns. Eight students out of a cohort of about 100 applied for the positions. All eight students were interviewed by the staff who teach Vector Spaces and Complex Variables and an additional member of staff. Four students were successful and commenced their internship in March 2011. They worked part-time for two hours per week between March and June 2011, conducting focus groups to collect the views of their peers about the teaching and learning of Vector Spaces and Complex Variables in order to inform the course design process. During July and August 2011, the students worked fulltime as student interns for six weeks. They worked closely with staff but with considerable autonomy to design teaching and learning resources. During that period, the first author immersed himself amongst the student interns; sharing an open plan office with them, interacting with them and responding to questions they may have about the use of technology in producing resources. While the student interns worked, Monday to Friday, the first author observed their activities and their interactions with staff and each other and took fieldnotes. The student interns also kept diaries, which they wrote up daily and sent to the first author at the end of each week. At the end of their internship, the student interns also wrote a self-reflection and evaluation report on their six weeks' experience. The qualitative data collected were subjected to thematic analysis [8] using NVivo 8 to generate codes which were later categorised into themes, three of which we describe and discuss in the next section.

#### 4. Findings and Discussion

#### 4.1 Role Played by the Student Interns

In this section we use extracts from transcripts, diaries, self-reflection and evaluation reports, and fieldnotes to provide evidence in support of answers to the research questions. Extracts attributable to the four student interns are identified as P1, P2, P3, and P4. Each of these identifiers is shown on the right of the related extract.

Staff and students formed a community of practising mathematicians. They formed a community of practice because they had a *joint enterprise*; that is, to produce engaging teaching and learning resources to enhance the student learning experience. Throughout their internship, the student interns interacted with staff, discussed the mathematical content of the resources they produced, and built equal but professional relationships with staff. Thus, there was a *mutual engagement* amongst staff and the student interns. During their internship, the four student interns had a one-hour tea break each working day when they met in the office of a member of staff who provided refreshments. Through their *mutual engagement*, staff and students engaged in mathematical discourse in ways that lectures and tutorials do not make possible and developed a *shared repertoire* of resources as the following quotations from the diaries of three of the student interns show:

"Meeting up with some of the staff for tea and biscuits was a good opportunity to get to know people a bit more, and made me feel much more involved and valued as a member of the project." (P2)

"Its good to be able to comfortably talk to lecturers about interesting points in mathematics, it's also interesting to hear what they do as mathematicians and how they work together or alone." (P3)

"I feel Lecturer 1 is more approachable now." (P4)

During the one-hour afternoon tea break, not only were the students acculturated to academic practice as the above quotations indicate, but they also received feedback on the content of the resources they produced. The mathematical accuracy of the resources the four students produced was of paramount importance since one of the aims of the course redesign process was to make the resources available for use by other institutions. Hence, notwithstanding the autonomy the students had in their role as interns, they felt it was essential that the content

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of the resources they produced was reviewed by members of staff. Where such feedback was constructive it was often well received and led to revision of the resources as indicated by the following extracts from the diaries of two participants:

"Lecturer 1 has reviewed all of the materials that I have produced and provided feedback for each of them, so I now have to amend these." (P1)

#### "Got feedback which I found helpful and constructive." (P4)

From the observations and fieldnotes data, we found that the students played two essential roles during their internship; *intermediaries and competent academic apprentices*. These new terms will be discussed in a future publication in *MSOR Connections* and the full research report. However, in this paper, we suggest that the student interns played the role of *intermediaries* between staff and the second year students by soliciting the 'student voice' through focus groups and other informal communication channels. The student voice sought for was more valuable than could be provided by the traditional feedback mechanism, which is perceived to have a different purpose; quality assessment rather than quality enhancement. The richness and depth of the students' views about the teaching and learning of *Vector Spaces and Complex Variables* would not have been obtained with the traditional quantitative survey on course evaluations.

The internship provided the student interns with opportunities to work with the content of *Vector Spaces* and *Complex Variables* as *competent academic apprentices*. Again, although we have not discussed and defined this terminology in this paper, we suggest that the student interns were competent in the content of the mathematics they worked on by the virtue of having taken and passed the examinations. At the start of their internship, three of the student interns, while being competent, showed lack of understanding in some aspects of the content of the courses they were working on. Through the process of resource production and feedback, we observed the students receive informal training and advice akin to the *'apprenticeship model'* in a work place. Hence our introduction and use of the term *competent academic apprentices* to describe the role played by the student interns.

Although the student interns were enthusiastic about their role and sought and received constructive feedback regularly, our observations and fieldnotes data indicated that when feedback was perceived to be overtly critical or unrelated to mathematics, such feedback had an unexpected impact on the way the students sought feedback thereafter. For example, one intern hesitated seeking feedback on a very well produced document with a novel approach to solving a problem on Orthogonal Projections because he did not want to receive what he perceived to be critical feedback. Another participant receiving feedback on the use of good grammatical structures of the English language was not amused. For these students, it was the enjoyment of the mathematics that sustained their interest in their role and anything else seen as not mathematically related was not welcomed. This was particularly evident in week 1 when two student interns, identified as P1 and P3, felt that much of what they were doing was administrative duty and not challenging as can be seen from the following two statements made by the two student interns and recorded in the fieldnotes:

"I am getting bored with this [creating LaTex files]" (P1)

"I created LaTex files [all day] which I found boring" (P3)

#### 4.2 Resources Produced by the Student Interns

While working during the six week internship, the student interns had to liaise with the course leaders, produce teaching and learning resources, and seek feedback on the quality and mathematical accuracy of the content of the resources they produced. Samples of resources that one pair of students produced for the *Complex Variables* course are shown in Figures 1 and 2 below. The screencast videos were produced for use by second-year students independently and out-of-lecture. The videos were produced to supplement lectures but not to replace them.

Also supplementary help sheets in the form of notes or problems and solutions were also produced for either independent use or for use in Peer Assisted Learning (PAL) sessions. These sessions were scheduled for second-year undergraduate mathematicians for the first time at the Department of Mathematical Sciences at Loughborough University in order to enhance the students' learning experiences during the 2011-2012 academic year.



 $I = \int_{C_1(1)} \frac{z}{z^2 - 1} dz = 2\pi i \frac{1}{2} = \pi i.$ 

Compare this result to example 2.1 of the Cauchy integral formula handout. You will notice that this theorem is just an extension of the formula.

# 4.3. Deepening Mathematical Understanding

residue theorem.

Figure 2: Screenshot of a help sheet on the

The internship and the course redesign process provided opportunities for the student interns to gain a much deeper understanding of the course they helped to redesign. Consequently, they gained increased confidence in their abilities as demonstrated through the following quotations:

"My knowledge of Vector Spaces is also improving, as I discovered an application for a Theorem that I had not previously realized was possible." (P1)

"I found that as I was creating videos my understanding of the topics is becoming much deeper and I hope these skills will be transferable to other modules I take in the future." (P2)

"I feel [that] my knowledge of the eigenvalue equation has improved a lot. My approach to learning will be very different after this internship." (P4)

Amongst the four student interns, the student identified as P1 was often positioned by the other three as the most able student. He is believed to be on track for a first class degree in Mathematics. However from the fieldnotes, we note that until the end of the six weeks internship, he did not have secured understanding in all areas of *Vector Spaces*, the module he worked on. He was observed on three occasions using a board and a chalk to devise a solution to a problem on Orthogonal Projection using a geometric approach and then used his solution to produce a supplementary help sheet for student use. He notes in his diary that his solution to the problem on Orthogonal Projection is different from the way the lecturer had previously explained it in lectures and tutorials. The following extract from the diary of P1 is typical of how the student interns believe that the internship experience has impacted on their mathematical understanding:

"I have had to use the blackboard several times to work through a problem, so that I understand it completely and can convey my understanding through the solutions. This has helped me understand the topics within the module better though, which I believe is very helpful." (P1)

## 4.4. Staff Approach to the Course Design Process

While our focus in this paper is on how the student interns benefited from their internship experience, we mention briefly the impact of the staff-student partnership on the two lecturers who normally teach *Vector Spaces* and *Complex Variables*.

First, we note that the changing relationship between the lecturers and the student interns provided impetus for the two lecturers to become more receptive to students' suggestions for changes to how the two courses had previously been designed. Suggestions for changes to the structure of lecture notes and the provision of additional resources such as mathematics screencasts were acted upon for both *Vector Spaces* and *Complex Variables*. While the lecturer responsible for *Complex Variables* responded to students' suggestions for lecture notes to have gaps ('gappy notes') for additional writing by students during lectures, the lecturer responsible for *Vector Spaces* did not do likewise. Furthermore, the staff member responsible for *Complex Variables* slightly changed the assessment policy in response to students' feedback from focus group discussions. Previously, there was neither a coursework nor a class test component as part of the *Complex Variables* course, but a class test has been introduced for 2011/2012 academic year.

Second, as a consequence of the successful working relationship between the staff and the student interns, the two course leaders provided support to the student interns to produce learning resources for mathematics peer support sessions which have been planned for the 2011/2012 academic year. Also, in addition to their normal office hours, the two lecturers offered to provide additional office hours so that they could provide assistance to peer support facilitators in relation to the mathematical content they will work through during peer support sessions. We intend to report fully on the staff experiences of the summer student internship later, as we collect and analyse more data from staff through interviews.

#### 5. Conclusion

This study showed that students can make a contribution as partners in mathematics course design and that they benefit from the experience in several ways including a deeper understanding of the mathematics on which they work. The limitation of the current study, however, is that the four student interns constituted a convenience sample and hence we do not make generalization from the experiences of these four students. Nonetheless, this study appears to support the call for higher education institutions to involve students in shaping their own learning. The full findings of our study including the discussion of students as *intermediaries* and *competent academic apprentices* will be published in due course.

#### **Acknowledgements**

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# Peer assessment in an undergraduate mathematics module

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## Abstract

Peer-assessment is the marking of students' work by other students. Its use can provide significant benefits for both teachers and students. At school level in the UK, its use is well established for the mathematics subject area. Indeed, the previous government established national standards relating to its usage in the teaching and learning of mathematics in schools. However, whilst peer-assisted learning schemes are becoming relatively commonplace and well established, the usage of peer assessment in undergraduate mathematics courses in the UK has not been extensively reported. In this paper, we will report on a peer assessment scheme that has been used over a number of years on a core second-year module in undergraduate mathematics courses at Plymouth University. We will discuss efficiency and scalability (mainly from the teacher's point of view), reliability and effectiveness (from both teacher and student), and desirability and fairness (from the student's point of view). We will conclude with recommendations for others that are considering such schemes.

#### 1. Peer-assistance and peer assessment

The idea of students collaborating with other students to aid their learning is well entrenched at all levels of education, and across subject areas. In particular, peer-assisted learning schemes are becoming more commonplace and well-established in many undergraduate courses. This is the case for the mathematics subject area, for which the recent guidelines published by the Mathematics, Statistics and Operational Research (MSOR) subject centre Sinka & Kane [1] provide a comprehensive list of recent references. Such schemes do not often include elements of formal assessment.

However, peer-assessment is also well-established in all levels of education in many subject areas, and in particular in primary and secondary school education in the mathematics subject area in the UK. Indeed, the previous Labour Government published guidelines on the use of peer assessment in mathematics for secondary schools (see [2]). The guidelines made it clear that such assessment required careful thought and was "much more than children marking their own or each other's work" if it was to engage children, develop learning and help them reflect on how to improve their work. It was claimed that peer assessment could promote independent learning and help children to take increasing responsibility for their own learning.

Any system in which students are, on the face of it, doing marking that most would expect to be completed by the lecturer, must be in danger of attracting controversy. Sadler & Good [3] report the case of "The 2001 U.S. Supreme Court Case of Falvo v. Owasso School System (Owasso Independent School District No I-011 v. Falvo)". Fortunately, the US law came down on the side of the academic: "in a unanimous decision the court reaffirmed the popular view that students grading each others' tests is valuable, saving teachers' time and augmenting student learning." Sadler & Good also point out that peer assessment involves sharing some of the teacher's power with students, that some students are not always ready to wield such power and that such power should not be exercised unchecked. They showed that students were able to mark papers in reasonable agreement with scores assigned by teachers, with some caveats regarding marks at the extremes. There were also some concerns regarding confidentiality where some students would necessarily know the marks of others if they had graded the papers. Crucially, the study claimed that student-grading can benefit both teacher and student when carried out carefully.

Gibbs [4] discusses some of the advantages and disadvantages of peer assessment in general. Gibbs' conclusion is that, even if students are as capable as teachers of marking scripts, the main value in peer assessment is not in the assignation of a mark for the work, but for the process of marking and reflecting upon the quality of the work being marked. He concludes that, rather than ask students to assign marks, it would be more productive to make peer-assessed tasks a course requirement and then concentrate on the usefulness of self and peer feedback itself.

Dochy, Segers and Sluijsmans [5] discuss many aspects of peer assessment. Again, one of the main issues is related to students assigning marks to other students. In particular, they review several studies of validity, fairness and accuracy reported in the literature. They report that group-based peer assessment can be controversial due to the difficulties in identifying individual contributions to the group effort. They also report a lack of consistency in studies of the accuracy of student marking, with perhaps a tendency for students to overmark compared with the teacher. They report several studies in which there were issues relating to trusting peers to mark correctly, difficulties in marking friends' work, and guidance of students in the process, but that in many cases, students appreciated the benefits of peer-assessment.

The study of Maugesten & Lauvås [6], cited in Hag and Hästö [7], reported spectacular improvements in student performance following a peer-assessment methodology in a class of around 100 Norwegian mathematics student teachers. However, the smaller-scale study by Hag and Hästö was less positive, though this was possibly due in part to shortcomings in the guidance given to students during the process.

In the HE sphere in the UK, peer assessment has many advocates but apparently few in the Mathematics subject area. Glaister & Glaister [8] reported on a 'buddy system' conducted with first-year Calculus students in in the Mathematics Department at the University of Reading in 2002-3. They concluded that their system could be beneficial and was cost-effective. Students also appeared to appreciate the system, with a majority of the cohort considering the buddy system to be a good idea.

# 2. The Module

The peer-assessment scheme in Mathematics at Plymouth University has evolved over the years to a reasonably steady-state. Currently, it is used in a core second-year module on differential equations, led by the author. Formally, the assessment weighting of the module is 50% from a final 3-hour examination and 50% from coursework. The coursework has two main aspects (i) in-class test (20% of coursework i.e. 10% of final mark), (ii) regular coursework that contributes the remaining 80% of the coursework mark.

## 2.1 Peer assessment arrangements

At the beginning of the year, the lecturer asks the students to arrange themselves into pairs and fours, and then fits any stragglers into random pairs and foursomes. The foursomes then work as two pairs A and B. Over a designated week in term time, each pair independently completes a mathematical task which typically involves solving ODE's, plotting the results and interpreting them. The following week, pairs swap scripts and mark the work of the other pair using the lecturer's highly detailed mark scheme. The scripts are then returned to the authors and each pair is asked to complete one-page reflective summaries on their experiences. In particular they are asked to comment on (i) how well the other pair completed the mathematical task and aspects to work on for the future, as well as (ii) how well the other pair marked their work, and again suggestions for how to improve this.

## 2.2 The mark scheme.

The regular coursework is comprised of nine different tasks. Two of these are marked by the teaching team and the remaining seven are peer-assessed. For each of the seven peer-assessed tasks, students are given 1 point for having a reasonable attempt at the task (as judged by peers) and 1 point for a reasonable job at marking the work. This contributes to a final peer assessment factor (PAF) equal to (sum of the points gained) / 14. The mark from the regular coursework is then given by (average of the 2 lecturer-marked assessments)\*PAF.

Currently, the lecturer checks the marking and annotates scripts accordingly for the assessments in the first term, then in term two asks students only to hand in the summary sheets. Note that the marking philosophy is close to that recommended by Gibbs (2010)[4]: thus serious participation in the peer assessment scheme is essentially a requirement of the course and the fine detail of which marks students award each other is less important.

## 3. Results

## 3.1 Peer assessment participation and module pass rates.

A key aspect of the scheme is that students must buy into it. Table 1 below indicates participation rates over the five-year period 2006/7 to 2010/11 (where the measure of the full participation rate is taken to be percentage of students whose peer assessment factor exceeds 0.8). It can be seen that full participation rates are generally high, but there are small numbers of students who do not engage sufficiently with the peer assessment process. Predictably, this is generally to the detriment of their performance in the module.

Session	Full participation rate (PAF>0.8)	1st-time pass rate	1st-time pass rate for PAF > 0.8
2006/07	89%	69%	77%
2007/08	98%	98%	100%
2008/09	97%	91%	94%
2009/10	93%	78%	84%
2010/11	87%	76%	88%
Overall	92%	82%	88%



Table 1: Participation rates in peer assessment and module pass rates



Figure 1 shows student performance in the module overall plotted against participation rate for the academic year 2010/11. The figure shows clearly that students who do not participate fully in the peer assessment scheme

often struggle in the module as a whole (of course, this might be expected given the high coursework weighting and the fact that the PAF acts as a multiplier on the coursework element). In fact (see Table 1), it was found that, between 2006/7 and 2010/11, 88% of students whose PAF is over 80% pass the module first time. This compares well with pass rates on other second-year modules. On the other hand, within this same period, **none** of the students whose PAF was less than 80% passed the module first time.



Figure 2: Examination component versus PAF

Figure 2, also for 2010/11 clearly shows that the students who do not fully engage with peer assessment are also likely to fail the final examination, the scores in which are not directly linked to the peer assessment. This is important. It gives a strong indication that, in order to gain a good understanding of the material, students really must work regularly, confirming what every lecturer tells them at the start of their course.

### **3.2 Module Feedback**

Student feedback from the scheme has been generally encouraging, but with some negative comments over the years. Typical positive comments are that students liked

"working in a group of two people, exchanging ideas on a given task",

"liked the courseworks and the peer-marked assignments"

"the coursework is well-balanced between peer- and lecturer-assessed"

"regular homework"

Negative comments included:

"peer-assessed courseworks are unnecessary"

"courseworks ... seem to take up a lot of time... for what they are worth"

"weekly courseworks are good but they are ... a lot of work ... for the % they're worth"

#### 4. Reflection on process

Related specifically to the mathematics discipline, the main benefits of the peer-assessment aspect of the module are that students develop good study habits by (i) working regularly, (ii) reflecting on their work and (iii) sharing their thoughts with others. In addition, and probably more important to the students themselves in the short term, they can gain an appreciation of the 'rules of the game' by seeing the lecturer's mark schemes before any

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summative assessment, and developing a good idea of where marks are to be won and lost when they complete such assessments in the future.

For staff, the most obvious benefit is that all the above are accomplished within a reasonable staff workload. However, it is the author's belief that the motivation for using such peer assessment schemes should be related to the benefits for the student rather than avoiding marking for the teaching team.

There are also potential issues. Some students are wary of marking the work of others (though this is much less of an issue when each of the seven pieces of work is essentially pass/fail, and contributes to the module mark only through the PAF multiplier). Not all students value reflection and some of the comments on the summary sheets are minimal. The logistics of the groups can also be problematical, especially when students disengage or drop out completely. A minor issue is that the mark scheme described above is highly non-standard when compared to most modules and has to be explained regularly.

## 4.1 Efficiency and Scalability

Lecturer involvement in the peer assessment scheme involves the following one-off tasks

- i) Explain system (in fact this has to be done several times)
- ii) Provide mark scheme (1 per question, reusable)

From the point of view of lecturer workload, both of these tasks are compact and easily manageable.

However, several tasks scale with cohort size, including

- i) Reviewing marking (first exercises)
- ii) Checking/annotating summary sheets
- iii) Collating marks / informing students

Again, these are reasonably compact tasks (especially when compared with the case if the lecturer marked all the scripts). This means that, for given amount of staff time and effort, much more frequent feedback can be provided for students compared with standard lecturer-marked assessment schemes.

## 4.2 Reliability and Effectiveness

The peer assessment arrangements provide a peer assessment factor that acts as a multiplier for the lecturermarked work. As such, there is no direct relation between peer-marked scores and those for the module. There are two questions related to reliability (i) whether pairs mark the work of other pairs appropriately and (ii) whether each member of a pair/foursome makes a contribution. The first question can be addressed by the lecturer overseeing the marking and checking that it has been done appropriately. The second relies upon a declaration by each student that they have contributed. An alternative to avoid any doubts related to this aspect would be to work as singles within a pair, but this would mean that students lose the opportunity to discuss the work with their partner in a pair. Current arrangements are preferred by the author.

The effectiveness of the scheme is demonstrated by the results in Section 3.1.

## 4.3 Desirability and Fairness

For the benefits from the student point of view, it is useful to refer to the National Union of Students' Ten Principles of Effective Assessment, cited by Attwood [9].

- 1. Should be for learning, not simply of learning
- 2. Should be reliable, valid, fair and consistent
- 3. Should consist of effective and constructive feedback
- 4. Should be innovative and have the capacity to inspire and motivate
- 5. Should measure understanding and application, rather than technique and memory
- 6. Should be conducted throughout the course, rather than being positioned as a final event
- 7. Should develop key skills such as peer and reflective assessment
- 8. Should be central to staff development and teaching strategies, and frequently reviewed
- 9. Should be of a manageable amount for both tutors and students

Table 2: NUS Principles of Effective Assessment, 2009 (cited in [9])

The assessment scheme described above ticks many of these boxes – more than would be the case for a more standard assessment regime.

As discussed above, fairness can often be an issue in peer assessment. However, under the arrangements described above, each aspect of the assessment is essential pass/fail, which takes much pressure off the students in assigning marks. The author has found that, under this system, student complaints about unfairness are very rare and are generally easy to resolve by the lecturer. The system compares very favourably with early implementations of the scheme in which students' marking explicitly contributed to module scores.

#### **5. Conclusions**

From the above discussion, the author concludes that the presented peer assessment system has benefits for both staff and students. From the staff point of view, the peer assessment scheme develops good study habits, encourages students to work regularly at set problems and enables regular feedback to be given to students with reasonable time and effort. The scheme scales up efficiently to large module sizes. Full participation in the scheme appears to be effective in developing understanding of the module material. From the student point of view, it is a fair system that gives rapid and frequent feedback and develops useful study skills. On the other hand, it is distinctly different from most assessment schemes and thus must be carefully presented to students. The lecturer's motivation is the key: the main purpose should be to increase the student performance rather to decrease the staff workload.

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# Do short screencasts improve learning?

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## Abstract

The algebra and calculus skills necessary for the study of all mathematical sciences continue to be a problem for a significant proportion of students, even at an advanced level. It is a particular problem for part-time students whose study is spread over an extended period of time. Not all students have a learning style suited to text books and lectures. It is thought that short audio-visual screencasts of handwritten or pre-typed explanations of common mathematical techniques could be of significant benefit to a wide variety of students, particularly those studying part time.

In this article we will report on a MSOR project we have recently undertaken in which we have produced and evaluated the effectiveness of such screencasts.

### **1 Introduction**

One of the difficulties often faced by students of the mathematical sciences is that, due to the linear nature of much of the subject, many topics being introduced to students rely on them being proficient in the skills and techniques presented at a previous level. Often it is these underlying techniques that cause students problems rather than the new topics being introduced. This is particularly true of part-time students for whom there may be a significant period of time between related courses.

In this article we consider how such students might be supported by short audio-visual screencasts reviewing various background topics, concentrating particularly on some techniques from advanced calculus. We first explain what is meant by a screencast and then describe how they could be produced, including some practical tips gained from our own experience. We next consider how effective such screencasts are, as shown by an evaluation of their use, particularly by students on the Mathematics MSc programme at The Open University.

## **2 Screencasts**

Screencasts are video clips showing activity on a computer screen with a voice over discussing the content. In this context, we are particularly interested in screencasts that show a mathematical example or argument being worked through, with the voice explaining the steps as they are produced. An example is shown in Figure 1. The mathematics might be written by hand, or might be typeset. It is thought that screencasts can be particularly useful to students with a visual or auditory learning style [1]. They have advantages over printed materials in that the associated audio can explain the reasoning when moving from one written line to the next, encapsulating the verbal communication that takes place in a traditional lecture.

Screencasts are becoming a popular method of disseminating information. The Khan Academy [2] contains thousands of screencasts on basic mathematical techniques. We are particularly interested in the use of

$$\begin{aligned} \mathbf{Tay lor \ series} \\ \hline \\ \hline f(x,y) &= \sum_{x=0}^{\infty} \frac{1}{n!} \left( (x-a) \frac{\partial}{\partial x} + (y-b) \frac{\partial}{\partial y} \right)^{x} f(a,b) \\ f(x,y) &= \underbrace{f(a,b)}_{=} + \underbrace{(x-a) \frac{\partial}{\partial x^{2}} (a,b)}_{=} + (y-b) \frac{\partial}{\partial y} (a,b) \\ &+ \frac{1}{2!} \left[ (x-a)^{2} \frac{\partial^{2} f}{\partial x^{2}} (a,b) + 2(x-a)(y-b) \frac{\partial^{2} f}{\partial x \partial y} (a,b) + (y-b)^{2} \frac{\partial^{2} f}{\partial y^{2}} (a,b) \right] \\ &+ \frac{1}{3!} \left[ (x-a)^{3} \frac{\partial^{3} f}{\partial x^{3}} (a,b) + 3(x-a)^{2} (y-b) \frac{\partial^{3} f}{\partial x^{2} \partial y} (a,b) \\ &+ 3(x-a)(y-b)^{2} \frac{\partial^{3} f}{\partial x \partial y^{2}} (a,b) + (y-b)^{2} \frac{\partial^{3} f}{\partial y^{3}} (a,b) \right] + \cdots \end{aligned}$$

Figure 1: A screenshot from a screencast

screencasts at a more advanced level, and as a mechanism of providing succinct revision materials to part-time students. Examples of screencasts at this level can be found on several sites, including http://www.maths-screencasts.org.uk.

Screencast are usually produced as, for example, mp4 video files, and as such can, with appropriate software, be viewed online or downloaded, either on a computer or mobile device (for example, a smartphone or tablet.). An example screencast being viewed on a mobile device is shown in Figure 2.



Figure 2: A screencast playing on a mobile device

#### **3 Producing screencasts**

Since the screencasts produced as part of this project were aimed at the succinct revision of specific identifiable topics, we decided to minimise their length as much as possible, aiming ideally for approximately 5 minutes. Most screencasts consisted simply of one worked example. The methods used to produce screencasts are outlined in the following subsections, including some good practice tips based on our experiences.

## 3.1 Preparation

Preparation is the key to producing a useful screencast. Before attempting to record anything, one should spend time deciding on a useful example and thinking about the key points you wish to bring out. One also needs to consider whether the screencast text is going to be handwritten or completely typeset beforehand and only voiced during recording. The former can be facilitated by the use of a tablet PC and any application

that supports handwriting on a canvas, for example Windows Journal or PDF Annotator [3]. One approach is to prepare problem statements using LaTeX and then handwrite the solution. PDF Annotator is particularly useful for this. The size of screens available on mobile devices is quite small, and hence a decision has to be made on whether to present the screencast as individual pages, with the downside that items at the bottom of one page cannot be seen when moving to the next, or as one continuously scrolling page. This has the difficulty that the start of the problem soon disappears off the top. If using individual pages, it can be useful to pre-type a summary of the problem at the top of each page. Similarly, one needs to consider if any formulae will be needed during the screencast, and how these will be displayed. Care should also be taken that the aspect ratio of the pages used (hence video made) matches as closely as possibly that of the device you are expecting users to use. (Some compromise has to be made here since the screencast might be viewed on a multitude of different devices.) It is also recommended that an outline script is prepared setting out the approach to the problem (and the results of any complicated algebra!) and highlighting any key points you wish to make during the presentation.

### 3.2 Recording

When undertaking the actual recording, it is useful to find a quiet working area in which you will not be disturbed. There are a number of different software applications which can be used to produce screencasts. Jing [4] is freely available and permits the production of screencasts of less than 5 minutes. In the project discussed here, we used the commercial package Camtasia studio [5]. When recording the screencast, remember to sound enthusiastic about the problem/techniques used and vary your voice appropriately.

Further technical details of how the screencasts were produced in this project can be found at http://www.maths-screencasts.org.uk/

### 3.3 Good practice tips

When a screencast is viewed, it can be difficult to see the precise location of the on-screen cursor, so use highlighting and/or pen colour instead, as illustrated in Figure 3. As mentioned above, if more than one page is used it is helpful to put salient points in the header of each page. When recording, remember that mistakes are likely - do not worry about them. You can retake or use editing. Finally, remember to keep the screencast as short as possible.

More tips can be found at http://www.maths-screencasts.org.uk/



Figure 3: Using colour

## **4 Evaluation**

The effectiveness of the screencasts produced in aiding student learning was evaluated using both an online quiz and the examination results of participating students. A survey was also undertaken and responses analysed.

### 4.1 The Quiz sandwich

A cohort of students studying the MSc in Mathematics at The Open University was given the opportunity of doing two quizzes with two screencasts between them, as an aide to their revision for their end of module examination. The quizzes contained questions where the screencasts were relevant and where they were not. No feedback was given after the first quiz and students were only able to attempt the second quiz (and get full feedback on both quizzes) after watching the screencasts. Results showed a definite improvement in the marks of those questions which related to the casts. Further details of this evaluation can be found in Jordan et al [6].

#### 4.2 An exam question

A month or so after students had the option of watching two screencasts (in conjunction with a pilot version of the quizzes), students sat an exam where the screencasts were relevant to part of one question. A regression analysis showed that the screencasts were just about significant (p value 0.051) in the performance on this part of a question.

#### 4.3 Some questionnaire responses

Students taking the quizzes described above also responded to an evaluation questionnaire. In addition, the website where we have placed the casts asked viewers to complete a survey. We had 54 responses generated this way. In general the screencasts were well received as can be seen from the example comments below.

"I found the screen casts very useful. They demonstrated the concepts, but most usefully showed how to apply the technique, and present the calculations in an efficient and readable way. This was especially true of L'Hospital's rule."

"It is certainly a useful support resource and most students have different learning styles. This is an extremely useful alternative to the text book and probably more accessible. I am eager to view the rest of your series".

## 4.4 Handwritten or typeset?





One of the questions that we asked was about whether students preferred handwritten or typeset screencasts. Here is a sample of the responses to that question.

"I find the handwritten ones help me to think each individual component of a problem because you link the speech to the part more naturally. Whereas with the pre typed ones it's quite easy to be more passive."

"The hand-written version felt more spontaneous and comfortable (the odd slip of the pen might add to this feeling). The big downside for the handwritten one I saw was the loss of the top half of the writing area half way through. The typewritten one organised the pages better by breaking the problem into page-size calculations."

Handwritten screencasts were generally preferred although there were comments covering technical issues as in the second comment above. The project team was surprised by the reasons given. None of the comments referred to the fact that handwriting the content has a tendency to slow down the delivery.

#### **5 Conclusions**

The students who participated in the evaluation are all learning at a distance and so do not see much live mathematics. No doubt partly for this reason, the screencasts were undoubtedly popular with the students who accessed them. The quiz and, to a lesser extent the exam evaluation demonstrate that screencasts do appear to be an effective method of teaching. This project did not attempt to compare using screencasts with other approaches so we do not claim that they are better than other methods. It will be interesting to see how much future cohorts of students use the screencasts.

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# **Promoting Student Led Education**

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### Abstract

This paper will discuss the encouraging outcomes of a small scale study in which students were encouraged to actively contribute to various aspects of their education.

It will share an innovative Student Led Education Initiative that emerged by extending the author's teaching practice. First year undergraduate students were encouraged to actively contribute to various aspects of their education. The rationale behind this was to inspire students to lead the way in their education. The initial outcomes are positive which implies that these ideas may indeed be worth exploring and extending, perhaps modifying the approach to make the entire process even more efficient.

The population of university students is becoming increasingly diverse as British universities continue to host students from across the globe. The variety of cultural, socio-economic and academic backgrounds of students manifests itself through diverse expectations and requirements.

Further, the recent Higher Education White Paper may lead a new era of change with the focus on students as they become increasingly aware of the potential of university degree courses to improve their employability which is of growing concern to them, especially with the imminent rise in tuition fees. Students are becoming better informed because of the transparency in university performance information readily available through the National Student Survey.

#### Introduction

The Higher Education White Paper, "Higher Education: Students at the Heart of the System" published by the Government (June 2011) for Business, Innovation and Skills sets out proposals for the reform of Higher Education in England putting students at the centre of the proposals. These changes transform the role of the Higher Education Funding Council for England (HEFCE) into a promoter of a competitive Higher Education (HE) system.

The key points of these proposals relate to the areas below:

- 1. Sustainable and fair funding
- 2. Well-informed students driving teaching excellence
- 3. A better student experience and better-qualified graduates
- 4. A diverse and responsive sector
- 5. Improved social mobility through fairer access
- 6. A new, fit-for-purpose regulatory framework

#### **Context and Concerns**

Universities are progressively required to align their degree programmes to the requirements of the employment market, and aim at enhancing the employability of graduates.

University students are considered consumers rather than partners in their education. Universities are committed to providing prospective students with more detailed information about their degree courses and their potential to enhance employability. The National Student Survey (NSS) carried out by Ipsos MORI (independent market research agency) [2] makes relevant information about universities easily accessible to prospective students. The survey provides information about students' perceptions of their university experiences. Universities are encouraged to use this data effectively to improve student satisfaction. Further, universities are required to publish an employability statement (HEFCE, 2010 [1]) to help students make informed choices. The stakeholders in Higher Education are becoming highly aware of the relevance of the additional skills students should be gaining in addition to course-specific skills.

A student centred teaching approach (SCTA) allowing students to actively participate in education may be an effective way to respond to these new developments in HE.

#### **Main Hypothesis**

Student Led Education (SLE) will follow from an enhanced student experience and improved graduate employability, achieved by a SCTA.

The two related research questions to be considered are:

- 1. Would a SCTA enhance student learning experience and graduate employability?
- 2. Would such an approach inspire students to lead the way in their education?

The author's study will address key points 2 and 3 of the proposals of the White Paper focusing on first year undergraduate mathematics/statistics courses. Nonetheless, its principles can be applied to the wider HE context.

#### Approach

Undergraduates taking mathematics/statistics service courses generally seem to lack commitment and enthusiasm due to inadequate understanding of the relevance of these courses to their degree programmes and poor perceptions of the subjects due to pre-conceived negative notions. Further, the skills of MSOR (Maths, Stats and Operational Research) graduates (QAA, 2007) [4] must be considered while designing and delivering these courses.

A positive influence can be created on students' perceptions of mathematics and statistics courses by changing various aspects of the course delivery. The rationale behind this is that it may help achieve the two desired objectives:

- 1. Enhancing their learning experience
- 2. Promoting SLE

A SCTA may increase student interaction and create opportunities for active contribution, engagement and involvement. This could enhance graduate employability, inspire students to actively engage with their education and promote a sense of belonging to their respective universities. Further, given the opportunity, students may feel better motivated to lead the way.

First year under-graduates (FYUG) in this SCTA are invited to provide input into their education. SLE may emerge from this approach as a result of the enhanced student involvement/experience in education.

#### **Encouraging Student Led Education**

Classes provide an ideal setting to promote students' contribution and participation because they allow flexibility in terms of making sessions student-centred, with the only constraints being syllabi requirements and the duration of classes.

The author had 12 class groups during the academic year 2010-2011 with 172 students altogether. Each class had 13-18 students on a variety of degree programs. These were Actuarial Science, Econometrics and Mathematical Economics, Economics and Economic History, Government and Economics, Accounting and Finance, Management, Philosophy and Economics, Environmental Policy with Economics, Management Sciences, Geography with Economics, Human Resource Management and Employment Relations, Mathematics and Economics, Business Mathematics and Statistics and Social Policy and Economics.

These hour long weekly classes are generally used to provide feedback on weekly coursework exercises. This was the approach initially used by the author who observed a few points that seemed to obstruct student engagement and needed some action. Hence, the author developed her own teaching approach to effectively address the variety of learning requirements resulting from the diversity in students' academic/cultural backgrounds, enhance student engagement, promote interaction and improve the social climate in teaching rooms. This SCTA involves a range of elements such as feedback on weekly coursework followed by group work questions that students are asked to solve in a workshop setting under the author's guidance. The author describes its successful application in her previous paper (Kotecha, M 2011 [3]), reporting how this approach not only fulfilled her initial expectations but far surpassed them making a positive contribution to academic self-efficacy and kindling interest in mathematics/statistics.

This SCTA was used for all 12 classes. In this approach, students are invited to contribute to the designing of classes in order to help develop a format that addresses their diverse learning requirements. This is done by providing information about the class format and the rationale behind it at the outset. They are advised on what is expected of them in terms of preparation for the classes and the extent of student participation required. This is necessary because several students may not be used to the idea of a student centred approach due to their multi-cultural backgrounds and the variety in their learning experiences.

Further, students are given the opportunity to provide feedback on the classes during the initial period of the first term. The significance of students' feedback is clearly communicated to them. Students are invited three times during the academic year to participate and contribute to the process in various ways. They are asked to comment on the aspects of teaching they find beneficial and those they consider to be obstructing their engagement with classes. They are also encouraged to share their anxieties/queries on issues of concern anytime during the academic year. This is to prevent such issues from impeding learning.

The class format is appropriately amended and aligned, in accordance with students' suggestions and learning requirements. This demonstrates to them that their feedback is taken seriously which promotes constructive two-way communication and a greater sense of belonging in students.

They are motivated to play an active role in the process of feedback on formative assessments by making feedback interactive. This is done by providing them with a feedback sheet before the first class. They are asked to attach it to each weekly assignment and write comments/concerns relating to that particular assignment in the 'student's comments' section. Classes are designed carefully taking students' comments on the attached feedback sheets into account. This helps align the classes to students' individual learning requirements/queries and promote enthusiasm and motivation to engage in classes with full commitment. Common problem areas and errors are
highlighted in classes thus advising students to review and annotate their marked scripts, to help improve their future work (Kotecha M, 2011 [3]). This helps them develop evaluative skills, encourages them to review their work critically and plays an important role in encouraging students to take ownership of their learning.

Classes commence with a short question followed by feedback/recap and finally group work questions for students to attempt in a workshop setting with the teacher circulating and helping them with their queries. The group work questions are set to intellectually stretch them, promote dialogue and help them develop employability skills (Kotecha M, 2011 [3]). This format improves the social climate of classes, enhances students' perceptions of the courses and increases student engagement.

Students enthusiastically participate in the process of providing feedback on classes and appreciate being asked to provide comments. Further, their unprompted qualitative feedback on the discussed approach reflects enhanced students' satisfaction and engagement, which leads to a transformation of their attitudes from lack of engagement to demonstration of a keen interest in the courses and enhanced commitment to engaging with the learning process.

The discussed SCTA contributes to creating a positive impact on students' attitudes towards the course. Students show a strong sense of commitment, obligation, responsibility and keenness to improve their performance standard/grades of formative assignments, as reflected in their work. The outcome is greater engagement and an outstanding display of interest in the course. They become motivated to optimise the author's guidance/ resources and office hours in order to be well prepared for the summative assessment.

Some comments are shown below to illustrate how much students appreciated being asked to provide feedback on classes.

"I currently enjoy your class very much... I will "vote" for continuing the current class format. Thanks very much for asking."

"...thanks for letting us give our opinions and for being so open about it - I really appreciate it. Let me know if you want to know anything else"

"I am really enjoying your classes I particularly enjoy the new questions we are given as they help me realise what I need to work on and what I understand."

Further SCTA promoted a sense of obligation to optimise the guidance and resources as shown in some comments below.

"...I thought I owed you some sort of "progress report"..."

"I would certainly make the most out of the extra resources..."

"...I just wanted to say a big 'thank you' for everything this year. I don't think I could possibly have been in better hands!"

#### Methodology

The author aiming to extend her existing SCTA, sent a message to all 172 students from her classes after the completion of their mathematics and statistics courses, asking if they would like to spare a few minutes talking to the new FYUG at the start of the following academic year, given that they benefited from the authors' classes. Further, it was explained that they were considered to be ideal candidates to advise the FYUG because they have had first-hand experience of her classes. It was proposed that they could make a positive contribution to the mathematics/statistics course experience of the FYUG by suggesting ways to make the most of the classes.

#### **Initial Outcome**

The initial outcome was promising and encouraging. 78 % of students replied and expressed a willingness to contribute. Further, a dialogue emerged highlighting the aspects of class teaching that they appreciated, which was an unintended outcome that could become a useful source for reference while designing future classes.

Some replies are included here and will be referred to in the discussion section.

#### Student A

"Indeed I benefited a lot from your interesting and engaging statistics classes over the academic year. I could tell that you took much effort in creating application questions that could help us understand the concepts well. You prepared us adequately for the exam, which was relatively simple. I do hope I score well in the exam, so that I can do you proud.

Regarding your suggestion, I think it's a good idea and wouldn't mind helping out to advise your students next year, provided the schedules do not clash. I think it will benefit them when they hear advice from a 2nd year student on the...course in general, providing them insight into possible strategies to approach the course."

#### Student B

"I'd be more than delighted to speak to the new students as I'm sure it will benefit them to know how best to make use of their time as well as your lesson time.

Oh, also thank you for your guidance for the past year; it has been pleasure learning from you. I speak for the whole class here when I say your lessons are really engaging and helpful to all of us, and we thank you from our hearts."

#### Student C

"With regards to your suggestion, I think that this is a very good idea and would be happy to help, as I certainly feel that I would have benefited from this, even just a few comforting words.

I think that sometimes students are more receptive to advice given from their peers, particularly concerning exams, as older students have been through the learning process so to speak...as first year exams can be a bit daunting..."

#### Issues

The main issue was the time table clash which made it difficult for several second year student volunteers who were keen to contribute. Further, it was time consuming to reply to the students' enthusiastic messages which also required developing selection criteria as only one volunteer was required for each class. Coordinating the ex-students' visits to classes required much organisation.

#### **Success**

The student volunteers came in at the beginning of the classes and gave a brief talk advising students to appreciate the extra support they receive in classes. They also made advisory comments on how to make the most of the class work questions and group work. FYUG students listened with interest and shared their queries and concerns relating to the course, which were addressed by the student volunteers. These 5-7 minutes spent on the entire process created a positive impact on the engagement of FYUG and on their attitudes towards the classes as well as the courses generally.

#### Discussion

The SCTA enhanced the student experience which kindled their enthusiasm to create a positive impact on FYUG students which could be a step towards SLE. The quotes from students A, B and C indicate how SCTA promoted a sense of responsibility, gratitude and commitment. The enhanced learning experience of students inspired them to contribute to the future of FYUG students and begin to lead the way. Further, it enhanced the student volunteers' presentation skills and helped them develop the ability to influence others. The student volunteers invested much effort into their talks to the FYUG. The author advised them to share their class experiences in their own words commenting on how they optimised the class time. This was to encourage them to use their own initiatives which turned out to be a risk worth taking because of the spontaneity, enthusiasm and genuineness that came through in their talks. They displayed self-discipline in arriving on time, remaining focused during their talk and addressing questions by the FYUG. This may help enhance graduate employability.

Further, this appeared to put the FYUG at ease. They were able to share their concerns about the course with their peers with greater ease because they could easily relate to them. The student volunteers' enthusiasm was transmitted to FYUG students as reflected in their enhanced engagement, greater commitment and interest in the course.

#### Conclusion

The suggested SCTA may be a way forward for SLE which may follow from students' enhanced university experience, which may contribute positively to enhancing graduate employability.

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# Mentoring students can lead to increased engagement and success with mathematics

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#### Abstract

In September 2009, the author commenced a research project with colleagues to investigate the reasons why students do or do not engage with mathematics. The initial stages of this project involved contacting and meeting students who were repeating at least one of their first year mathematics modules. The author decided to offer the students an opportunity to participate in a mentoring scheme. This paper will describe the scheme, the mathematical background of the students and focus on their engagement levels, their behaviour and feedback. We look at the students' reactions when they were asked to bring in their attempted work. We also present evidence that suggests a positive impact on student progression, and we will briefly present the outcomes of the project in terms of how it impacted on further initiatives and interventions run by our department.

#### 1. Introduction

Increasing numbers of students who struggle with basic mathematical skills are entering third level education [1-2]. One response has been the establishment of a range of mathematical learning support initiatives to help students to adjust to third level mathematics [3-4]. Several studies have been carried out to measure the effectiveness of these initiatives [5-7].

A common feature in much of this research is the observation that a significant minority of at-risk students, those most in need of the support, are not availing themselves of the support available. This had led to a number of recent studies to investigate the reasons behind this lack of engagement [8].

At the National University of Ireland Maynooth (NUIM) we started a research project in September 2009 to identify the reasons why students do or do not engage with mathematics. We contacted 39 students who were repeating at least one module of mathematics and asked them to participate in this project. The author decided to offer a mentoring service to these students to help them overcome their difficulties.

In this paper we will describe the mentoring process. In particular we report on the mathematical backgrounds of the students involved (mentees), how they participated with the project and report on any changes in their behaviour and their engagement levels. We will compare them to students who did not avail themselves of the mentoring process and we will also briefly present anonymous feedback from the mentees. Finally, we will discuss how the results of this project have helped to guide the Mathematics Support Centre (MSC) and the Department of Mathematics and Statistics in the establishment of additional initiatives to target these students.

## 2. Methodology (The mentoring process)

The author rang and emailed 39 students in October 2009 to inform them about the research project and ask if they wanted to be involved. At this stage students were made aware of the availability of the mentoring process and were invited to arrange a meeting with the author to discuss the research project and the potential mentoring scheme. Eighteen students responded and 14 agreed to participate in the mentoring scheme. Two of these students subsequently did not avail themselves of the scheme.

The author and the mentees agreed to meet once every fortnight for 20-30 minutes; all meetings were on a one-to-one basis in the author's office. The meetings involved discussions of the student's experiences, and the importance of working on and submitting assignments. In particular, mentees were encouraged to try material they were not comfortable with and advised on how they could deal effectively with incorrect solutions or approaches by using the wide range of supports available. Students were encouraged to avail themselves of free help in the MSC, to become independent learners and to engage fully with mathematics.

The amount of mathematics covered during these sessions was minimal, and the majority of the time was spent discussing study methods, time management and effective use of resources. Students were encouraged to raise one mathematical issue each week that they were struggling with, to show their attempts and the author would try to clarify this for them. All mentees were asked to look at previous exam papers over the Easter break. Students were not required to do the questions; rather they simply had to note the questions that they thought they could solve, the technique they would use and how they would start a solution.

Towards the end of the first semester the department made the author aware of 2 additional students who were experiencing difficulties with mathematics. They were both second year students and were included in the project. Information on these students is not included here as they were, for the most part, studying different modules. For the last 3 weeks of semester two, the meetings were increased to once a week. This was possible due to the decreased engagement levels of some of the mentees.

The author maintained written records of all the meetings and issued an anonymous questionnaire to the participants at the end of the year with basic questions on the project. The author also had access to most of the students' records of engagement with mathematics. He received their permission to use these records anonymously to help measure the impact of the scheme. Some of the records are incomplete and numbers are given out of the total number of records available for that student and activity. Prior to the commencement of the scheme, the author researched material on similar projects and found an interesting overview of a variety of work on student mentoring and peer tutoring [9-10].

#### **3. Results**

The 12 first year mentees were composed of 6 students doing Science or a variation, e.g. Biomedical Science, and 6 students taking Mathematical Studies which is mathematics for Arts and Finance Students. Three of these were doing Finance and Accounting in which mathematics is compulsory in first year, 2 were Arts students who has chosen to do mathematics and the final student was doing Finance and had also chosen to do mathematics. Mathematics is compulsory in first year Science. All mentees were repeating modules of mathematics internally which meant that they were expected to attend the appropriate lectures and tutorials and complete the necessary assignments which would form part of their continuous assessment.

Eleven of the mentees were deemed at-risk, and 1 was not deemed at-risk. We describe students as at-risk if they have failed an incoming diagnostic test (less than 21 out of 60) or have a B1 or lower in ordinary level Leaving Certificate mathematics. We believe these students stand a high risk of failing first year mathematics at NUIM if they do not actively engage with the support available.

Of the 27 students who did not participate in the project, 21 made no response, and 14 of these were at-risk, 5 were not. The remaining 6 (4 at-risk and 1 not) did respond initially but did not participate in the mentoring scheme.

## 3.1 Students who responded but did not engage with the mentoring scheme.

Three students responded to the initial telephone contact but did not meet with the author. Two of these were at-risk and blamed personal (not mathematical) issues for their problems in first year. Both these students were registered with the Disability Office at NUIM. The mathematical background of the other student was unknown. All 3 students displayed extremely low levels of engagement in 2008-9; they never visited the MSC, sat none of their exams and deregistered from NUIM in 2009-10.

Three other students responded and agreed to visit the author. The first student was not at-risk and was repeating second semester modules only. They agreed to meet with the author at the start of that semester but did not attend and did not respond to any subsequent contact. In 2008-9 the student had shown good engagement levels in semester 1 (and passed) and very low levels in semester 2 (and failed). In 2009-10 they had better levels of engagement in semester 2 and passed by compensation, though they had failed 7 out of a total of 9 exams taken in mathematics.

The remaining 2 students met with the author and were both taking science. They agreed to partake in the mentoring project, and one also agreed to be interviewed as part of the related research project. It was clear from the initial meetings that both students were extremely nervous about mathematics, they were afraid to ask questions and did not want to do mathematics the wrong way. Both were at-risk students and extremely weak. They failed to engage with the mentoring scheme after the initial meeting and did not respond to subsequent attempts at contact. In both years they showed relatively good attendance records in lectures, however their attendance at the smaller tutorials and their submission of assignments was very low. Neither of them ever attended the MSC and they failed 20 out of a total 24 mathematics exams taken. They have both now left NUIM.

## 3.2 Students who did not respond.

Year	Record Details	Tutorials	Lectures	MSC	Homework	Exams failed	Exams Absent
8-9	8/10	41/160	53/192*	10	8/56*	37/48	5/48
9-10	10/10	44/167	-	4	43/167	36/40	3/40

Twelve of the twenty one students who did not respond to any contact failed to progress into second year in 2009-10. Ten of these were science students and 2 were mathematical studies students.

\* One student accounted for 23 lectures and for 5 assignments.

Table 1: Non-responders in Science who failed

The engagement details of the 10 science students are included in Table 1, though they submitted an increased percentage of assignments in 2009-10, there was no marked improvement in their performance or attendance. 9 of these students were at-risk and 1 was not at-risk. Of the 2 mathematical studies students, 1 was absent from all exams and had practically zero engagement with mathematics. The second student showed increased engagement in 2009-10 and passed 3 modules. They passed the fourth module in 2010-11.

The remaining nine non-responders progressed into second year, 5 of these were at-risk and four were not. The engagement details of the 7 science students are included in Table 2. Four of them passed their exams and 3 passed by compensation. Again, there was no marked increase in their engagement levels but these students had, on average, better mathematical backgrounds than the students who failed, and had fewer exams to repeat. Both mathematical studies students who passed were not at-risk and had very low engagement levels in 2008-9, e.g.

attended 5/40 tutorials and had very low continuous assessment grades. They both showed a marked increase in 2009-10, e.g. attended 14/42 tutorials and completed 23/41 assignments.

Year	Record Details	Tutorials	Lectures	MSC	Homework's	Exams failed	Exams Absent
8-9	7/7	66/140	69/168	10	21/49	29/44	3/44
9-10	7/7	43/84	-	9	43/84	9/17	8/17

Table 2: Pass non-responders in Science

## 3.3 Mentees

Of the 12 first year mentees, 11 were at-risk and 1 was not. If we consider the 12 students in total, they showed a marked increase in their levels of engagement, especially in terms of their assignment submission and visits to the MSC.

Year	Record Details	Tutorials	Lectures	MSC	Homeworks	Exams failed	Exams Absent
8-9	12/12	95/220	50/144	16	9/49	65/81	3/81
9-10	12/12	92/193	-	57	133/193	21/41	0/41

Table 3: Records of mentees

#### 3.3.1 Mentees who failed to progress

Three mentees failed to progress to second year and they had amongst the lowest levels of engagement with the mentoring process. The author was not surprised by this outcome. They were all at-risk, had very weak mathematical backgrounds and repeatedly failed to deal directly and appropriately with their mathematical issues. They attended a total of 17 meetings and rearranged or cancelled 15 meetings. Their surface engagement with mathematics did increase, going from 9/40 tutorials in 2008-9 to 28/54 in 2009-10. In 2008-9 they submitted 2/40 assignments and 33/54 in 2009-10. They also attended the MSC but only during the last weeks of term.

Their lack of effective engagement with the scheme was highlighted by their complete failure to bring any of their attempted work to the sessions. When asked to bring in their material on exam papers after the Easter break, one student forgot their bag, a second said that their computer had crashed and the third missed the next two sessions. All three students stayed out of contact for several weeks in the middle of the term and only arrived back during the last week of term. They brought in questions that they said they could not do, but never brought in attempts. Despite repeated assurances from the author that it was important to bring in attempts and that this was the best way to identify weaknesses and make progress, it was clear that they were afraid of showing lack of knowledge and showed constant signs of performance avoidance. This is consistent with the initial findings of the research project [11-13] which all three participated in. Two of these students have left NUIM and the third, while still registered, has never taken a mathematics exam since.

#### 3.3.2 Mentees who passed by compensation.

Three mentees passed by compensation. All 3 had very weak mathematical backgrounds and were deemed atrisk. They met with the author a total of 21 times and they rearranged or cancelled 8 times. Their submission of assignments did increase, rising from 4/57 in 2008-9 to 30/51 in 2009-10. Their attendance at tutorials dropped. They also attended the MSC but only 9 times in total compared with 10 times in the previous year. Again, none of these students brought in material on the exam papers.

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Two of these mentees were registered with the Disability Office in NUIM and struggled to engage on a regular basis. They were receiving private tuition, and though they rarely brought in attempts to the author, it was clear from their queries that they were making some effort to address their problems. They did not bring in their work on the exam papers but both said they had brought it to their private tutors. They did not use their disabilities as an excuse and appeared to be straight talking, and willing to try and address their mathematical issues. The author was not confident that they would pass, but they did give themselves a chance.

The third mentee was extremely inconsistent in their behaviour and repeatedly failed to deal directly with their issues with mathematics. They said that they were attending all tutorials, going to the MSC on a regular basis and submitting all their assignments. This contradicted the records, though they were doing some work. This student never brought any attempts to the author and said that they had done everything they had been asked to do and had no problems. This was clearly not the case and when pushed on these issues the student would fail to show for a few weeks. They also said that they had looked at the exam papers and had some problems but they never brought these in. The author was not confident that this student would pass and was surprised that they progressed into second year.

#### 3.3.3 Mentees who passed

The 6 mentees who passed engaged to a high level with the mentoring scheme. Five of them were at-risk but showed determination to get through. They attended 41 meetings and cancelled 12 times. One student accounted for 6 of these cancellations. This student had a full time job in a different part of the country. Only one of these students had a very weak mathematical background and they all showed increased engagement with mathematics, though their initial engagement was not a low as the other groups. In 2008-9 they attended 54/120 tutorials and handed in 44/120 assignments. In 2009-10 this rose to 50/82 tutorials and 64/82 assignments. They also attended the MSC a total of 33 times as opposed to 2 times in 2008-9.

Five of these students dealt directly with their mathematical issues, they consistently brought in questions and all of them had the exam paper material dealt with as requested and even had a list of follow up questions. They gave a wide range of reasons for their problems in first year including part-time jobs, personal problems, laziness and financial distress. It was not difficult to mentor these students.

The remaining student failed to directly deal with their mathematical issues. This student was very similar to a previous student in that their responses were always extremely inconsistent. For example, the student consistently received 100% in continuous assessment and could not understand how they had failed first year. The student had a severe lack of understanding of the basics of mathematics. When pushed on this issue by the author, the student admitted that all assignment solutions in their first year were copied from peers or found on-line. The author pointed out the folly in this approach, but was never satisfied that the student stopped. This student also failed to bring in any attempts or material related to the exam papers. The student consistently asked the author to do solutions to questions from exam papers and when the author refused to do so, the student's engagement levels decreased. The author was surprised that this student passed.

## 4. Student Feedback.

The author gave an anonymous questionnaire to all 12 mentees at the end of the second semester before they sat their exams. Nine were returned and in fact these were from the students who actually progressed into the next year of their studies.

As one would expect from a questionnaire on such a scheme, the responses were all positive. In particular, the students highlighted the importance of knowing that there was someone that they could talk to about their experiences, the importance of being consistently encouraged and advised about the correct supports to avail

themselves of and a constant reaffirmation of the progress that they were making. They reported that the fact there was someone monitoring their behaviour was an added impetus to get the work done. They also stressed how significant it was that they were contacted by the department directly as they thought that they were unlikely to seek help themselves.

The following responses are typical:

What was your experience of maths before being contacted? "Very distant and detached, I didn't get involved at all and once I wanted to, I didn't know where to start"

Would you have sought help if not contacted? "I don't think I would've looked for help, I probably would have just put it on the long finger and hope for the best"

Did you benefit from the mentoring? "I feel much better knowing I have someone definite to talk to, also this motivated me to try and work on the hard stuff without fear of failure"

Has your behavior towards Maths changed? "I attend more now that I know if I don't understand something in class etc., I can talk about it later rather than just getting annoyed and being put off from going again."

# 5. Conclusions

Students who do not engage with mathematics are often unwilling to admit to themselves that they have a problem with mathematics and often experience fear and embarrassment in relation to mathematics [11-13]. The purpose of this mentoring project was try and assist non-engaging students to engage appropriately, to encourage them to admit to themselves that they have a problem and advise them on how best to seek help.

It is impossible to make any sweeping statements as a result of this scheme. As is normal for these types of initiatives, there is always a law of diminishing returns. Every additional intervention is aiming to target students that did not engage or receive benefit from a previous or existing support. These are the students who remain always in our minds, what new effort we can make to help these students, for example the three 'at-risk' students who did not engage fully and failed to progress, or the two 'at-risk' students who agreed to join the mentoring scheme but failed to do so and also failed to progress.

However, overall the process was a very rewarding, if somewhat frustrating experience for the author. It was extremely time-consuming but the positives far outweighed the negatives. The majority of the mentees increased the range and quality of their engagement with mathematics. Nine of the twelve first year mentees (8 of these 'at- risk') proceeded into second year and it is reasonable to assume that not all of these would have succeeded without the scheme. For example, if we look at the records of the 18 at-risk students who did not avail of the service, we see that 13 of these failed to progress.

The positives of the scheme led the author and a colleague to apply for and receive a scholarship from the Centre for Teaching and Learning in NUIM towards the establishment of a peer mentoring scheme. This scheme commenced in September 2011 and specifically targeted approximately 40 of the most at-risk students entering mathematics at NUIM. Initial records indicate that the vast majority of mentees are engaging with the process. We look forward to reporting on this scheme after a full year of operation.

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# Teaching of mathematical content in a real-time wavelet application

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#### Abstract

In engineering, signal processing technology relies upon mathematics. Wavelet mathematics is supported within Matlab, with the 'Wavelet Toolbox' add-on. A new real-time example is being developed for a previously described Wavelet Toolbox Guided Learning Handbook. A significant subset of signal processing is real-time work. Analysis of some of the mathematics in the algorithm is being provided for postgraduate students to help prepare them for future design work in the area. Experience from teaching practice has shown that students benefit enormously from seeing complete worked examples from the beginning to the end that show how fundamental mathematical and engineering principles relate together in order to achieve a desired result. The real-time wavelet algorithm demonstrated at the conference was a digital audio processing method which can be used to eliminate noise from a signal. It used a pre-recorded guitar and software-synthesized noise. The demonstration showed a reduction in the noise, as the algorithm was switched in and out. Pointers are provided to areas of underlying mathematics needed by students in this area in order to indicate to those developing mathematics curricula for engineers what topics are actually used by engineers in the process of their work. Analysis of the mathematics in the algorithm has shown that the filter banks can be analysed by extensions of the normal undergraduate engineering and computing mathematics curricular. Therefore support by detailed worksheets is appropriate. The study of wavelet thresholding moves into the area of statistics and estimation theory. Hence discussion in the Wavelet Toolbox Guided Learning Handbook needs to be briefer.

## 1. Background

Student-led education can be greatly helped by understanding the way in which students tend to learn. Today's students have time limitations, often combining part-time work and family commitments with study. For these reasons, full lecture attendance may not be possible. Therefore flexible internet-based learning methods are embraced by students who use portable devices to store and catalogue this information.

The author had noticed a learning gap between theoretical materials taught by lecturers and the manuals for typical software simulation environments. One of these environments is Matlab which is a mathematical software environment which is popular amongst engineers. It can incorporate a wavelet toolbox which allows various kinds of calculations using wavelets, a currently popular function approximation method. The Wavelet Toolbox Guided Learning Handbook (WTGLH) has been designed to provide assistance within this learning gap. It was first described at the ELATE conference [1]. It takes the form of a web site based in a Coventry University resource environment called CURVE [2], which provides a centrally-maintained system, with useful aspects like Digital Rights Management. CURVE resources can be made available outside Coventry University. Some additional music technology-based lab sheets within the toolbox were presented at CETL-MSOR 2008 and reported through MSOR Connections [3].

One of the guiding themes for the development of the WTGLH has been detailed description of the link between theory and practice. Engineers need to understand the underlying mathematics or a process well enough to

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make the design decisions needed to make that process work within a product. An example product is the mobile phone that uses digital signal processing algorithms to respond instantaneously to signals that come from the antenna or microphone. Digital signal processing uses specialist computer chips to process information from the outside world. For some time it has been planned that the Guided Learning Handbook would include work on real-time analysis-synthesis wavelet applications. In the author's discipline of signal processing, real-time work is critical. Real-time basically means that an electronic system outputs a result of a processing operation shortly after the input signal has arrived.

## 2. Case study development

The chosen case study for the extra teaching material on real-time wavelet signal processing is a wavelet de-noising algorithm based on a pre-written demonstration version supplied by Mathworks. The purpose of denoising is to remove wide-band noise from a signal like speech or music. A signal is a variable that can change and represents some information. Noise can occur naturally due to the intrinsic operation of electronic components. Simulink, part of Matlab, was used to simulate the algorithm, as shown in Figure 1.



Figure 1 – Simulink wavelet noise reduction conference demonstration

The major mathematical areas in the algorithm were identified, namely a 3-level analysis and synthesis filter bank and a soft thresholding element. Detailed analysis of the algorithm has shown that the design of the two filter banks is relatively straightforward for engineers and computer scientists, but the understanding of the thresholding method uses more mathematics and statistics than is appropriate for them in a taught module. However research students, staff and industrialists would need to gain more understanding of this.

The key teaching concepts in the algorithm are now summarised in order to explain the choice of subjects in the WTGLH. The algorithm is non-linear. Most undergraduate teaching is based upon linear algorithms as the mathematical analysis is straightforward. The definition of non-linearity is covered in text books hence is not needed in the WTGLH. To make it easy for academics to write assessments, design calculations that result in a number and a unit are helpful. The parts of the design that actually involve wavelets are the analysis and synthesis filter banks. The term 'filter' here means a linear discrete-time transformation used for frequency or time shaping a signal. If there was no processing technique between the filter banks, then the output should be the same as the input, apart from calculation errors caused by limits in computer word lengths. Hence filters are designed so as to obtain a perfect reconstruction analysis-synthesis filter bank.

The 3 level analysis bank used in the wavelet noise reduction uses filters that split the signal into multiple bands. This is how the approximation and detail coefficients are generated. In the simpler example of a 2 channel filter bank, there is a filter combination called the Quadrature Mirror Filter (QMF) [4]. For filters  $H_0$  and  $H_1$ , the QMF requires:  $H_1(z) = H_0(-z)$ . *z* here is as used in the *z*-transform. For perfect reconstruction, the filters need to have an infinite impulse response, except in the case of the Haar wavelet. This filter has the advantage that the high pass magnitude response  $|H_1(e^{jw})|$  is the mirror image of the lowpass magnitude response  $|H_0(e^{jw})|$  with respect to the middle frequency  $\frac{\pi}{2}$ , the quadrature frequency. The typical student at postgraduate level in electronics-based engineering may have done an undergraduate degree in a similar engineering subject or may have qualified in an allied field, e.g. computing. When writing materials for the WTGLH, assumptions have been made about likely background knowledge. For example, the analytical material makes use of the *z*-transform. DSP systems are based on difference equations, which are implemented in sampled data microprocessor systems, normally running at a fixed data rate. The *z*-transform enables the user to take a different route to the solution of difference equations. Typical problems in DSP involve an input signal, an output signal and a transformation equation. Generally one knows two of these and needs to find the third, or possibly an aspect of the third. For example the *z*-transform of the system impulse response. The amplitude of the frequency response is frequently needed in digital filter analysis and it is obtained by evaluating the *z*-transform on the unit circle in the *z*-domain.

An electronics-based student will typically have seen some or all of the Fourier Series and Transform, Laplace Transform and *z*-transform. A computing-based student may not have seen these or only in a mathematics module. This presents a teaching challenge at postgraduate level. However the *z*-transform can be presented as a set of rules that have to be followed. One is given a signal sequence. By applying rules involving tables of *z*-transform pairs and properties, the *z*-transform can be evaluated. The author has found it necessary to go over background material such as set theory and Venn diagrams as these are needed in calculating regions of convergence.

The best way of supporting detailed design calculations in the WTGLH is by individual worksheets on topics. So, for example, the quadrature mirror filter and the perfect reconstruction condition can have separate worksheets. Topics like *z*-transforms are already well-covered by standard textbooks in digital signal processing.

The area of analytical design work in thresholding, which is most likely to be useful to research students and staff, will be supported though brief discussion and references to outside sources. The initial work by Donoho and Johnson [5,6] and the recent Ph.D. work of Jansen [7,8] will be the starting points for this. If undergraduate project students need to work in this area they can use an experimental technique for threshold level selection.

Taking these various discussions into account, the methodology is now devised. One group of students seeing the WTGLH will be postgraduate students on taught courses in electronic engineering or computing. Detailed design work such as the design of quadrature mirror filters will be covered by individual worksheets. Research students or staff will need a wider range of topic information. This is best served by brief discussion with useful references.

Some practical points need to be made concerning implementation. When Simulink runs on a PC, there is an audible latency (time delay) between input and output. At Coventry University, there is a communications and signal processing laboratory. Here, digital signal processor boards supplied by Texas Instruments enable the fast computation of the wavelet algorithm in order to significantly reduce computational time. This kind of technology is used in the kinds of portable devices that use wavelets.

## **3. Conclusions**

This work has involved the adaptation of an existing Simulink model in order to create a noise reduction demonstration of wavelet usage. The mathematics involved has been analysed in order to identify that which is suitable for different student groups. This has provided planning information for a case study in an existing web resource, the Wavelet Toolbox Guided Learning Handbook. It has been found that the analysis of wavelet sub-band analysis-synthesis filters is appropriate for postgraduate taught students in engineering and computing. Worksheets in this area are being developed. The more complicated analysis of wavelet thresholding is most suitable for postgraduate research students and is being covered through brief discussion and access to external references.

The majority of work in the Handbook is supplied as Word documents. This is a relatively static use of a web resource and it is planned to provide more interactive content. For example Matlab-generated applications can be provided that can run in less expensive tools like Excel or directly on the site.

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