MSOR connections

Articles, case studies and opinion pieces relating to innovative learning, teaching, assessment and support in Mathematics, Statistics and Operational Research in HE.

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Editorial

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It is with great honour that I introduce the next chapter in the long and established history of MSOR Connections. I look forward to this exciting new beginning with a keen sense of anticipation, and I would also like to take this opportunity to briefly reflect upon the rich history of Connections, making it an integral part of the MSOR Higher Education community.

Since 2001, under the umbrella of the Maths, Stats and OR Network, Connections established itself as a key resource for those interested in sharing ideas related to mathematics learning, teaching and support. In 2012, the publication was taken over by the Higher Education Academy (HEA) and a further two issues were published. Following the well documented cut in funding, the HEA was unable to continue its support for Connections from November 2013, and it soon became apparent that this left a significant gap in the reporting and dissemination of learning and teaching activities across the sector.

In the subsequent months, a great deal of background work has been undertaken by sigma, and special thanks have to go to all those involved, without whose hard work, it would not have been possible for Connections to continue. Thanks to the continued support of sigma, and in collaboration with the University of Greenwich, the publication will now continue as a peer-reviewed online research journal that will maintain the traditions of Connections past. That is, research articles, case studies and opinion pieces relating to innovative learning, teaching, assessment and support in Mathematics, Statistics and Operational Research from across HE will be welcomed. To assist the ‘relaunch’ of the journal, additional support has been provided by sigma, to produce and distribute the current issue in hard copy at the CETL-MSOR conference in September.

In keeping with the theme of this introduction, the articles in the current issue capture the changing landscape across the sector of mathematics learning, teaching and support. The article by Lawson and Croft reviews the development of mathematics support over the last 25 years, before providing a glimpse in to the future of maths support and the continued role of the sigma network. This is not unrelated to the item provided by Cronin and Breen, who report on the current activities in mathematics support as presented at the 9th Annual Workshop of the Irish Mathematics Learning Support Network. And Lingham and Baughan describe how a bespoke workshop has been developed to support students in preparation for undertaking increasingly common and important graduate numeracy tests.

Another key theme across the remaining articles is student engagement. The case study by Ní Shúilleabháin provides details on an initiative that involves university students supporting widening participation activities; Cornock outlines how the Maths Arcade programme has been developed to engage and support students at various levels of university study; and Knight reports on learning activities that have been employed in a final year undergraduate mathematics module that aim to engage students, as well as develop their understanding of the mathematics introduced. In relation to these aspects of engagement, Waldock details how a well-designed learning space has positively contributed to student interaction and group working activities.

Finally, I would like to thank my fellow editors and the editorial board for their continued support in preparing this issue. I very much believe that it continues the long-standing traditions of Connections, and I strongly encourage all readers to consider contributing their own articles in order to build on this foundation in future editions. More information on deadlines is available on the inside back cover.

To register for submissions/notifications, and for further information relating to Connections please visit https://journals.gre.ac.uk/index.php/msor.

REVIEW ARTICLE

Mathematics Support – past, present and, most importantly, future

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Abstract

This article briefly reviews the development of mathematics support in higher education over the last 25 years, highlighting in particular the work of **sigma**, centre for excellence in university-wide mathematics and statistics support as a Centre for Excellence in Teaching and Learning and subsequently as part of the National HE STEM Programme. A description of **sigma**'s current HEFCE-funded programme of activities is included, giving particular attention to the development of the **sigma** network. The article closes by focusing on the legacy of **sigma**'s current work and the future sustainability of the **sigma** network.

Keywords: Mathematics support, centre for excellence, sustainability

1. Introduction

Mathematics support has been defined by Lawson et al. (2003, p.9) as *"a facility offered to students (not necessarily of mathematics) which is in addition to their regular programme of teaching, lectures, tutorials, seminars, problems classes, personal tutorials, etc."* The case for mathematics support has been made extensively elsewhere and is not rehearsed here beyond giving three key quotations from important national reports:

"Higher education has little option but to accommodate to the students emerging from the current GCE process" from *Making Mathematics Count,* the report of the Smith Inquiry into post-14 mathematics education (Smith, 2004, p.95);

"Many students require some additional academic support, especially in the mathematical skills required in science, mathematics, engineering and technology" from the National Audit Office report, *Staying the course: The retention of students in higher education* (NAO, 2007, p.33);

"We estimate that of those entering higher education in any year, some 330,000 would benefit from recent experience of studying some mathematics (including statistics) at a level beyond GCSE, but fewer than 125,000 have done so" from the Advisory Committee on Mathematics Education (ACME) report *Mathematical Needs: Mathematics in the workplace and in Higher Education* (ACME, 2011, p.1).

The way in which many universities have chosen 'to accommodate to' the needs of the students that they recruit has often been through the introduction of some kind of mathematics support provision. The most common model that is used is a 'drop-in' centre which offers one-to-one support to students who drop-in at a time of their choosing during the centre's opening hours. In addition to the personal support from a tutor, most support centres also offer a range of resources, both paper-based and on-line.

2. Mathematics support – the past

In September 2015, the Mathematics Support Centre at Coventry University will begin its 25th year of operation. This centre began in 1991 as the BP Mathematics Centre, having received start-up funding from the BP (British Petroleum) Engineering Education Fund, covering the capital cost of equipping a dedicated room (complete with green chairs and yellow cushions) and the revenue cost of a full-time centre manager for two years. The Coventry Centre drew visitors from many higher education institutions from across the UK, some of which established their own centres along similar lines. Loughborough University was one of these institutions, setting up its Mathematics Learning Support Centre in 1996.

The early days of mathematics support have been described by Kyle (2010, p.103) as *"a form of cottage industry practised by a few well meaning, possibly eccentric individuals"*. However, despite these humble beginnings, mathematics support gradually gathered momentum. In a survey of UK universities carried out in 2000, 46 out of 95 responding institutions indicated that they had some kind of mathematics support provision (Lawson et al., 2001). A similar survey carried out in 2004 indicated that the number had increased to 66 out of 101 responding institutions (Perkin and Croft, 2004). It should however be noted that, notwithstanding the well-developed centres at places like Coventry and Loughborough, much of this provision could probably still be fairly described as a cottage industry provided by enthusiastic individuals. In the 2000 survey, one third of those providing mathematics support did so for less than 5 hours per week and, similarly, a third (quite possibly the same institutions) provided help to fewer than 10 students per week.

In 2005, a joint submission by the Mathematics Learning Support Centre at Loughborough University and the Mathematics Support Centre at Coventry University to HEFCE's Centres for Excellence in Teaching and Learning (CETL) scheme was successful. The resulting centre was named **sigma**, Centre for Excellence in University-wide Mathematics and Statistics Support. The recognition, and the funding, that came with being a CETL enabled mathematics support to become much more firmly established across the higher education landscape.

From the outset, **sigma** determined to be outward looking. It had been written into the CETL proposal that, using the University of Leeds as a test-bed, **sigma** would develop a 'blue print' for the establishment of a mathematics support centre in a university that did not have such a provision. After successfully initiating mathematics support with the Skills@Library student support at the University of Leeds, **sigma** then offered two years of funding (which had to be matched by the bidding institution) through a competitive bidding process for two universities wishing to set up mathematics support. The universities of Bath and Sheffield were successful in securing this funding and both chose to call their support provision MASH (Mathematics and Statistics Help). These three mathematics support centres have flourished in the years since they received **sigma** funding and today receive far greater funding from their own institutions than they received during the **sigma** pump-priming days.

In addition to distributing funds to initiate mathematics support in other institutions, some CETL funds were used to establish a research programme to provide a rigorous scholarly underpinning to mathematics support. Three **sigma**-funded PhD's were completed exploring different aspects of mathematics support.

In 2009, HEFCE and HEFCW initiated the National HE STEM Programme (www.hestem.ac.uk). This programme had a number of different aims; one was to enhance the student experience in STEM disciplines in higher education. The Programme identified that across STEM, mathematics is a barrier to success for many students. It therefore commissioned **sigma** to continue its work of assisting institutions to establish mathematics support provision. During the lifetime of the National HE STEM Programme, **sigma** assisted the establishment of 22 new support centres and provided funding to six institutions for enhancement projects to improve already existing mathematics support provision.

A key new initiative that **sigma** introduced during the National HE STEM Programme (2009-2012) was the creation of six regional hubs covering the whole of England and Wales. The idea behind regional hubs was to address the sense of isolation that many involved in the provision of mathematics support felt. In newly emerging mathematics support provision (and, indeed, in more established but small provision) the individual providing mathematics support was often on his/her own either as the only mathematician in a wider student support unit or as a student support-focused tutor in a mathematics department dominated by research. Each **sigma** regional hub had the role of providing local opportunities for mathematics support providers to meet to share good practice, exchange ideas and offer each other mutual support.

The impetus given to mathematics support during the period from 2005 to 2012 established it as an important element of wider student academic support across the whole of the higher education sector. Kyle ended his previously cited article with the conclusion that, notwithstanding his early reservations, *"Mathematics support came of age in the first decade of the 21st century"* (Kyle, 2010, p.104). There was further national recognition in 2011 when **sigma** won the Times Higher award for *Outstanding Support for Students* and the then Minister of State for Universities and Science, David Willetts, championed the work of **sigma** in a number of speeches and in his booklet *Robbins Revisited* (Willetts, 2013, p. 51).

With the ending of the National HE STEM Programme in 2012, external funding for national co-ordination of mathematics support activities ended. During the academic year 2012-13, the activities of **sigma** were maintained primarily through the regional hubs and the annual conference. Each hub continued to offer at least two meetings during the year at which mathematics support practitioners could engage in professional development and also have a forum for exchange of practice.

3. Mathematics support – the present

During 2012-13, the **sigma** Directors had been in discussion with HEFCE about the importance of mathematics support and, in particular, of firmly establishing the embryonic **sigma** network. In October 2013, HEFCE announced funding for **sigma** to undertake a three year programme of activities to further embed mathematics support across the sector and to establish a sustainable community of mathematics support practitioners.

There are several strands to **sigma**'s work within the current HEFCE programme. The competitive allocation of pump-priming funds (to be matched by the institution) has continued. Funding has been allocated to ten institutions to set up mathematics support. The institutions are: University of the Arts, London; Bournemouth University; University of East London; University of Greenwich; Halesowen College; Kings College, London; Lancaster University; University of Leicester; Royal Holloway, University of London; and Vision West Nottinghamshire College. These institutions include two FE colleges (Halesowen and West Nottinghamshire) who are developing mathematics support for their HE in FE students. This is a new avenue of work for **sigma**. The University of the Arts is the first specialist art college to engage with **sigma** and they have produced some innovative support resources, particularly in relation to geometry, that are of especial relevance to art students.

The survey of the extent of mathematics support provision that took place in 2000 and again in 2004 (reported above) was repeated in 2012. This was before the 10 new centres above were established. The findings of the 2012 survey (Perkin et al., 2013) were that 88 out of 103 responding institutions offered some form of mathematics support. This means that the percentage of responding institutions offering mathematics support has grown from 48% in 2000, to 65% in 2004 to 85% in 2012 and, given the institutions that **sigma** has supported to establish mathematics support during the current HEFCE funded programme, the figure is likely now to be even higher.

In addition to providing funding to institutions to set up mathematics support, **sigma** has also provided each new centre with an experienced mentor who acts as a point of contact and source of advice to the new centres. Furthermore, **sigma** delivers annually a series of workshops (one in each regional hub area) to train tutors working in mathematics support to assist the new centres in providing students with a high quality service.

With a view to the future, **sigma** has used part of the HEFCE funding to further develop the open learning resources for students that are available through the **math**centre and **stats**tutor websites (www.mathcentre.ac.uk and www.statstutor.ac.uk). Resource development grants have been targeted on the development of resources in areas where these websites have gaps. In addition, the resources for mathematics support practitioners (such as the guides to setting up mathematics support provision, evaluating mathematics support provision and resources for training tutors available from the **sigma** network website, www.sigma-network.ac.uk) are being extended.

A significant piece of research, a ‘sector needs analysis’, has been commissioned. 23 senior staff (typically PVCs for Learning and Teaching) from across the sector have been interviewed to establish their views of the mathematical and statistical needs of students across their institutions and how these need are being met in a strategic (rather than piecemeal) manner. The findings of this work show a high level of awareness within university senior management of issues relating to mathematics and statistics. The researchers found that *“All of the HEIs questioned reported having students who are challenged by mathematics and statistics … Furthermore, all the universities questioned recognised that unless they provide appropriate forms of learning support for mathematics and statistics, it is inevitable that there will be an adverse impact on their students’ satisfaction, retention, achievement and employability”* (Tolley and MacKenzie, 2015, p.2).

4. Mathematics Support – the future

Given the findings of the report of Tolley and MacKenzie (2015), referred to above, it is clear that the need for mathematics support is going to remain for the foreseeable future. The current HEFCE-funding for **sigma** runs until the end of the academic year 2015/16. A key element of this funding is to plan for sustainability beyond this time when it is likely no further funding will be available. Working towards sustainability has been integral to much of the work that **sigma** has undertaken since the start of the current grant in 2013. This has taken a number of forms.

Firstly, there has been a deliberate policy of establishing legacy materials. The importance of the **math**centre and **stats**tutor websites as repositories of shared, high quality learning resources for students has been acknowledged. So-called ‘community project’ areas of the websites allow for the uploading of resources that members of the mathematics support community have developed. Anyone can upload learning resources to the repository – but, as a quality control mechanism to ensure the maintenance of the websites’ reputation, the resources must be peer-reviewed by someone from another institution before they are openly shared with the wider community. Other legacy resources are aimed at mathematics support providers rather than students. So, for example, the materials used during tutor training workshops have been made available via the

sigma network website to assist in local delivery of such workshops in the future when there is no funding for central 'trainers' to tour the country running workshops in each hub region.

Alongside legacy materials, **sigma** has focused on capacity building amongst the community of practitioners. There are a number of strands to capacity building but the annual CETL-MSOR conference, the regional hub meetings and the provision of experienced mentors are key elements. Respondents to a recent survey carried out by the External Evaluator of the current **sigma** programme highlighted ways in which this capacity building is being effective:

***"sigma** staff have been very encouraging – without that support we would not have had the confidence to get started"*

*"Engagement with other practitioners at workshops, meetings and the conference … is likely to translate into work with collaborators at other institutions which could not have occurred if the **sigma** network had not existed"*

*"I am the only maths support tutor at the University of … - the support of **sigma** has been vital in helping me sustain and develop ideas for the maths support service we provide"*

Since its inception in 2006, the CETL-MSOR conference has grown into the leading UK conference for all aspects (not just mathematics support) of learning and teaching of mathematics, statistics and OR in higher education. There has never been any difficulty in identifying an institution to host the conference nor in finding people to take on conference committee roles, giving confidence that the conference can continue in the future. The conference has been subsidised by **sigma**'s external funding which has enabled delegate rates to be set well below those of other conferences and in the future these rates will need to rise to ensure that the conference fully covers its costs. However, the conference is now held in such esteem that there is confidence that there will continue to be strong demand amongst practitioners to attend the conference.

The Tolley and MacKenzie report (2015) identified continuous professional development (CPD) as a key area of need. The PVCs in the survey expressed the view that provision from outside individual institutions would be welcome and ideally such training should be recognised formally or lead to some kind of professionally accredited status. Although **sigma,** through its conference and workshop provision, offers a range of CPD, it is beyond **sigma**'s capacity, even with the current HEFCE funding, to operate a system of professional accreditation. However, **sigma** does seek to explicitly align much of the CPD it provides with the UK Professional Standards Framework (UKPSF, 2011) and this should assist individuals in seeking professional recognition through the different grades of fellowship of the Higher Education Academy.

The sustainability of mathematics support in individual institutions appears to largely be secure. Institutions recognise the value of mathematics support to their students (as indicated in Tolley and MacKenzie, 2015). Several institutions cite their mathematics support provision in their OFFA[i] access agreements and publicise the provision to potential students as an attractive marketing feature during the recruitment process.

What is more vulnerable is the wider community of practice and the sharing and mutual support that it offers. As one respondent to the evaluation survey, cited previously, put it *"It's great to have such a supportive network to tap into for advice and help. I find the support of the **sigma** network invaluable. It is like a big family."* In an attempt to maintain this supportive network, **sigma** is currently exploring the possibility of establishing an 'unincorporated association' whereby individuals and institutions will be able to become members of a formally constituted network with individuals from across the community taking on roles within the network, such as Chair, Secretary and Treasurer, as part of their academic citizenship. This development is as yet in the early stages of planning, but it appears to be a promising avenue to explore and it is anticipated that further details will be available by the time the CETL-MSOR conference takes place in September 2015.

5. Conclusion

It is clear that the need for mathematics support in higher education is not going to disappear in the near future. It is also clear that over the last ten years much has been gained from the collaboration of mathematics support providers. The mathematics support community of practice that has developed during this time is, as has already been referenced, highly supportive and welcoming to new individuals and institutions. Despite governmental pressures towards the marketisation of higher education which have led to increased competition amongst universities, mathematics support has remained highly collaborative. This collaboration has not only been effective in enabling the expansion of the mathematics support community, it has also been efficient in that it has reduced the amount of duplicated work (for example, by promoting the sharing of resources across the sector rather than the reinventing of the wheel). The **sigma** Directors, the Chair of the **sigma** network and regional hub coordinators are committed to seeking to sustain the **sigma** network as a thriving community of practice into the future.

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[i] OFFA stands for the Office for Fair Access, the independent regulator of fair access to higher education in England. In order to be able to charge fees above the 'basic' level an institution must produce an Access Agreement outlining how it promotes fair access and have this Access Agreement approved by OFFA.

WORKSHOP REPORT

Maximizing the impact of digital supports in Mathematics Learning Support in Higher Education – An overview of the 9th Annual IMLSN Workshop

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Abstract

In this article we give a short description of the 9th Annual Workshop of the Irish Mathematics Learning Support Network (IMLSN). The workshop theme was 'Maximizing the impact of digital supports in Mathematics Learning Support in Higher Education'. We briefly describe the Irish Mathematics Learning Support Network (IMLSN) and outline the factors that motivated this workshop theme. We will also discuss the presentations, some of the issues that were raised during the workshop and we close with some brief conclusions on this very successful event.

Keywords: Digital support, mathematics support, higher education.

1. Introduction

The 9th Annual Workshop of the Irish Mathematics Learning Support Network (IMLSN) Workshop was held in the new Science Centre at University College Dublin (UCD) on Friday May 29th 2015.

Maths Learning Support (MLS) is now an established part of the Higher Education landscape both in Ireland and the UK (Gill et al., 2008; Perkin et al*., 2012).* As a reflection of the increasing importance of MLS to Irish Higher Educational Institutions (HEIs) an annual workshop on MLS has been held at various locations around Ireland since 2006. These workshops have proven invaluable to the MLS community as a forum for sharing ideas and for disseminating 'best practice' in the field. They have attracted delegates from all over Ireland and the UK. Further information, including some of the presentations, from these workshops can be found on the IMLSN website (IMLSN, 2015).

There were 39 delegates in attendance at the UCD workshop including visitors from Norway (University of Agder), Canada (University of British Columbia), the United States (Stanford University), as well as keynote speakers from the UK (Loughborough University, University of Glasgow, Ulster University and the Open University). There were 18 Irish Higher Education Institutions represented at the workshop. Companies such as Google, Folens and Infonalis were also represented.

The UCD Registrar and Deputy Vice-president Professor Mark Rogers opened the event and he emphasised the importance of ensuring that an evidence-based approach is taken when examining the effectiveness of maths support centres. In particular, he commended the recent large-scale evaluation report of the IMLSN (O'Sullivan et al., 2014) and stressed the importance of inculcating this research culture across the sector.

Professor Rogers recalled the origins of the Maths Support Centre (MSC) at UCD. It originally started in a small, out-of-the way room and its mission was to support students in making the mathematical transition to university. However, as Professor Rogers stated, the centre has developed enormously since then with the MSC's mission in 2015 significantly changed to enhance the mathematical learning of all students throughout the university. He remarked that the seminal moment in the UCD MSC's history was the move to 'centre stage' within the university with the location change to the main campus library in 2013. This location change has meant that not only do the students who need the maths support the most are assisted but that the enhancement of all maths learners across the university is catered for.

The Registrar also spoke about looking to the future and highlighted how maths support has to be cognisant of the needs of the students in the digital space. He highlighted his excitement with the UCD MSC's pilot project of a digital system which provides the lecturers and module coordinators of all students who visit the MSC, with real time anonymous feedback on the mathematical issues their students are experiencing. This ability to affect the learning in the classroom as it is happening because of feedback from the MSC via this digital data management system is of particular interest to him and he is looking forward to seeing this rolled out to the Academic Writing Centre, which is also housed in the Library Link space.

2. Keynote Speakers

2.1. Chris Sangwin, Loughborough University. Using GeoGebra as a problem solving tool

In this talk the speaker demonstrated, via an interactive session, how the free software GeoGebra (http://www.geogebra.at) could be used as a dynamic problem-solving tool in mathematics. The speaker outlined how he has used the Moore Method of instruction for many years now and how via GeoGebra, this enables a user to undertake direct experiments in mathematics to test a conjecture or explore some area of mathematics. This is particularly useful in elementary mathematics where simple algebraic expressions and graphs often have a strong interplay. GeoGebra has a potentially very useful role in mathematics support, providing students of all abilities with an opportunity to visualise and experiment. The speaker also reported on experiences of using this software to support a problem solving class with higher achieving students. The speaker ended with some encouraging words to anyone wishing to take the plunge into incorporating mathematical software into their practice; once one is 'willing to play' there are benefits in private maths play, use in lectures, students' presentations and in the maths support centre setting.

Figure 1. Delegates at the IMLSN Workshop

Figure 2. Chris Sangwin presenting an interactive keynote on GeoGebra

2.2. *Shazia Ahmed, University of Glasgow. Providing academic support and improving transition into university life through Facebook groups*

In this presentation, the speaker outlined an initiative to provide academic support to students through the use of Facebook groups. This initiative was first established four years ago for Level 1 Mathematics and Computing Science students in order to evaluate whether this could be a viable alternative to traditional Peer Assisted Learning (PAL) sessions. The speaker noted that Facebook was chosen over the virtual learning environment Moodle because of the high engagement levels with Facebook among students: in the Digital Native survey in 2011, 89.2% responders stated that they access their Facebook account at least once a day.

The speaker then described the day-to-day workings of these Facebook groups: they are closed groups, which are initiated and moderated by support staff. Senior students are also invited to join, and the speaker noted that their input has proven to be invaluable: they answer questions from junior students, that staff are often unable to answer, helping to alleviate concerns from those beginning university, and continuing to help them throughout their university careers. In addition, these groups are used by students to share questions with each other, and virtual PAL sessions happen spontaneously. Students also share resources, ask when and where lectures and labs are and generally support each other. Many examples of such interactions were included in this presentation as well as feedback from students who had made use of this service. Among the positive points noted in the student feedback was the sense of community that the Facebook groups created.

In the second half of this presentation, the speaker outlined in more detail how the Facebook groups can be used to ease the transition to university. It was noted that there are many entry points into the University of Glasgow, this leads to a diverse student body and gives rise to many transition issues, such as unfamiliarity with formal terminology or commuting large distances to attend university. In order to assist incoming students with these matters, a pre-entry Facebook group for incoming College of Science and Engineering students has been set up. Examples of conversations that arose in this group were given, and it was evident that students find this group to be very useful in coping with these transition issues.

The presentation concluded with the results of a recent evaluation survey involving 4th year students, who were the first cohort where Facebook groups were formally introduced in the manner outlined previously. It was found that the majority of students joined in first year, students found the groups to be very useful academically and the main reason that students gave for not joining the groups that was given was that the students ‘didn’t know about them’.

2.3. Madonna Herron, Ulster University. Using pencasts to extend and enrich the student learning experience

This keynote was on the topic of using pencasts to enrich the learning experience of students in mathematics and engineering programmes at Ulster University. The speaker began by describing the equipment used to create the pencasts, the Livescribe 3 smartpen with Livescribe paper and the Livescribe+ App, which is compatible with the IOS8+ or Android KitKat v4.4.2 operating systems. Some advantages of using pencasts over screencasts were given, such as the ease of use, the portability of the devices and the fact that no editing is required. The speaker also outlined some of the benefits for the students of pencasts, including the ability to provide step-by-step solutions with rich audio explanations, which can be replayed at any time and from any location.

Using screenshots and screencasts the speaker demonstrated the process involved in producing pencasts and noted that the pencasts produced can be emailed to students or uploaded directly to the Blackboard virtual learning environment. It was noted that the screencasts produced by the speaker are used by students in Ulster University for self-directed learning and self-assessment and are also used to provide one-to-one support to students.

One piece of feedback from a student noted that being able to see mathematical operations carried out, with commentary audio, was one of the advantages of pencasts over other study aids, such as textbooks.

The presentation concluded with the observation that while pencasts are a very useful education tool, they do require a significant amount of work and time to create. The speaker gave many useful tips on how best to approach creating a pencast, such as the use of a script or the pre-drawing of some elements of the pencast in advance and stressed the importance of gaining feedback from students, so that the pencasts can continue to be refined.

3. Contributed Speakers

3.1. Cormac Breen*, Ciaran O Sullivan[1] and Damian Cox[2]. Mathematics Learning Support across a Multi-Campus Institution: A Trial of Virtual Support

In this presentation, the speaker outlined a study that was undertaken across three institutions intending to form the Technological University for Dublin: Dublin Institute of Technology (DIT)*, Institute of Technology Blanchardstown[2] and Institute of Technology Tallaght[1]. This study consisted of a survey that was circulated to both staff and students in each of the three institutes. This survey was an attempt to identify the students' needs for Mathematics Learning Support (MLS) in each of the institutes as well as the preferred method of provision of MLS, on a scale ranging from exclusively online to exclusively in person. The main results of the survey were that the majority of staff (71%) and students (69%) surveyed were in favour of having MLS provided either exclusively or mostly in person. There was a strong preference among both staff (66%) and students (50%) that some portion of this MLS be provided online. Another notable result of the survey was the difference in opinion between staff and students on the topic that students would most need MLS with. Students across the three institutes picked Calculus as the main topic, while staff selected Basic Algebra. The speaker noted that this resonates with tutors' experiences in MLS centres, where students often present with what they believe is a Calculus problem, but they are actually struggling with the underlying algebra.

The speaker then went on to describe a virtual drop-in service that, as a result of the outcomes of the survey, was introduced on a trial basis across the three institutes. The speaker outlined the technology used, Wacom Intuos Tablets and the Adobe Connect software package. Students in one institute were, using the Wacom Intuos Tablets, able to pose a question on a shared virtual whiteboard in Adobe Connect. The tutor, in another institute, was then able to respond to that question on the same whiteboard and students could have screenshots of the whiteboard sent to their email account. The feedback from the students was quite positive to the concept of virtual drop-in, mostly for the flexibility (both geographical and temporal) that it offered, but were concerned that technical issues, such as a bad connection, could discourage students from making use of the service. The speaker concluded by stating that more trials are planned for the summer, with the aim of having the service running on a wider basis by September 2015.

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3.2. Nuala Curley, UCD. To collect and analyse useful qualitative data on mathematical difficulties as experienced by students in a Mathematics Support Centre – A challenge?

This speaker, a PhD student in mathematics education from UCD, spoke about the challenges in collecting and analysing detailed qualitative feedback data generated at a busy maths support centre. The mathematical topic covered by the tutor is available to the module lecturer on a real-time basis.

The speaker explained that in order to identify the mathematical topics and concepts that cause persistent difficulties for students she needed to identify the nature of the data required and then find ways that this could be recorded efficiently. She described her efforts, and those of the maths support tutors, over the last eighteen months to collect this data. The collection period involved eight weeks of intensive collaborative work with 23 tutors to ensure the quality and authenticity of the data collected. The purpose of this research is to identify university students' mathematical 'trouble-spots' in a maths support centre setting and to develop effective supports. Initial details of the research project are described in Curley and Meehan (2015).

A more detailed analysis of the data has revealed that even when identifying and classifying basic mathematical difficulties, it makes more sense to do this within the context of a module, rather than across modules. For example, it was surprising that the number of students seeking help with statistics was similar to that for vectors, despite the statistics content being increased in the Leaving Certificate mathematics syllabus (Project Maths) and vectors no longer being included. It is hoped that the data collected, along with feedback from the module coordinator, will in the future help to predict when and where students will require additional support throughout the semester. Further analysis is ongoing.

3.3. Jack Parte, Jonathan S. Cole, and Timothy J. Crawford, Queens University Belfast. Development of an app to support learning in A-level maths*

This talk explained a project involved in producing an app for smart devices to enable modernised learning for A-level maths students. Research in a stakeholder school showed that 94% of pupils surveyed within the upper-secondary level owned a smartphone and most owned a tablet also, emphasising the opportunity for using apps to support learning. The app was developed using iBuildApp, an online app-creation programme that requires no programming. Past exam questions and solutions, notes and video tutorials were included and the topic was vectors, identified by teachers as problematic. Pupils generally found the app easy to use and wanted further development. The videos were popular despite this not ranking highly as a preferred method of revision previously. Teachers were happy for pupils to use the app to supplement their learning, both in the classroom and outside.

Figure 3. Jonathan Cole discussing the use of an app to support A-level mathematics

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3.4. Gerry Golding, The Open University. Virtual Mathematics Support at the Open University

This speaker outlined the virtual mathematics support centre at the Open University (OU), a pilot project under development in Ireland for Irish students studying service mathematics with the OU. Delivered over the Moodle platform, the virtual centre will offer stage one and stage two students, access to digital mathematics support resources, primarily developed by the OU, but supplemented by links to external resources. Using screencasts, wikis, forums, dedicated context based online workshops, and one to one drop in sessions in our OU Live rooms (Blackboard Collaborate), the project aims to complement our new tuition strategy by providing an alternative learning experience for students struggling with mathematics.

4. Conclusions

The workshop closed with a general discussion of various smaller scale initiatives implemented across several Maths Learning Centres in Ireland. These included:

- Assigning homework exercises to maths support visitors - Diarmuid Ó'Sé, IT Carlow;
- Monitoring and engagement of 'at-risk' students - Eabhnat Ní Fhloinn, Dublin City University;
- Creating 'Hot Topics'; specialist sessions on module prerequisites not covered by lecturers but with which a significant minority of a class struggle - Anthony Cronin, UCD;
- The use of Google spreadsheets to track attendance in a maths support setting - Richard Walsh, University of Limerick;
- Student directed support tutorials using online polling - Cormac Breen, DIT;
- The use of Khan Academy in providing targeted online support and as a means of monitoring engagement with resources - Fiona Lawless, Dundalk Institute of Technology.

During a conversation with Shazia Ahmed the local organisers felt it would be of benefit to the maths support communities in both Ireland and Scotland to have a joint Irish and Scottish Maths Support conference in 2016 and the IMLSN committee has broadly welcomed this idea. In general, the workshop was a great success, facilitating the sharing of new ideas and further strengthening the collaborative links that exist between providers of MLS across Ireland, the UK and beyond. Any person interested in viewing these talks can do so from the online video of the day which is hosted on the IMLSN website (IMLSN, 2015).

5. Acknowledgments

This workshop was funded by the National Forum for the Enhancement of Teaching and Learning through their Seminar Series funding round, the Irish Mathematical Society, the UCD Media Services team for recording the day's talks and the UCD School of Mathematical Sciences for extra funding and administrative support.

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CASE STUDY

Designing and using informal learning spaces to enhance student engagement with mathematical sciences.

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Abstract

By helping create a shared, supportive, learning community, the creative use of custom designed spaces outside the classroom has a major impact on student engagement. The intention is to create spaces that promote peer interaction within and across year groups, encourage closer working relationships between staff and students and support specific coursework activities - particularly group work. Such spaces make better use of time since students are motivated to stay and work during long gaps in their timetable, provide a sense of 'home' within the institution and can lead to a cohesive community of practice. We describe how this has been achieved and currently delivered in Mathematics at Sheffield Hallam University and provide evidence for its success.

Keywords: Mathematics, learning community, student engagement, peer support, partnership learning.

1. Context

At the outset, it is important to be clear about what we mean by student engagement in the mathematical sciences. We are suggesting the following (based on Duah and Croft, 2011):

"The time, energy and resources that students devote to the study of mathematics, including (but not limited to) active participation in directed study tasks such as coursework and revision as well as participation in relevant extracurricular activities, learning to become part of the community of practising mathematicians".

Student engagement, satisfaction and academic success is built upon this sense of belonging – of being part of a professional community that provides, amongst many other things, comprehensive support. Croft and Grove (2015), discussing reasons for the 'sophomore slump' - a common and well documented dip in achievement suffered by many students in their second year of study - stress the importance of a sense of belonging and inclusion in a peer or departmental mathematical community and the learning and teaching relationship between staff and students; alienated students refer to lecturers' lack of interest in them, existing on the margins and not being part of the learning community. This can be achieved through a culture of expectation and behaviour, the provision of appropriate support structures and the effective use of carefully-designed physical and virtual learning space. It is self-evident that active participation is more likely to happen in an environment that learners are happy to study in.

In the Student Experiences of Undergraduate Mathematics (Brown et al., 2005), feeling part of a mathematical community emerged as a crucial factor in the student experience; in SEUM this community focused on one physical space where students could work together and also meet academic staff in an informal way. A critical factor identified was the opportunities provided for interactions with other students and staff.

Suitably-designed open learning space facilitates staff-student and peer interaction by supporting new patterns of social and intellectual behaviour (Oblinger, 2005); providing spaces where faculty and students can ‘run into’ each other increases engagement and learning (Hunley and Schaller, 2009). Learning is an active, collaborative and social process, hence ideal learning spaces should be designed to encourage personal interaction; they also need to be IT-enabled to encourage virtual interaction. Working in close proximity to friends or peers to create a sense of community, for co-support and for someone to take a break with was a key learning preference expressed by learners (Harrop and Turpin, 2013).

Another aspect of community is the feeling of a common purpose. Many learners reported that working in a shared learning environment is motivational. It seems that students are aware of what makes a space feel like a place. Place is about environment, but also about people and what is going on inside.

Incorporating a disciplinary focus in the design helps learners identify with that discipline and feel they belong to a professional community; this, together with a managed peer-support network, helps create a partnership learning community within which student engagement can flourish (Boys, 2011; Healey et al., 2014). New students can ask questions of students from later years of the course that they may not feel comfortable asking of academic staff, increasing confidence and self-efficacy (Walker, 2015). There is clearly wider recognition of this; as pointed out by Harrop and Turpin (2013) *"across the higher education sector worldwide, in particular the UK, Australia and the US, you do not have to look far for examples of new or redeveloped learning spaces, with particular growth taking place in what are termed informal learning spaces."*

As part of a major refurbishment project at Sheffield Hallam University the Mathematics Subject Group were offered the opportunity of relocating to a new area, and because of having achieved excellent staff-student relations - as evidenced by the National Student Survey - were also given the chance to design the layout of this space.

For some years we had observed our students gathering to work in whatever open space was available close to staff offices. Although their principal reason for doing this was so they could more easily call upon staff for help, a supportive network - involving all year groups - began to develop naturally as a result. In addition to academic support, cross-level Peer Support Groups underpin an effective learning community. We knew of supplemental instruction (University of Missouri-Kansas City, 2015) and were familiar with Manchester’s Peer-Assisted Study Sessions scheme that evolved from it (University of Manchester, 2015). Such supportive ‘spaces of influence’ provide additional value from existing structures with low resource implications (Vygotsky, 1978; Ladyshewsky and Gardner, 2008) and are highly valued by students (Croft, Solomon and Bright, 2008). Recognising that students will look first to each other for support (e.g. Waller, 2012), we were keen to further encourage this, and set up a Peer-Assisted Learning (PAL) scheme (Waldock, 2011) in which final year volunteer PAL Leaders facilitate a first year group task both helps embed links across year groups and also supports induction into University for new students by creating friendship groups. Although the PAL initiative in mathematics at Sheffield Hallam University runs for just one semester in year one, these groups normally persist naturally throughout students' entire course and sometimes beyond forming a powerful peer-support mechanism - a phenomenon also identified by Croft and Grove (2015) and Inglis et al. (2012). These factors informed our thinking when considering the design of the new space.

Based on this experience, a core principle in the design was that staff offices and student workspace would be co-located; the University's initial recommendation of a large open-plan staff office behind locked doors was rejected in favour of an open shared learning space. This was to encourage informal contact between staff and students, seen as a vital element in a successful learning partnership. We also wanted to provide a place that facilitated both individual and group work where students could work productively in between classes. Part of the space therefore was given over to six group-working tables for 4-6 students each equipped with a PC and large plasma screen (see Figure 1). The importance of providing mobile IT support was also recognised and hence a high capacity wireless network was installed.

Figure 1. Illustrating two of the IT-enabled group working tables. This is also the Maths Arcade area - the grey games cabinet can be seen on the back wall next to the printer. Note also the provision of wall-mounted whiteboards wherever possible.

Other parts of the space were used for informal seating allowing group discussion, and two small meeting rooms were provided where interviews, private discussions or practice presentations could take place (see Figures 2 and 3). Altogether there is room in the open learning space for up to 60 students at any one time.

Figure 2. Illustrating some of the group working space, including fixed PC provision, easy seating and staff offices.

Figure 3. Illustrating further fixed PC provision and one of the two small meeting rooms.

The SHU Mathematics programme aims to deliver employable graduates. As indicated in the QAA benchmark statement (QAA 2015) mathematics programmes vary across the spectrum from being practice-based to being theory-based but all should focus on developing graduates with good study skills, being able to work independently or in teams, being adaptable, comfortable with IT and good at communication. The benchmark statement for mathematics (QAA, 2015) recommends that *"teaching spaces have appropriate facilities that allow both the development of extended mathematical arguments (requiring space) and effective projection equipment"*. The group working areas provide these facilities. We also installed wall-mounted whiteboards wherever possible - clearly a popular feature as students were using them before the fitter had even finished installing them!

Further modifications to the space are taking place soon as part of the University's 'Expressions' project, in which newly refurbished space is customised to enhance the identification of the space with the academic discipline. These will include large designs on the interior and exterior of the curved meeting room walls, additional posters of work carried out by students while on industrial placement, 3-D designs on some vertical pillars and a frosted panel adjacent to staff doors with section heights determined by twin Fibonacci sequences (the room number in binary will be engraved on a centre section).

As the SHU course has a practical focus we want graduates to be proficient in putting theoretical concepts into practice. There is strong evidence (e.g. Kolb and Kolb, 2005) that experiential learning, involving an interactive and immersive approach, stimulates interest and engagement and helps students become more aware of the practical applications of the theoretical concepts they are studying. This was a strong influence on the model adopted for the teaching room, which has space for 50 students to work around small group tables (see Figure 4). A large teaching wall was provided for lecture presentations and a set of 50 laptops in lockable cabinets allowed the room to be used for IT enabled sessions. The cohort size is around 100 per year, and one planned use for the room was to redesign delivery from the 'standard' large lecture followed by four group tutorials to two doubly-staffed sessions of 50. This would allow the session to be a mix of lecture and tutorial/seminar activity - involving elements of experiential learning - and although there is an additional cost of delivering part of the material twice we judged that it would be more than made up for by the benefits in enhancing the student experience. We also plan to employ the SCALE-UP approach to developing student-centred active learning in this teaching space (Nottingham Trent University, 2015).

Figure 4. A view of the teaching room, with movable group working tables, a large teaching wall and one of the two laptop cabinets visible.

Figure 5. The teaching room has been used for a variety of activities, such as the Sheffield Royal Institution masterclass series, shown here.

2. Measuring the benefits

The new space has been designed to achieve a range of objectives, as discussed in the previous section. In order to identify the extent to which these objectives are being met, a short online survey of staff and students comprising three questions was carried out. These were:

1. What do YOU feel the benefits are of this new space?
2. Is there anything you feel better able to do now compared to before?
3. What else should this space provide?

An open space for free text comments was also provided.

Responses were received from 9 staff and 27 students (full details available at https://maths.shu.ac.uk/staff1415/poll/poll_results.php). The student responses are categorised as follows (with representative comments shown).

Improved availability of staff

"*Having such a wealth of knowledge just a knock away is brilliant - it is so much easier to approach staff than previously.*" (Second year student)

Developing a mathematical community

"Having a home for the discipline makes the maths department seem more united." (Final year student)

"Working around people studying the same subject - a sense of 'home'." (Second year student)

"As the area is purely maths it is easier to find someone who also studies a module you do and promotes students to help one another and interact." (Final year student)

"There are always people to ask if you are stuck, even ask other years for help." (First year student)

Facilitating work

"It's a very bright, open space with good modern features - three things for me that make working easier." (Second year student)

"Big round tables are excellent for team work and sharing ideas." (First year student)

"Whiteboards and pc TVs promote group work and problem solving." (First year student)

"It is also open and tidy and I can think better in spaces like that. The meeting rooms and group booths are great for when you want to work with friends as well." (Second year student)

"It's conducive to group work since there are tables we can huddle around and whiteboards." (Final year student)

Additional benefits. Students also identified some specific benefits of working in the new space that offered a significant advantage to them:

"I can get to work much faster due to the computers being very good." (Second year student)

"I can also use gaps in the timetable to do work before going to lectures which may be right next to the main PC area." (Second year student)

"Before I only came into university for lectures and worked at home, which isn't always effective with the distractions of student life. Now I can spend all day in the maths department meaning that I work much more efficiently and get to spend more time on my studies." (Final year student)

"I feel better able, and more willing, to do work at uni now I know there is a good chance of getting workspace whenever I need it. It means I'm more inclined to stay at uni (and be more productive) instead of going home after lectures." (Final year student)

Other student comments

"Really like this idea, it's made everything generally a better atmosphere rather than being lost within the uni not having a home."

"Overall I feel this space is a great for all mathematicians. Its spacious design has led to a great social atmosphere as well as providing excellent study facilities. Intermingling between year groups has also been created and the extra interaction between student and staff will no doubtably (sic) aid in the provision of work and assignments. The space has been a great addition to the university."

"A great space to be in and I enjoy going there to study!"

"It's great, I love it, haven't been to Library all semester."

Staff Comments

"More inter-year communication. Conversations between year groups is happening more."

"Events can be held. Within a classroom they might have not been appealing."

"Interactions with students. This includes saying just saying hello. It also includes things like being able to introduce students to people in other year groups who are struggling with making elective choices and would like more info about what the modules are like."

"Course cohesiveness. There is a definite feeling of belonging. Proximity between staff and students seems to encourage approachability. It seems like a really nice area to work in and is well used."

"Really friendly good atmosphere amongst all maths students of different years in particular Maths Arcade and the de-stress day have both taken off because of it."

"I feel like I am now more approachable!"

"Sense of identity and community for both staff and students. A little bit intangible but important and ties in very well with our ethos."

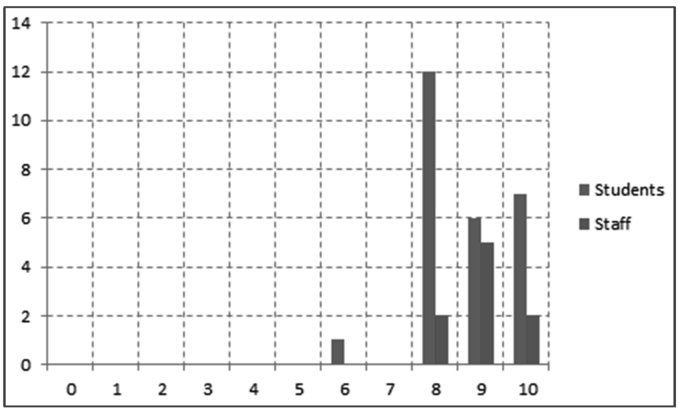

Figure 6. Frequency of subjective ratings of the new learning space

Staff and students were also asked to rate the new space on a scale of 0 to 10 (Figure 6). This illustrates the extent to which all users of the space are satisfied with it. Ratings less than 10 are associated with comments along the lines:

"There are lots of students from other courses coming in to do their work making it sometimes harder to find spaces to sit as peak times."

The University mistakenly advertised the space as available to all, but this was corrected and signs put up stating it was for maths students only, and the problem has been resolved.

3. Commentary

A new mathematics 'hub' space for mathematics at Sheffield Hallam University has been created, designed to encourage students to engage in course-related activity outside scheduled class time, improved staff and student partnerships to build a supportive discipline community.

It has been in use since the start of 2015, and early indications are that expectations of the benefits of its design are being met, with more students engaging proactively in group work outside taught sessions and feeling better supported by staff and peers. There is a clear discipline specific focus to the space and participation in regular events it hosts such as the Maths Arcade, a national project set up by the University of Greenwich in which logical thinking is developed through the use of strategy games (Bradshaw, 2011), have risen significantly; situating the activity in an open space has the effect of drawing in additional participants who might otherwise either not know it was happening or be deterred because it was taking place behind a closed door.

Student comments indicate that the provision of custom designed discipline space in which they have had an active part to play in the design leads to increased motivation to use the space to engage with curricular and extra-curricular activity, to take part in group work and to form an active learning community.

Not to be neglected is the added benefit of staff motivation, engagement and participation in forming this active community. Focus is often placed on building an engaging and dynamic student experience without explicit recognition that this is equally important for staff. Staff responses to the survey indicate that initially at least, fears that they would be inundated with requests for support have not been realised; students recognise that to become an independent autonomous learner they need to call upon staff for support after first working on a problem either alone or in groups, and respect the fact that staff also have other demands on their time.

There will be future difficulties to be faced, such as finding room for expansion to support increased levels of undergraduate recruitment. We also recognised our good fortune in having an institutional estates strategy that has allowed us to take a leading role in the design of this new space. Across the sector, the central involvement of academic teaching staff in planning and design is not the norm, however perhaps the successful experience reported in this case study may help support a case for a similar involvement of colleagues when planning redevelopments elsewhere.

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CASE STUDY

Playing Games: A Case Study in Active Learning Applied to Game Theory

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Abstract

This paper describes two active learning activities which aim to introduce students to the game theoretic concepts of best response dynamics and repeated game analysis. An overview of some literature on active learning and the benefits therein is provided. This highlights that activities such as the one described in this manuscript, not only help engage students but more importantly improve their learning and understanding. The final section of this work describes how these activities fit in the pedagogic framework of a particular undergraduate mathematics class. Students generate data that can be used as context for the understanding of theoretic concepts. It is suggested that this framework is not restricted to the subject of game theory.

Keywords: Active Learning, Game Theory, Prisoner's Dilemma.

1. Introduction

Modern pedagogic theories as to how learning takes place such as constructivism and socialism. Illeris (2009) and Jordan et al*.,* (2008), indicate that an **active learning** approach is of benefit to student learning. As stated in Prince (2004) there are a variety of complementary definitions of active learning, however the general definition given in Prince (2004) is the one assumed in this paper:

"Active learning is generally defined as any instructional method that engages students in the learning process. In short active learning requires students to do meaningful learning activities and think about what they are doing."

One could argue that all learning is active as simply listening to a lecture is perhaps taking part in a 'meaningful learning activity', however as stated in Bonwell and Eison (1991) active learning is understood to imply that students:

- Read, write, discuss, or engage in solving problems;
- Engage in higher order tasks such as analysis, synthesis and evaluation.

A variety of studies have highlighted the effectiveness of active learning (Hake, 1998; Prince, 2004; Freeman et al*.,* 2014). These two papers are in fact meta studies evaluating the effectiveness of an active student centred approach. Note that the definition used in Freeman et al*.,* (2014) corresponds to simply any pedagogic approach in which students are not passive consumers of a lecture during the class meeting. Some examples of active learning in a variety of subjects include:

- The flipped learning environment in a Physics class: Bates and Galloway (2012);
- Inquiry based learning for the instruction of differential equations: Kwon et al*.,* (2005);
- Using collaborative learning in a pharmacology class: Depaz (2008).

The above sources (and references therein) generally discuss the pedagogic approach from a macroscopic point of view with regards to the course considered. This manuscript will give a detailed description of two particular active learning activities used in the instruction of Game Theoretic concepts:

- Section 2.1 will describe an in class activity used to introduce students to the topic of best response dynamics and dominated strategies (Macshler et al., 2013);
- Section 2.2 will describe an implementation of Axelrod's tournament (Axelrod 1980a; 1980b).

These activities aim to introduce participants to concepts and aspire to their curiosity as to the underlying mathematics. Note that if there is any doubt as to the effectiveness of active learning approaches, for example Andrews et al*.,* (2011), which identifies no such relationship, inciting curiosity and engagement are still beneficial to the students' learning. Indeed in Poropat (2014) the greatest predictors of academic performance are identified not as general intelligence (Wright, 1905), but personality factors such as conscientiousness and openness.

Section 2 will describe the activities and Section 3 will detail how these fit in a more general pedagogic context. Finally, all source files for this paper (including data and the analysis) can be found at the url: https://github.com/drvinceknight/Playing-games-a-case-study-in-active-learning.

2. An exemplar: a course in game theory

Game Theory as a topic is well suited to approaches that use activities involving participants as players to introduce the concepts, rules and strategies for particular games and/or theorems presented.

In Brokaw and Merz (2004), one such activity is presented: a game that allows players to grasp the concept of common knowledge of rationality. Another good example is: Yale's Professor Polak's course (Polak, 2008), the videos available at that reference (a YouTube playlist) all show that students are introduced to every concept through activity before discussing theory (this is akin to the framework discussed in Section 3.

Just as the activity presented in Brokaw and Merz (2004), the activities presented here are suited for an early introduction to the concepts (although the activity of Section 2.2 is potentially better suited to being used at a later stage). Furthermore, these activities have also been used successfully as outreach activities for high school students with no knowledge of further mathematics.

2.1. Best response dynamics and dominated strategies

The first step in this activity and potentially before any prior description of Game Theory is to invite participants to answer the following simple question:

What is a game?

Through discussion the participants will usually arrive at the following consensus:

- A game must have a certain number $N \geq 1$ of players;
- Each player must have available to them a certain set of strategies that define what they can do;
- Once all players have chosen their strategy, rules must specify what the outcome is.

This corresponds to the general definition of a strategic form game. The main goal of this activity is to not only understand the vocabulary but also the important concept of best response dynamics which aims to identify what is the best option given prior knowledge of all other players (Maschler et al*.,* 2013). A particular game that can be analysed using base response dynamics is often referred to:

The two thirds of the average game.

A good description of the game and the human dynamics associated to it is given in Nagel (1995). The use of this game in teaching is not at all novel (The Economics Network, 2013). The rules are as follows:

- All players choose a number between 0 and 100;
- The player whose guess is closest to $\frac{2}{3}$ of the average of the choices wins.

To make use of this game in class as an introduction to the concept of best response dynamics students are handed a sheet of paper inviting them to write down a first guess. After this initial play, a discussion is had that demonstrates that the equilibrium for this game is for all players to guess 0. This is shown diagrammatically in Figure 1.

Following this discussion students are invited to play again and write down their second guess. All of the results are collected, the author has used paper forms but an automated approach could also be used. In general the input and analysis of the data takes less than 10 minutes and can be done by a helper during another class activity. Following this, the results (corresponding to the results of Figure 2a) are shown and discussed. This discussion usually revolves around the observation that not everyone acted rationally and second that some participants felt like they should 'spoil' the game by guessing larger in the second round.

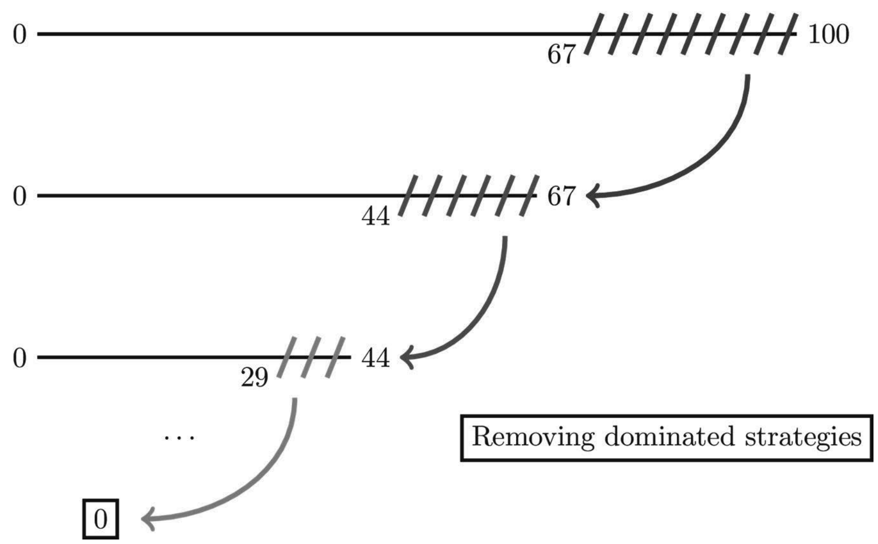
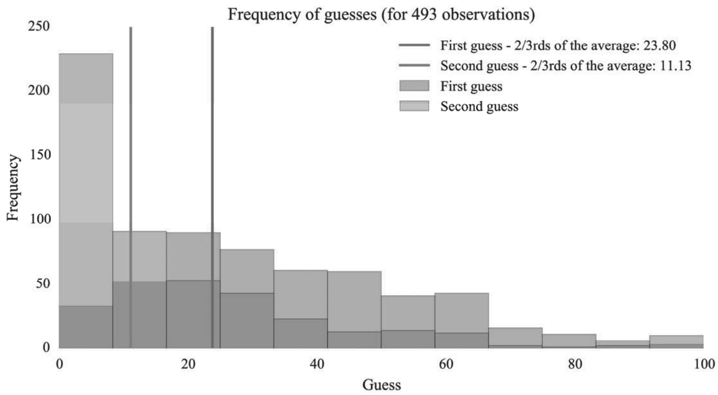
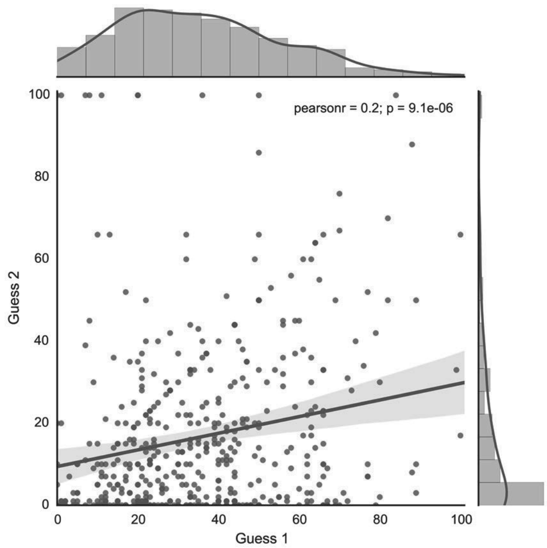


Figure 1. Equilibrium behaviour in the two thirds of the average game.

The author has used this activity on a large number of occasions and at all times collected the data. Figure 2a shows the distribution of the guesses (depending on the round of play).



(a) Frequency of guesses depending on the round of play



(b) Linear relationship between guesses of each round of play

Figure 2. Results from all data collected.

We see that the second round (after the rationalisation of play described in Figure 1) has guesses that are closer to the expected equilibrium behaviour. Figure 2b confirms this showing the linear relationship (albeit a weak one with $R^2 = 0.2$):

$$\text{(Second guess)} = 0.203 \times \text{(First guess)} + 9.45 \qquad (1)$$

The fact that the coefficient of the relationship (0.203) is less than one highlights that the second guess is in general lower than the first guess. As can be seen in Figure 2(b) not all students reduce their guess. Figure 3 shows the results when removing these irrational moves. In this particular case the linear relationship is in fact stronger $R^2 = 0.43$:

$$\text{(Second guess)} = 0.33 \times \text{(First guess)} + 0.20 \qquad (2)$$

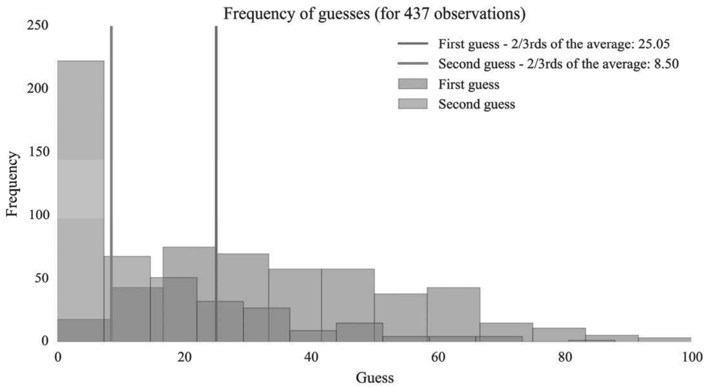
Finally, if time permits (and depending on the level of the participants), the linear relationship of (1) is used to discuss what would happen if more rounds were to be played. In particular it is possible to discuss ideas of convergence (cobweb diagrams in particular) when generalising (1) to be:

$$\text{Guess}_{n+1} = 0.203 \times \text{Guess}_n + 9.45 \qquad (3)$$

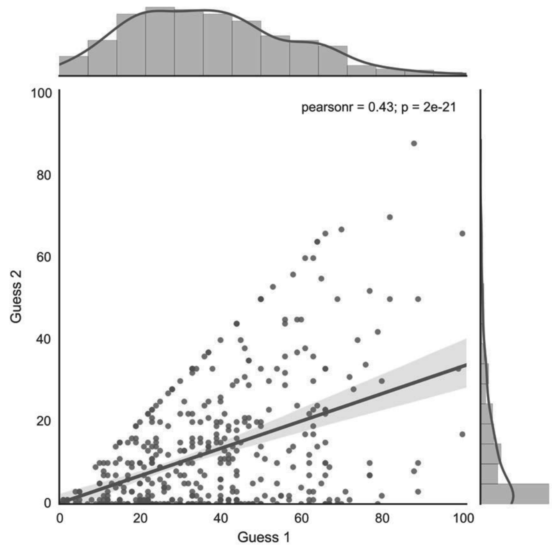
To summarise this activity has the following steps:

1. Participants are explained the rules and play one round of the two thirds of the average game.
2. A rationalisation and explanation of equilibrium behaviour is described.
3. Participants play another round.
4. Results are analysed and discussed.

This activity is still quite passive in terms of physical activity (participants are seated throughout). Nevertheless it allows the data used for the discussion of the theory to come directly from the participants. Furthermore all students are active participants and there are no difficulties with regards to encouraging participation (references to these are discussed in Rocca, 2010).



(a) Frequency of guesses depending on the round of play



(b) Linear relationship between guesses of each round of play

Figure 3. Results from data when removing increasing guesses.

At the time of writing this article, software is being written to help quickly analyse plays of the tournaments (and produce the graphs seen above). Documentation for this can be found at: http://twothirds.readthedocs.org

2.2. Repeated and random games

This activity is used to introduce students to the concepts of repeated games (Maschler et al., 2013). The mathematical details can be omitted from the initial description of the activity to the participants but for completeness they are included here.

A repeated game is played over discrete time periods. Each time period is indexed by $0 < t \leq T$ where T is the total number of periods. In each period N players play a static game referred to as the **stage game** independently and simultaneously selecting actions. Players make decisions in full knowledge of the **history** of the game played so far (i.e. the actions chosen by each player in each previous time period). The payoff is defined as the sum of the utilities in each stage game for every time period.

One of the most renowned repeated games is referred to as **Axelrod's tournament** (Axelrod, 1980a; Axelrod, 1980b), which is what is recreated in this activity.

Initially a description of the prisoner's dilemma is given. The prisoner's dilemma is a simple two player game that is often used to introduce the very basic notions of game theory. It is described by the following two matrices:

$$A = \begin{pmatrix} 3 & 5 \\ 0 & 1 \end{pmatrix} \qquad B = \begin{pmatrix} 3 & 0 \\ 5 & 1 \end{pmatrix}$$

The row player has utility given by A and the column player has utility given by B. The strategies available to each player are to cooperate: C or to defect: D. Playing C corresponds to players choosing their first row/column and D, the second row/column.

Thus if both players cooperate they both receive a utility of 3, if one player defects, the defector gets a utility of 5 and the cooperator a utility of 0. Finally if both players defect they receive a utility of 1. As players (in this framework) aim to maximise their score, the Nash equilibrium for this game is for both players to defect.

After describing this activity and in particular explaining the simple mathematical idea of **dominated strategy** (which is what is used in the activity of Section 2.1) participants are made aware of the concept of Nash equilibrium (This in turn can lead to a brief description of the tragic yet brilliant life of John Nash).

At this point the activity is described:

1. All participants will form four groups/teams;
2. Teams will 'duel' each other in repetitions of 5 to 8 rounds (depending on available time).
3. All teams will play in a round robin tournament with cumulative scores being recorded.
4. The victorious team will be the team with the highest total score.

The tournament is run with all participants present (even those not involved in a duel). All participants are invited to stand and confer in their teams. The importance of standing (as a physical activity) is noted in Donnelly and Lambourne (2011) (whilst that reference is mainly concerned with the impact of activity on physical well-being it also describes advantages in terms of concentration). Before every round of every duel, opposing teams are encouraged to discuss strategies, after which they face away from each other and following a prompt hold up a card indicating either C or D. Duels are recorded on a wall-board in a table similar to the ones shown in Tables 1 and 2. Table 1 shows two strategies, which constantly cooperate (thus obtaining a utility of 3 in each round). Table 2 shows an example where a strategy that is alternating plays against a strategy that always defects. Figure 4 shows a photo of a final board for a particular implementation of this activity.

Table 1. Playing Tit for Tat against Cooperator

Tit for Tat	3	6	9	12	15
Cooperator	3	6	9	12	15

Table 2. Playing Alternator against Defector

Defector	5	6	11	12	17
Alternator	0	1	1	2	2

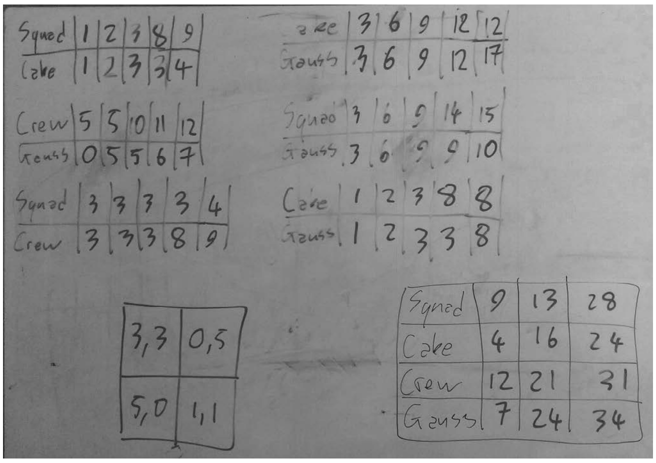


Figure 4. A photo of an actual implementation of the tournament.

The names of the strategies shown in Tables 1 and 2 are strategies that were used in the original tournaments run by Axelrod (Axelrod, 1980a; Axelrod, 1980b). The interesting fact of repeated games and one that usually becomes apparent to participants through the activity is that whilst repeating the stage Nash equilibrium (always defect) is indeed a Nash equilibrium for the repeated games, this equilibrium is not unique as reputation now has a part to play.

Note that if participants do not realise this, it is important to remind them that the goal is not to win each duel but to obtain a high score overall. Often during the tournament one team will (during the pre-round discussion) exclaim:

"We will cooperate until you defect, at which point we will defect throughout."

Without realising it the participants have described a well-known strategy (**Grudger**) which takes in to account the entire history of play.

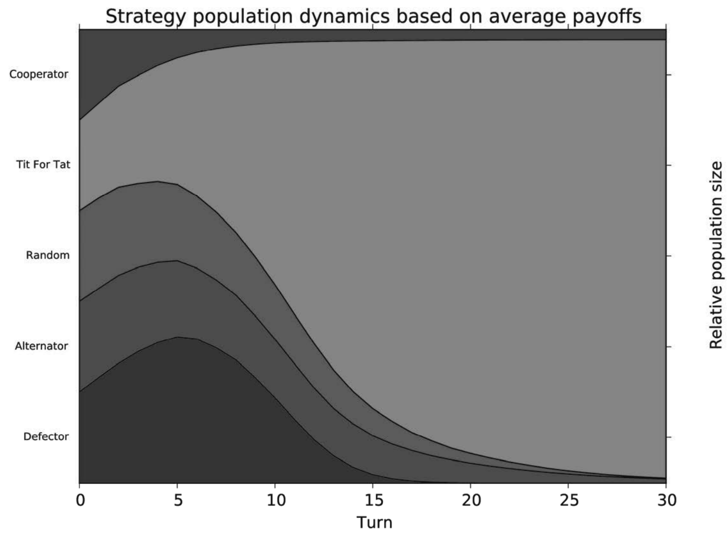


Figure 5. Repeated games in an evolutionary context.

This activity can be complemented with a demonstration of software that allows for the rapid simulation of Axelrod's tournament team (Axelrod-Python Project Team, 2015). Figure 5 shows the performance of the strategies when put in an evolutionary context.

One of the inconsistencies of this approach is that all participants observe the play by all the teams. Whilst from a mathematical perspective reputation is inferred to mean the reputation gained during a particular duel, this has the effect of teams being able to observe how other teams seem to play. A true replication of Axelrod's tournament would not allow for this. One possibility would be to invite participants to leave the room, which might be logistically constrained. From a pedagogic point of view however, having participants observe the duels often leads to a much more engaged discussion (after, as well as during the activity).

This activity is usually very enjoyable and leads to a lively discussion. Further to the fun had by participants, the theoretic discussion about repeated games can be placed in the exact context of the tournament that has just been played.

The activity can also be used to introduce further game theoretic topics with slight modifications:

- **Infinitely repeated games with discounting**: the discount factor can be interpreted as a probability of the duel continuing for another round (this can be randomly sampled);
- **Markov games**: two random game states can be a true game and an absorbing game so that this corresponds to an infinite game with discounting;
- **Evolutionary games**: this follows from considering strategies in an evolutionary context as shown in Figure 5.

3. Summary and place within a pedagogic framework

These activities have been used by the author during outreach events during which students take part in the activity of Section 2.1 and whilst the results of that are being analysed take part in the activity of Section 2.2. These two activities complement themselves and form an accessible introduction to novel mathematical topics for a wide range of age groups.

More notably however these activities have been used as part of a family of activities used in a final year undergraduate course. This particular course is taught in active learning pedagogic framework akin to a flipped class where students are introduced to theoretic concepts through prior 'playing of games'. Other examples of these activities include:

- **A rock paper scissors lizard tournament:** this serves as an introduction to mixed strategies;
- **A variety of games using coin flips:** this serves as an introduction to games with incomplete information;
- **Playing paper bin basketball in teams:** this serves as an introduction to cooperative game theory.

The general pedagogical basis for this is discussed in Section 1 and the particular framework is shown in Figure 6. Students are active participants in the creation of 'data', which drives a discussion:

- Why did you all guess this?
- Why did that team say that on that particular occasion?
- What would be a fair way of sharing the spoils for this particular game?

Following that discussion the theory can be put in context by highlighting particular theoretic results and how they correspond (or not) to the behaviour exhibited during the activity. Furthermore, this encourages immediate feedback with regards to student comprehension, which can be reactively addressed.

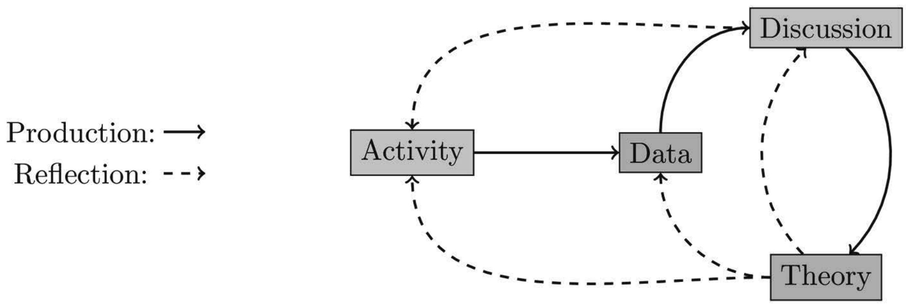


Figure 6. The active generation of data by students.

This pedagogic approach is used throughout the course (from the first lesson) and so after a few class meetings students are used to the high level of participation. Here are some examples of written feedback concerning the activities used in class:

“Classes were fun.”

“The games helped make the content interesting.”

“This course teaches me to not trust my classmates.”

Nonetheless at the start of the course certain class management techniques described in Rocca (2010) are used. For example, the extension of the ‘waiting time’ for responses to questions is implemented. For students to be active participants it is vital that they are given the time to do so.

The activities described in Section 2 are particular to game theory however the author does not feel that the general pedagogic strategy outlined in Figure 6 is constrained to a particular subject. Similar activities could be devised in other subjects where students generate ‘data’ that aids the contextualisation of theory so as to aspire to not only a constructive learning model but also a social one.

4. Acknowledgements

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CASE STUDY

A proactive collaborative workshop approach to supporting student preparation for graduate numerical reasoning tests

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Abstract

Numerical competency and reasoning skills are of high importance and high concern to graduate recruiters. The use of numerical reasoning tests in graduate recruitment is increasing. Many students are unaware of the prevalence of these tests, and the need for refreshment and practice of numerical skills. We describe a stand-alone workshop that is jointly run by the Maths Learning Centre, and the Careers and Employability Service at De Montfort University. This workshop helps students to proactively prepare for these tests by providing test information, preparation tips and signposting to further maths and career support. The workshop's main feature is a testing activity that is run individually and for small groups. Findings suggest that these workshops have been effective and are popular with students.

Keywords: employability, graduate, recruitment, numerical, psychometric.

1. Introduction

This paper describes an innovative approach to supporting students in graduate recruitment numerical test preparation, based on:

- Close collaboration and team workshop design and presentation, by the Maths Learning Centre (MLC) and Careers and Employability (C&E) at De Montfort University (DMU);
- Development of a bespoke workshop, 50% mathematics, 50% test preparation tips and skills;
- Using individual and team testing to assess and develop successful numerical techniques;
- Signposting to further mathematics and careers support;
- Follow-up access to an online graduate recruitment test programme that measures progress and suggests areas for development.

2. Background

Hughes, Sheen and Birkin (2013, p.17) report that "Amongst the cross-cutting skills identified by employers as being in greatest demand, competency in mathematics frequently appears high up in lists of desirable characteristics of graduates." Another report finds that general numeracy is in short supply among graduates and postgraduates in many industries (Docherty and Fernandez, 2014, p.7). It is therefore unsurprising that the use of numerical reasoning tests has increased from 33% of graduate recruiters in 2004 (CFE Research, 2004) to at least 52% of employers in 2014 (CFE Research, 2014). (The survey found that 67.4% of graduate recruiters use psychometric testing, and that 77.2% of these used numerical reasoning tests.)

In 2012, the Maths Learning Centre observed an increased number of students who were coming for mathematics support for graduate recruitment tests. Often these students came looking for help at ‘the eleventh hour’ – that is, after they had been invited to take part in an online numerical reasoning test (often with a 48 hour deadline). Maths preparation and support at this late stage was inevitably of limited benefit to the student and, arguably, an inefficient and ineffective use of staff time within an open mathematics drop-in support session.

It was clear that a new approach was needed to support students in their numerical reasoning test preparation. Students needed to be informed about the prevalence of numerical reasoning tests, and the need to refresh their numerical reasoning skills as an integral part of their graduate recruitment preparation. The importance of extensive question practice needed to be emphasised, and a proactive approach to problem acquisition and solution needed to be encouraged. Accordingly, the Maths Learning Centre approached Careers and Employability to work together on an approach to address these issues.

3. Overall design of workshop

Although various solutions were possible, we needed an approach with minimal cost that would be relatively quick to implement, and which would reach as many students as possible. We also hypothesised that students attending open drop-ins were there because of wanting face-to-face support (otherwise they would have found online resources already). Although we invested in online resources for follow-on support, we considered that initial face-to-face contact was a key factor in motivating students to do more preparation.

3.1 Aims

There were two main aims in the creation of the numerical reasoning preparation workshops:

- Encourage a proactive approach among students, and early extensive revision of numerical reasoning skills;
- Provide signposting to the full range of mathematics and careers support that is available in the institution, and suggest ways to maximise effective and efficient access to it.

Achievement of these aims would benefit students in their search for graduate jobs and also staff within support services by stream-lining this particular aspect of work.

3.2 Delivery

To maximise the number of students who could access the numerical reasoning workshops, we decided to develop a ‘standalone’ format that would run monthly (more often in the autumn term) at a time outside of timetabled lectures for most students. Hence, it usually runs on Wednesday lunchtime and is 1.5 hours in duration. Places are open to all students and graduates and can be booked through the online student portal. We limit spaces to 40 per session, to promote smooth running of the testing activities.

The workshops have two presenters (one apiece from MLC and C&E) so that we can each lead on our own speciality (although we are both able to present solo on occasion, as needs arise).

We begin with a description of graduate recruitment tests and an explanation for why companies use them, while emphasising their prevalence. We then run a testing activity, where participants have ten minutes to individually complete a seven question test. In the following ten minutes, they tackle the same test in teams of three or four. We then discuss the solutions in plenary, and provide hints and tips for successful test preparation. Further maths and careers support options are then highlighted. We also promote the verbal reasoning workshops run by colleagues. Directions are given to the online graduate recruitment test programme to which the institution has subscribed. The workshop concludes with a question and answer session, and feedback evaluation sheet.

3.3 Testing activity

When designing the workshop, we decided that including a short individual testing activity would give students a chance to self-assess their numerical reasoning skills in a supportive environment. In order to avoid deterring anxious students, we do not mention the individual testing activity in promotional literature, and when introducing the test, we take care to do so in a positive encouraging way.

To maximise the usefulness of the test, we designed seven multiple choice questions of industry-level standard, that cover a broad range of numerical reasoning skills (percentages, ratios etc.) as well as a broad range of question contexts (engineering, business etc.). We chose a time limit of ten minutes to put students under some pressure, but not excessive pressure. We use an online countdown timer to encourage an exam-like atmosphere.

The individual test is followed by a ten minute team activity where students work on the same questions in groups of three or four. This is a chance for them to explain their work to others, or see how other people problem-solved. We assign the teams using a brief (random) maths activity, and encourage students to see the team 'test' as an opportunity for them to self-assess their use of graduate employability skills such as assertiveness, leadership, teamwork. The fact that they are working with peers that they have never met before is very useful here. At the end of the activity, teams submit a solution sheet so that we can assess their work and announce the winning team.

In the solutions section of the workshop, we focus on questions where the teams have struggled to get the right answer. As well as explaining the techniques, we emphasise faster ways of answering questions. Due to time constraints, and the range of maths skills among participants, we speak broadly about the questions and distribute full solutions at the end of the session.

3.4 Evaluation

We use paper evaluation forms to gather feedback on sessions. As part of this, we ask participants to self-assess their numerical reasoning confidence and knowledge on a scale of 1 (very low) to 10 (very high), at the start and end of the workshop. We also gather comments about the session and ask the student where they heard about the session. Forms are collected at the end 'in exchange' for a copy of the slides and solutions. Analysis of the participant population as a whole can now be undertaken annually using data obtained from the online booking system. We aim to gain further insight into the diversity of students accessing the workshops and their employment outcomes.

4. Outcomes

Participants in the last two years have reported increased knowledge and confidence for numerical reasoning as a result of attending the workshop. The increase reported by participants the previous year is shown in brackets. For 2014/15, the average increase in knowledge was 4.1 to 7.9 [4.4 to 7.3], and for confidence from 3.5 to 7.2 [3.8 to 6.6]. This data reflects virtually the entire participant population as our collection method ensures almost 100% completion of feedback forms.

Attendance on these standalone workshops has been high (113 in 2013/14 and 96 in 2014/15). The latter figure excludes over 30 participants attending workshops that are now embedded into C&E employability programmes.

In terms of future enhancements, due to student demand, and the timing of graduate recruitment, we plan to run a similar number of standalone sessions in 2015/16 but frontload more into the autumn term. Also, the online booking system has enabled us to look at diversity data for participants, and gives us the potential to tailor advertising to reach low participation groups such as white males (66% of participants are female compared with a DMU profile of 57%). We are looking at the possibility of running specific workshops to target some of these under-represented groups (for example, technology students). One option would be to run an in-faculty workshop as part of one of the university's 'Enhancement Weeks'.

Finally, the MLC has seen fewer 'last minute' numerical reasoning test students. In terms of the overall aims of setting up the workshops, this suggests that students have become more aware of the prevalence of numerical reasoning testing and the need for extensive practice. It also suggests that signposting to the full range of maths support that is available is becoming more effective. C&E are very satisfied with the partnership and the establishment of a programme to provide a high quality, proactive psychometric testing support service to students across the university.

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CASE STUDY

Maths Sparks: Developing Community and Widening Participation

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Abstract

Improving the engagement of university students in wider issues of teaching and learning is now an important driver in higher education. Additionally, widening the participation of those who access higher education is a matter of increasing prominence. In this paper we report on a case study initiative addressing both of these issues in a university mathematics department. Staff and university students collaborated in developing a series of mathematics workshops, called Maths Sparks, for secondary school pupils from disadvantaged socio-economic backgrounds. We report on the development of student-staff community as a result of establishing this programme and discuss the increased engagement and motivation of both university students and secondary pupils participating in the series of activity-based workshops.

Keywords: student engagement; student-staff community; widening participation; outreach

1. Introduction

Two prominent concerns of mathematics education in higher education are improving the engagement of undergraduate students who have chosen to study mathematics, and diversifying the range of students choosing to enter higher education to study mathematics. A lot of work has been done in the UK Mathematics, Statistics and Operational Research (MSOR) community in the past 15 years to widen participation to higher education of students with low socio-economic status (SES) (Cox and Bidgood, 2002). However, for these students there is a trend to move away from studying mathematics due to a lack of confidence in their ability to succeed in the subject and to a narrow understanding of mathematics (Lubienski, 2000). Participation in educational activities external to the classroom has been shown to influence students' attitudes about, and interest in mathematics, particularly for students from more disadvantaged social groups (Bhattacharyya et al., 2011). However, while many outreach activities can be aimed at gifted students, evidence from higher education institutes across the UK has shown that widening participation in such programmes is necessary to connect with more students of a diverse range of social backgrounds (Cox and Bidgood, 2002).

The Irish Higher Education Authority (HEA) has set a target for universities to widen participation rates for students from disadvantaged groups to 21% by 2016 (Higher Education Authority, 2014). Within University College Dublin (UCD), the 2015-2020 Strategic Report outlines a key objective to *"attract and retain an excellent and diverse cohort of students, faculty and staff"* (University College Dublin, 2014, p.10) and is focusing activities on widening participation to undergraduate programmes At UCD, the Access Centre has developed links with local schools, which have been designated by the Irish government as being disadvantaged, to provide opportunities for students to experience third level[i] education via summer schools and other outreach events. There remain, however, distinct differences in the proportion of students from lower SES schools (described as DEIS - Delivering Equality of Opportunity in Schools) choosing to go to third level and, specifically, choosing to study mathematics (Higher Education Authority, 2014; Smyth et al., 2015).

While it is important to focus on diversifying the range of students choosing to study mathematics at third level, it is also important to retain those students who are already studying mathematics at undergraduate level. Research has shown that engaging undergraduate students in activities involving both their peers and educators has a positive effect on student attainment (Duah and Croft, 2011) and many higher education institutions are already working to foster more student-staff partnerships (Duah et al., 2014; University College Dublin, 2014). One of the key findings of the recent UK HEA report ‘Building student engagement and belonging in Higher Education at a time of change’ (Thomas, 2012) states that relationships between staff, students, and peers promote and enable student engagement and success in higher education. In addition, the report suggests that these relationships should be nurtured pre-entry to higher education. These findings relate both to current and potential university students; emphasising the importance of a sense of community within a mathematics department where students are encouraged to engage with their peers and with staff in various ways, from participating in outreach activities, to improving learning experiences (Duah and Croft, 2011; Trowler and Trowler, 2011).

With these factors in mind the authors set about developing a mathematics outreach programme where upper secondary students could engage with extra-curricular mathematics topics while learning from third-level peers in an active and collaborative environment. Inspired by the successful ‘Maths Arcade’ (Bradshaw, 2011) and ‘Maths Circles’ (Ó Conaill, 2012) initiatives, we set about establishing mathematics workshops which could be delivered to secondary school students (henceforth referred to as ‘pupils’) by their undergraduate colleagues. These workshops would incorporate mathematical games, problems, and puzzles which would involve mathematical topics outside of the post-primary curriculum. With this programme we hoped to foster an appreciation of, and interest in, mathematics for the secondary pupils which could, in time, lead them to consider choosing a mathematical programme at third level. Simultaneously, we hoped this programme would begin to develop a learning community of staff and students within the School of Mathematical Sciences at UCD.

In the following two sections we report on the outcomes of this pilot case study.

2. Establishing Maths Sparks

In December 2014, students in the School of Mathematical Sciences were invited to volunteer to participate in the inaugural Maths Sparks programme. Eleven students (eight undergraduate and three post-graduate[ii]) volunteered to participate, and this group of students met with the authors in January 2015 to discuss potential mathematical topics to explore and incorporate over four workshops. These students grouped themselves into teams of 2-4 to develop content for their topic and over a number of weeks these workshops were planned, trialled, peer-reviewed, and refined prior to their final presentation.

It was important that pupils taking part in the workshops could appreciate the value of not being able to immediately solve a mathematical problem in their puzzles and games. Instead, activities within the workshops could provide a useful context to develop pupils’ mathematical thinking where they did not always expect to win but could analyse the strategy behind a game (similar to the activities in Maths Arcade (Bradshaw, 2011)). Our university volunteers were therefore encouraged to develop activities which contrasted with traditional text-book exercises (O’Keefe & O’Donoghue, 2011) and encouraged pupils to communicate their mathematical thinking to one another in ‘making sense’ of the problem/game/puzzle (Thomas et al., 2013). In the trialling of workshops it was also emphasised that the content:

- Explained some mathematical principle;
- Was solvable for the students;
- Could include a ‘eureka’ moment;

- Was entertaining for students (Badger et al., 2012).

Teams also had the option of inviting a guest speaker (usually academic staff) to conclude their workshop and outline the applications of that particular topic to pupils. A list of developed workshop content is included in the Appendix[iii].

Collaborating with the UCD Access Centre, pupils from six secondary DEIS schools local to the university were invited to participate in the workshop series. 42 pupils (in the final three years of upper secondary education) participated in the weekly two-hour workshops held over four weeks in an Active Learning Environment[iv] room in the College of Science. These workshops were held on a Wednesday evening from 5pm-7pm and pupil transport was organised and sponsored by the UCD Access Centre. Workshop resources were purchased following successful application to the UCD Teaching and Learning 'SPARC' initiative.

3. Generating Feedback

In attempting to measure pupils' engagement in workshops, each of them was invited to participate in a post-workshop survey every week. The survey contained both quantitative and qualitative feedback, with some questions measured by Likert scale and other questions asking pupils to elaborate on their responses to the workshop. Observation field notes were recorded by the authors to note both the university students' and secondary pupils' participation as facilitators and attendees respectively. In addition, a focus group was held with the university students following completion of the workshop series in order to explore their responses to, and reflections of, their own learning from participation in the programme.

Qualitative survey responses were thematically analysed using open coding (Braun & Clarke, 2006) and the findings from these responses, combined with our other data sources, are reported on below. While this case study was held as a pilot to identify the sustainability and suitability of such a programme, these initial findings provide a strong basis to continue with Maths Sparks in the next academic year as a means of widening university participation and developing student-staff community within the department. We report below on feedback from students and pupils under three themes: pupil motivation and engagement, communication and transferable skills, and student-staff community. In our conclusion we suggest ideas for developing both the programme and subsequent research on this initiative.

4. Findings and Discussion

4.1 Pupil Motivation and Engagement

Through their participation in the Maths Sparks programme we wanted pupils to foster an appreciation of, and interest in, mathematics that might encourage them to continue their study of the subject. Despite having self-selected to participate in these workshops, 17 of the 35 pupils who completed the first survey were 'neutral' about or 'did not enjoy' mathematics in school (see Figure 1).

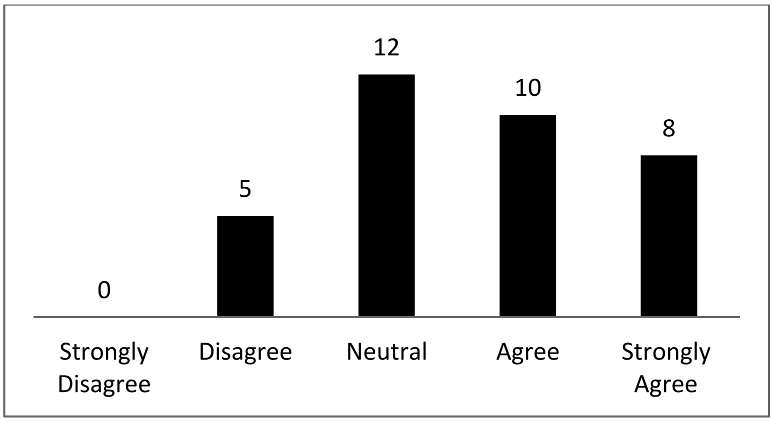

Figure 1. Pupil response to ‘I usually enjoy maths in school’, in week 1 post-workshop survey

This was surprising as we had expected that all pupils who volunteered to attend a four-week course explicitly focused on extra-curricular mathematics would have enjoyed the subject. Interestingly, all students reported on their positive engagement with the mathematical content contained within the first workshop and this favourable feedback continued throughout the rest of the four workshops.

Students continually noted that they enjoyed the mathematical content of the workshops since it was applicable to real life. They were encouraged to think about mathematics in a new way since the practical applications of concepts were emphasised in the workshops and in the concluding academic presentations. The positive responses from the students included the following:

“I liked the way maths I did here related to everyday life.”

“It made me think about maths in a new way.”

“Made me realise that maths can be used everywhere.”

It was also a dominant theme within pupils’ feedback that they enjoyed participating in these workshops since it contrasted with how they learned mathematics in school. Students continually referred to their experiences of learning mathematics as *“boring”*, despite an emphasis in the new secondary curriculum on problem solving and constructivist approaches to teaching and learning (Cronin and Carroll, 2013; Ni Shuilleabhain, 2014). Students highlighted the fact that in the Maths Sparks workshops they liked *“figuring out”* the mathematics as a collaborative, social activity in the workshops.

It is worth noting that pupils found the mathematical content of the workshops challenging, but that this was, in the majority, viewed as positive.

“It was difficult and I like a challenge.”

“I liked the challenge and learning the maths behind card tricks.”

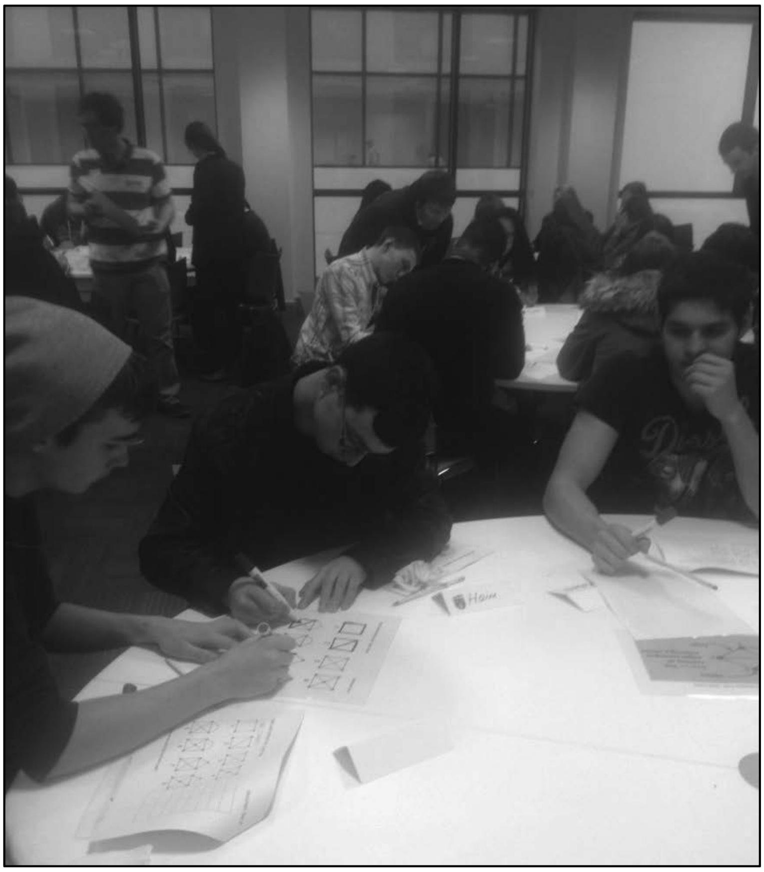

Figure 2. Pupils from different schools work together on a Graph Theory activity

Figure 3. Pupils collaborate on calculations in base 3

Pupils who had previously announced they were "*no good*" at mathematics began to develop their confidence in suggesting solutions as part of group and whole-class discussions and concluded that, while they might not be good at mathematics in school, they were good at this type of "*university mathematics"*. There were a small number of negative reflections where pupils noted times when they would prefer to have been given the answer without having to conjecture and trial their ideas, but the majority of them responded positively to engaging with new mathematical topics and to having their university peers as workshop facilitators.

Figure 4. Pupils working out a strategy by backwards induction in the 'Stick/Nim Game'

In motivating these pupils to continue studying mathematics, one university student relayed a particular conversation she had had with the secondary school attendees. Following the first workshop pupils had joked about their future at the university as cleaners, but after the final workshop this same group of pupils spoke legitimately to one another about returning as undergraduate students. While this feedback was anecdotal within the focus group, we wish to pursue this line of research in widening student participation in the study of mathematics at third level. Within the workshop themselves, a small number of pupils expressed a new interest in continuing to study mathematics and other science subjects after secondary school. As yet, the conversion rate of these pupils cannot be tracked as they have not completed their secondary education, but we hope to incorporate this data as part of future studies.

4.2 Communication and Transferable Skills

Pupils found their university counterparts *"friendly and helpful"* and from classroom observations, the easy-going and sociable atmosphere in the room was notable. Pupils had fun deconstructing particular activities with university students and enjoyed collaborating on difficult problems.

Figure 5. Pupils and students work together in attempting to solve the Pirate Puzzle

Over the four-week programme there was a marked improvement in our university students' communication and presentation skills from the first week where, *"the [university] students seemed very nervous and it was hard to understand them – they talked a bit low",* to them confidently conducting and directing full workshops in weeks three and four.

In the focus group, university students reported an increase in their confidence to present their mathematical knowledge - an important skill highlighted by the HE Mathematics Curriculum Summit (Rowlett, 2011). They also noted that this perceived improvement in their transferable skills would benefit them in giving presentations and in interviews with possible future employers.

4.3 Student-Staff Community

Due to their active participation in this programme, our university students began to see themselves as part of a community within the department. They built relationships with their peers across different year groups and with staff members through collaboratively developing workshop content, inviting guest lecturer speakers, and trialling workshops within the department. This is not an irrelevant finding since such increased student engagement within teaching and learning has been highlighted as a priority by the UK HEA and as a characteristic of mathematics departments with high levels of student satisfaction (Duah and Croft, 2011).

Reflecting on the workshops one university student noted:

“I did not anticipate the relationship made between the students and the workshops and [I] was taken back by the attendance and involvement in all activities.”

Figure 6. Group of undergraduate and postgraduate students who facilitated workshop 1

Students further noted that they liked the fact that they now knew peers at different levels of study within the department and were happy to advise and assist one another in deciding to study future mathematics modules. Students also suggested that more staff be involved in future to broaden the sense of community in the Maths Sparks group.

Each of the volunteers expressed a wish to return next year despite the lack of reward or credit for their work over 12 weeks of preparation and delivery[v] and a number of students have since been involved in additional outreach activities within the department[vi].

5. Conclusion

While the formations of peer networks and links with academic members of staff have been noted in the literature as playing a crucial role for student engagement and retainment (Bradshaw, 2011; Duah and Croft, 2011) the formal mentoring of pupils by university students is something we have not found explicitly reported. The Maths Sparks programme was a novel way of incorporating mathematics games and activities within a university department, with university students presenting and developing content for their second school peers under the guidance of their lecturers.

While developing the initial Maths Sparks programme took an investment of time on behalf of the authors, we found it of benefit in developing a student-staff community within our university department. While we cannot yet be certain of the conversion of secondary students in their continued study of higher mathematics at second or third level, we feel this was a valuable programme in developing pupils’ opinion of and future plans to engage with mathematics. We hope to continue to develop this programme next year with scope to further investigate the development of community as a result of student-staff participation and the enhancement of students’ transferable skills as a result of participating in these outreach workshops. We would also like to investigate the possible impact of increasing pupils' likelihood of pursuing mathematics at third level.

While many higher level institutions offer pastoral support to visiting pupils, we feel this academic support across learner-levels can be positively exploited and we hope to continue developing this idea.

6. Acknowledgements

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7. Appendix

7.1 Pupil Survey Week 1

Please rate the following on the scale provided:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I usually enjoy maths in school.					
I enjoyed participating in this workshop.					
I feel like I learned something from participating in this workshop.					
It was difficult working on problems that are very different to my school textbook.					
I enjoyed working with other students that I did not know.					

What did you like about the workshop?

____

What did you dislike about the workshop?

____

What could we do better in the next workshop?

____

7.2 Workshop Programme 2015

Maths Sparks Programme 2015		
Week	**Part 1**	**Part 2**
1	Cryptography (Caesar Cipher & Vigenère Cipher)	Cryptography & Presentation 'Coding & Encryption'
2	Graph Theory (Eulerian & Hamiltionian Paths)	The Mathematics of Angry Birds
3	Modulo Arithmetic/Number Theory (27 Card Trick)	Probability (Liar's Dice) & Presentation 'Mathematics of Card Tricks'
4	Game Theory (Stick/Nim Game)	Game Theory (Prisoner's Dilemma) & Presentation 'Financial Maths and Game Theory'

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[i] Third level education (also referred to as ‘higher education’) refers to post-secondary education.

[ii] Including two Professional Masters in Education students who will qualify as secondary mathematics teachers.

[iii] Please contact authors for further details of resources and workshops.

[iv] ALE Rooms contain multiple white boards and round tables (which can each seat nine students).

[v] All eleven of the university students involved in Maths Sparks are currently being vetted by the university’s Diploma Supplement group to have their contribution to this project added to their transcripts.

[vi] At the time of going to press, five of the Maths Sparks university students have being involved with further outreach activities including the UCD Summer School and the UCD Leaving Certificate Maths Support sessions.

CASE STUDY

Maths Arcade at Sheffield Hallam University: Developments made in a new space

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Abstract

The Maths Arcade at Sheffield Hallam University has been developed since it was established in 2012. The move to a new space has led to an increase in its popularity and inter-year interactions. It has added to the extensive number of factors that help ease the transition into university. In particular, it now features in the induction week programme and plays a part in our peer assisted learning scheme. In addition to the weekly sessions enjoyed by the students, the Maths Arcade has also been used at a number of events such as the final year de-stress day, and by the Women in Engineering and Mathematics Society. The Maths Arcade has also hosted another Rubik's cube championship.

Keywords: Games, recreational mathematics, mathematics community, transition, student support

1. Background

The original Maths Arcade was created at the University of Greenwich to stretch stronger students, support the weaker ones and encourage interaction between both staff and students (Bradshaw, 2011). Their objectives included *"providing a weekly drop-in session where students could play various strategy board games and puzzles designed to hone and develop strategic thinking, alongside providing a safe place for them to obtain help on tutorial work"*.

Since then, the Maths Arcade has been rolled out to a number of universities including Manchester, Salford, Leicester, Bath, Nottingham, Keele and Sheffield Hallam (Bradshaw and Rowlett, 2012). After an initial trial (Cornock and Baxter, 2012), the Maths Arcade at Sheffield Hallam University is now run as a weekly session with the focus being on adding to the development of a maths community and giving the students a break from their studies. The sessions take place during term time and the students are welcome to come and play the strategy games or just call in for a cup of tea or coffee. The games vary in their duration and difficulty. Games such as Quarto are very quick to pick up and play, but then the students can develop appropriate strategies which may involve engineering *"a situation where your opponent is only left with pieces that give you a win"* (Bradshaw, 2011). Some games tend to last a lot longer, such as Ingenious which involves *"placing tiles on a board with a clever scoring system"* (Bradshaw, 2011). Students are free to choose which games they play from the collection of over twenty games. They can join the Maths Arcade at any point during its weekly slot as the atmosphere is very relaxed and informal, either to join in or watch some of the games. Some students arrive in groups, but those who arrive on their own either join the other students or challenge the staff present.

Despite being set up with first year students in mind, the Maths Arcade is enjoyed by students in all the year groups. Evaluation took place at the end of 2014-15 through a questionnaire sent to all students asking for open responses; a total of thirteen students responded. The majority of the responses from the students have been used from this questionnaire; repeated comments and irrelevant ones have been excluded. Results from another survey on the department's new learning space have also been used; nine members of staff and twenty five students made comments on the benefits of the new space. The Maths Arcade wasn't asked about specifically in this questionnaire, but relevant comments have been used. In addition to this, results from a survey about a final year de-stress day have been used as the Maths Arcade was part of this; four students provided comments. Unless otherwise stated, all comments are from the end of year questionnaire on the Maths Arcade.

When the students were asked what they like about the Maths Arcade, the responses included the following comments:

"*I like to be able to have a bit of chill out time with my friends playing some games! I enjoyed doing it with Claire as well because she was enthusiastic about it."* (First year student)

"Nice break from normal Uni work with friends that gets you thinking in new ways due to the numerous types of games." (Second year student)

"The company and the coffee." (Second year student)

"The way it's helped me make friends." (Second year student)

"Relaxing atmosphere, coffee and interesting games." (Second year student)

"It allows you to get to know the other students who you might not usually talk to and also to get to know some lecturers better." (Placement year student)

"It forced me to step back from work and have a break from work. It enabled me to meet new people and socialise with my peers." (Final year student)

"The chance to mix with other people who may not be in my seminars/lectures." (Final year student)

"Fun, enjoyable, takes your mind off revision." (Final year student)

"I really enjoyed that it took my mind off assignments and revision." (Final year student)

"Yes, it's a very good idea to relieve stress for an hour or two half way through the week!" (Final year student)

2. New location

During the first few years, the Maths Arcade was based in a classroom with a timetabled weekly slot. This limited the number of students that attended, even with the added incentive of caffeine and snacks. However, it was still enjoyed by a number of students. Students were asked whether they attended the Maths Arcade when it was in its old environment, how they found it if they went and why they didn't attend if they didn't go. Responses included the following remarks:

"I went every week. It was nice to spend time with other students at uni not doing work. It kept me thinking before my afternoon lecture." (Second year student)

"I did, and it was lovely, it made me make many friends in different years." (Second year student)

"I did not attend. Main reason was due to its location." (Second year student)

"Maths Arcade was a welcome break from work and conveniently right next to my next tutorial." (Final year student)

"I attended when it was in harmer - I found it was a great break between my lecture and seminar." (Final year student)

"Attended but didn't find it as enjoyable as in the open space in Norfolk." (Final year student)

"I really enjoyed going in first year. It was a nice break from everything else." (Final year student)

In January 2015, the maths subject group moved to a new space. The working area was designed from scratch to encourage interaction between staff and students. Large open plan working areas were created around staff offices that contain lots of space for group work. When the group moved to the new space, it was obvious that the Maths Arcade would move to this area as well. When asked in the separate survey about the new space in general, students mentioned that some of the benefits of the space are that it "*creates more of a mathematical community*", that its "*spacious design has led to a great social atmosphere*" and that it brings a "*sense of 'home'*". Staff comments have included that it "*gives everybody a nice feeling of community and partnership*", that it creates a "*good atmosphere amongst all maths students of different years*", that staff "*can easily say a quick hello to students as [they] walk through*", and that it's a better space to hold events. When the students were asked in the Maths Arcade questionnaire whether they had attended it in the new space and how they found it, the following comments were received:

"Yes. I loved it in Norfolk I got to speak to people from other years and play games with them. My friends also attended so I got to spend time with them as well!" (First year student)

"It is a really calm atmosphere and you get to talk to students and lecturers. The perfect time for a coffee too!" (Second year student)

"I did, same again, a nice friendly atmosphere." (Second year student)

"Yes and I thoroughly enjoyed it. Perfect location in the middle of the day and really relaxing. The coffee addition was really welcome." (Second year student)

"Very easy to find." (Final year student)

"I found the atmosphere was better in Norfolk but the cakes got eaten too fast!" (Final year student)

"Feels much more sociable in Norfolk." (Final year student)

Since the move to the new space, the popularity of the Maths Arcade has increased. It has also been observed that a number of students and staff now call in just to say hello. When students were asked why they attend the Maths Arcade when they didn't before, the response has always been about the new space making it more appealing. When asked what is better or worse about the Maths Arcade being in the new space, the responses included the following comments:

"It's bigger and it seems more comfortable." (First year student)

"More people see it and come as easier to find as in the maths space. If a game overruns the time, can finish it without losing the room." (Second year student)

"Nicer atmosphere." (Second year student)

“More people will join.” (Second year student)

“The new space enables students and lecturers to easily discuss topics over a game. It is also a perfect location as most lectures/tutorials are close by.” (Final year student)

Figure 1. The Maths Arcade in the new space

Figure 2. The Maths Arcade in the new space

Figure 3. The Maths Arcade in the new space

3. Events and uses of the Maths Arcade

As well as the weekly Maths Arcade sessions, there have been a number of other occasions that the games have made appearances.

3.1 Induction week and peer assisted learning

At Sheffield Hallam University, there is a large amount of attention focussed towards easing the transition into university. In addition to the Maths Arcade, other factors that help the maths subject group towards this goal include the use of year tutors for support, an open door policy, an extensive induction week programme, various events held throughout the year and the use of a peer assisted learning (PAL) scheme. The PAL scheme has been running for a number of years (Waldock, 2010) and has recently been thoroughly reviewed and developed. Part of this development has been within the training of the PAL leaders and introduction of the first year students to the scheme.

A number of the factors mentioned above have been combined together. The Maths Arcade now features in the induction week programme. At this session, the students sit with their PAL groups and meet their final year PAL leader. The Arcade is a great ice breaker for the students to get to know each other and their assigned final year leader in a relaxed and informal setting. There were a few comments from students who didn't enjoy the experience during induction week as the Maths Arcade isn't appealing to everyone. The positive responses from the students when they were asked whether they enjoyed the Maths Arcade in induction week included the following:

"Yes because I got to talk to people I hadn't previously and also got to bond with my PAL group." (First year student)

"It was laid back environment and didn't feel awkward." (First year student)

"Yes. Great way to introduce yourself to your classmates. This year's 2nd years went to the 1st years induction session so I got to meet some of them too." (Second year student)

"Yes, because it allowed me to get know my fellow students a little better." (Placement year student)

"Yes, it was a good ice breaker." (Final year student)

3.2 Women in Engineering and Mathematics social event

The games from the Maths Arcade were borrowed by a couple of the students to be used at a social event run by the Women in Engineering and Mathematics Society. They ran games as well as activities and the organisers reported back that the games "*were good for people to socialise over, especially when some of the people hadn't been to one of the meetings before*". The engineering students who hadn't played many logic games before particularly found them interesting.

Figure 4. The Women in Engineering and Maths social event

3.3 Final year de-stress day

A de-stress day was organised for the final year students in March 2015 when the students were under the most amount of pressure from coursework deadlines, “*exactly when it was needed most*” as mentioned by a student in response to the de-stress day questionnaire. The focus of the event was on the students’ well-being and was attended by most of the final year students at some point throughout the day. Activities and resources included Indian head massages, Lego, bubble wrap, stress balls, knitting, Wii sports, tea and coffee. The Maths Arcade was available throughout the duration of the day and was enjoyed by the students. It has been noted by a member of staff in the survey on the new space that the “*Maths Arcade and de-stress day have both taken off because of [the new space].*” The students who filled in the questionnaire on the de-stress day found it “*fun and relaxing*”, thought it “*was a really nice idea*”, found it “*very enjoyable*” and described it as “*a nice break*”. Out of the four students that completed the surveyed, two of them said that they had enjoyed the Maths Arcade at the event.

Figure 5. The final year de-stress day

3.4 Rubik’s cube championship

Following on from the original Rubik’s cube championship in 2012 (Cornock and Baxter, 2012) in which students from all year groups were invited to take part in the competition, the Maths Arcade ran another championship in March 2015. The move to the new location and the added incentive of inter-year rivalry saw the number of participants increase from four to twelve, which included teams from all year groups. Points were available for just taking part as well as extra points available for completing the cube within five minutes, two minutes and one minute. In addition to the students competing, the championship was also enjoyed by an audience of staff and students who didn't take part themselves. Feedback from the students included the following comments:

"It was really good to do something with the other year groups. I managed a personal best. More people showed up than the amount that attend arcade so there were lots of fresh faces." (Second year student)

"I watched it and it was a great atmosphere." (Final year student)

Figure 6. The Rubik's cube championship

4. Further improvements

The Maths Arcade at Sheffield Hallam University has become more successful since moving to the new space, but there are still further developments and improvements that can be made. Suggestions from students have included holding more specific events like the Rubik's cube championship for different games, having more tables in the area, holding more sessions and also longer sessions. There is a large demand for the Maths Arcade from students that aren't in the first year, especially since the move to the new space. The timetable for all students will be evaluated as the inter-year interaction should be encouraged further.

5. References

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Future Issues

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