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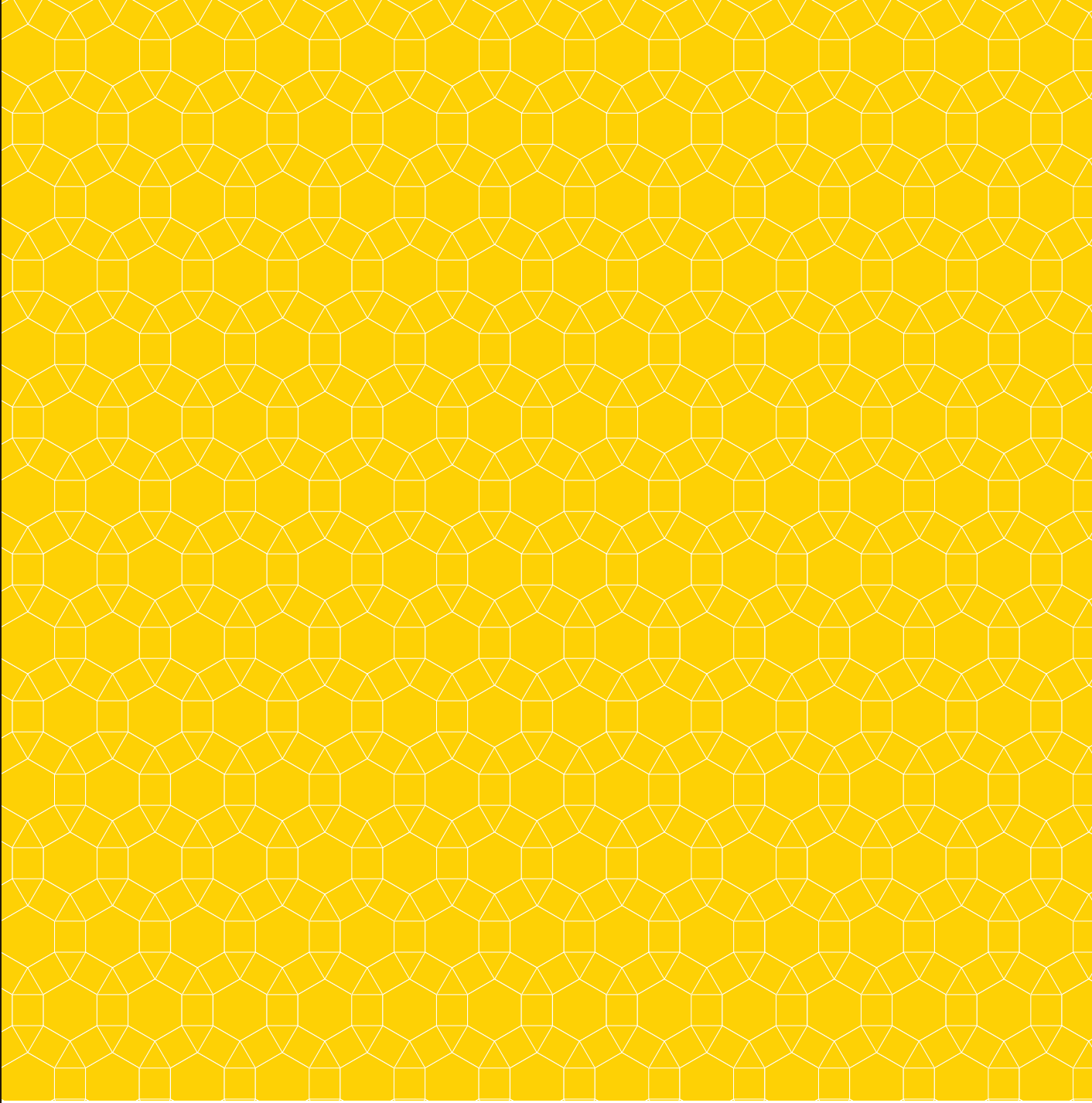
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# Student-centred Approaches in Mathematics

Mathematical Sciences HE Curriculum Innovation Project



Edited by Carol Robinson



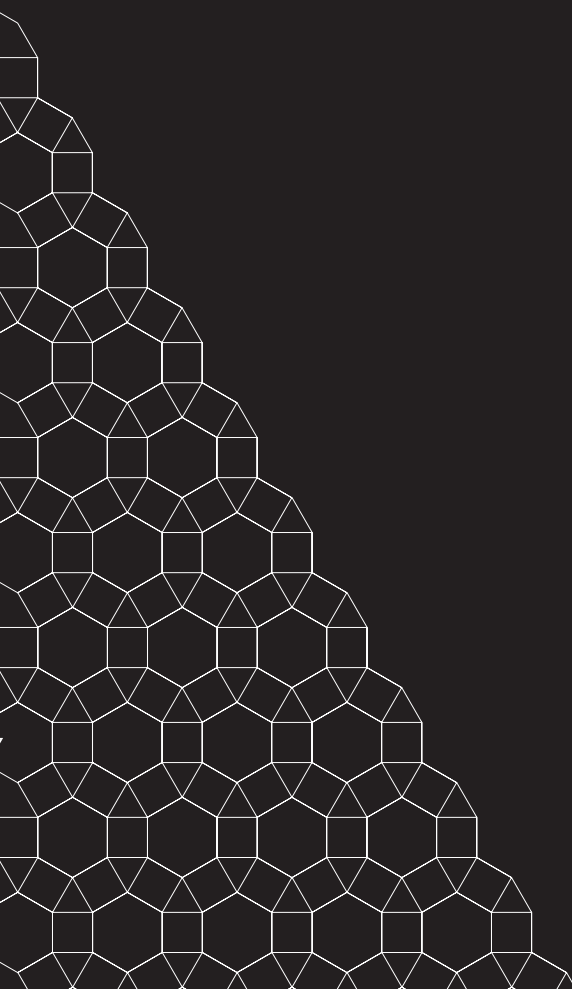


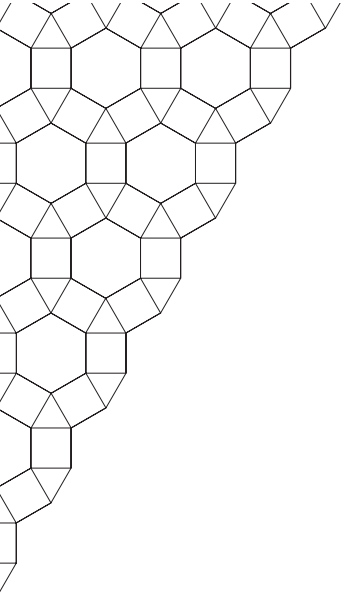
# Student-centred Approaches in Mathematics

– Case Studies of Innovative Practice

Edited by Carol Robinson

July 2012



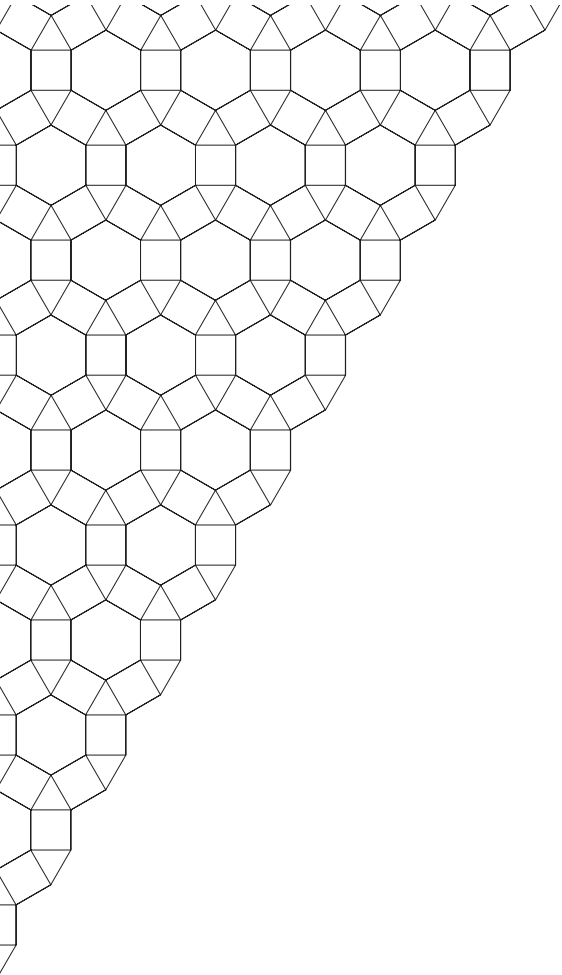


## Acknowledgements

This booklet was commissioned from the Maths, Stats and OR Network as part of the Mathematical Sciences Strand of the National HE STEM Programme. It reports on a series of projects supported by the Network under the National HE STEM Programme, whose common theme is student-centred approaches in mathematics.

Thanks are due to all the authors for their contributions and to Peter Rowlett for his support and very helpful advice and comments.

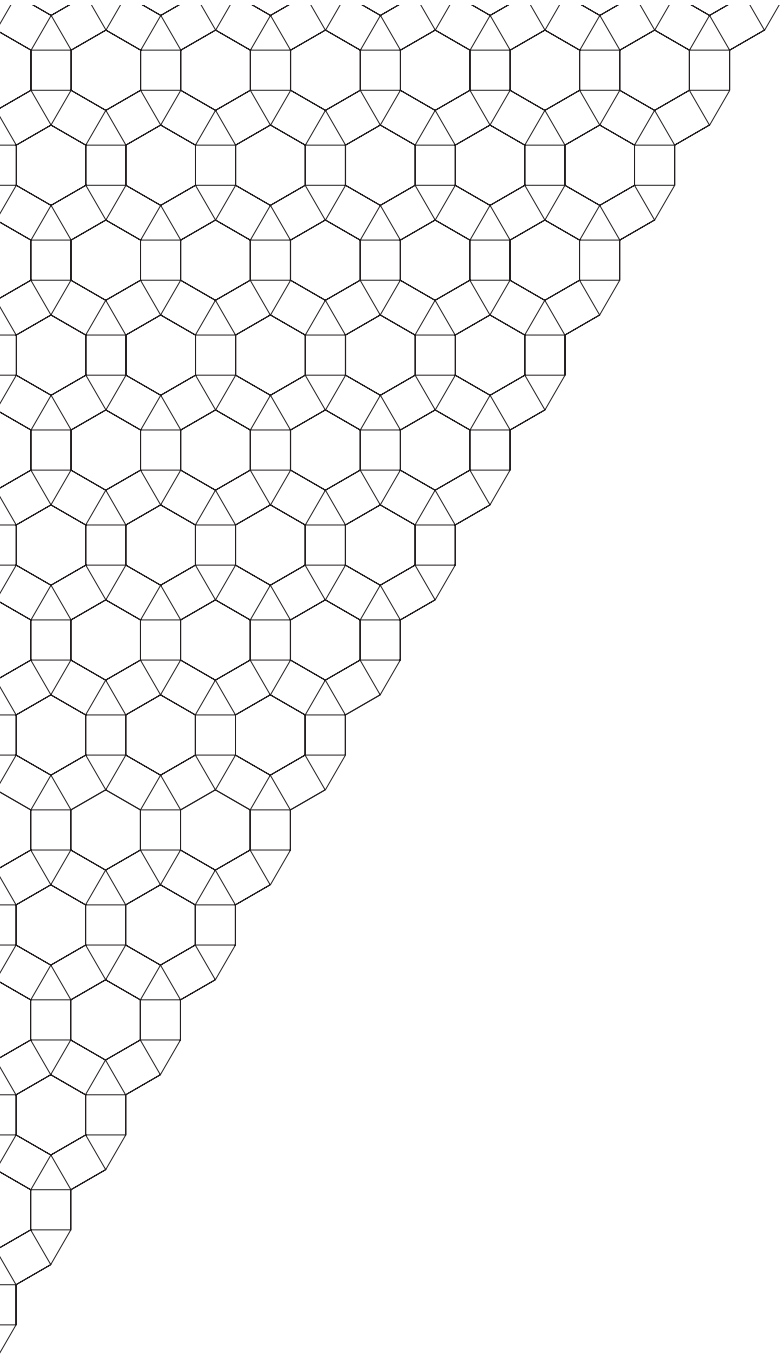
In addition, I would like to thank Chantal Jackson, of the University of Birmingham, for her work in typesetting the material.



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# Introduction

## Background

The current Higher Education (HE) system in the UK has moved increasingly in recent years to a 'mass' system. At the same time there is a drive to implement a teaching and learning environment which puts the student at its heart. These two factors would appear to be in contradiction with one another and yet, as teachers in HE, this is the dilemma that we all face. What does it mean to adopt student-centred approaches in mathematics and how can this be done in the current climate?

Student-centred learning is concerned with the student's needs, abilities, interests, and learning styles, with the teacher as a facilitator of learning, helping students access and process information. Moreover, as noted in Gosling (2003):

*"Part of being 'student-centred' is recognizing that, although there is a subject content which all students must learn in order to pass, each student approaches the subject from their own perspective, their own unique past experience and their own understanding of themselves and their aspirations. They have their own identity, or rather identities, influenced by factors such as gender, age, past educational experience and achievement, class, ethnicity, nationality, sexual orientation, self-perception, goals, abilities and disabilities, language skills and so on. These multiple identities inevitably shape their learning."* p.163

Student-centred approaches give the learner increased responsibility and autonomy. They rely on active as opposed to passive learning and there is an emphasis on deep learning and understanding.

There is an increasing body of evidence of the effectiveness of student-centred approaches to learning. Kember (2009) provides evidence of the effectiveness of a multi-pronged initiative at a research intensive university in Hong Kong. Interestingly, particularly in the context of mathematics, he also concludes that:

*"Disciplines which have traditionally reserved the initial parts of programmes for building a solid foundation of basic knowledge, for which there are accepted positions, have tended to find it more difficult to introduce active learning experiences than those in which knowledge is more contested. Disciplines which rely principally on more didactic forms of teaching run the danger of reinforcing the preference for passive forms of learning which many students assimilate during their schooling."* p.12

Thus we see that, in the context of mathematics, there can be additional barriers to introducing student-centred approaches. The projects highlighted in this booklet provide examples of how such barriers have been overcome in a variety of universities and contexts.

An important aspect of adopting student-centred approaches is in ensuring that the curricula are inclusive. Inclusive curriculum practice refers to "the process of developing, designing and refining programmes of study to minimise the barriers that students may face in accessing the curriculum" (Gravestock, 2011). In mathematics this can be especially challenging, due to the difficulties in producing materials in a format which can be adapted for students with a range of additional needs. This issue is addressed in the report in this booklet by Emma Cliffe and Jane White on producing flexible and accessible learning resources in mathematics.

However inclusive curricula encompass more than accessible materials. It is about ensuring that all aspects of the curriculum are accessible to all students. In mathematics this can include, for example, group work and presentations. There are some excellent guidelines on introducing group work in mathematics, written by Judith MacBean, Ted Graham and Chris Sangwin. These were produced in 2001 and there are now legal requirements to make reasonable adjustments

for students with additional needs and to anticipate potential barriers and resolve them in a proactive manner. There are clearly special considerations to be taken into account when we are dealing with students with additional needs such as autistic spectrum disorders and this issue is addressed by the report in this booklet by Emma Cliffe and Noel-Ann Bradshaw which provides an excellent addition to the work by MacBean et al.

## **The Projects**

This booklet presents a fascinating series of short reports on projects supported by the MSOR Network as part of the National HE STEM Programme which have focussed on student-centred approaches to mathematics. All have some element of support tailored to the needs of students, although the projects themselves are quite distinct. The first is focussed on supporting mathematics students and the next three focus on student-centred approaches for students from other disciplines. The focus then changes, with three reports on inclusive curricula and student-centred approaches for students with additional needs. Finally, no booklet on student-centred approaches would be complete without a consideration of how one might use social media to engage students and the final report presents an overview of this topic.

All of the projects have as their key concern the student and have introduced initiatives which recognise the diverse needs of students and have striven to put the student at the heart of these initiatives. Each project endeavours to enable the student to approach the subject from their own perspective and recognises that each student has their own identity which shapes their learning.

In the ensuing sections there is a short account of each, emphasising some of the key findings.

### **Building on the Maths Arcade: Supporting Mathematics Learning**

The Greenwich Maths Arcade provides mathematics support with a difference. It was designed to support mathematics students, particularly at the transition between school or college and university. It provides a venue for mathematical talk, games and problem-solving, with a range of mathematical games available, and weekly puzzles contributing to a termly competition. Academic staff who are free at the time attend, and students can get help with tutorial work from colleagues or teachers. It arose following concerns that some students were reluctant to attend 'help sessions', since there is a perception that these are for the weaker students and they don't wish to identify themselves as such. The sessions have proved popular, attracting both stronger and weaker students: some attend to play games whilst others attend to work through exercises and talk to staff. The Arcade has helped to motivate students and has resulted in improved retention and progression levels.

For other universities wishing to implement this approach, a very helpful guide, *The Maths Arcade Start-Up Guide*, has been produced by Noel-Ann Bradshaw (Bradshaw, 2012).

### **Engineering Students Understanding Mathematics (ESUM)**

ESUM is a developmental research project at a UK university. The lecturer has modified teaching, intending to create a more student-participative approach and encourage students to develop more conceptually-based understandings of mathematics. A small research team studied and contributed to the innovation which included small group activity, a variety of forms of questioning, an assessed group project and use of the GeoGebra medium for exploring functions. Inquiry-based questions have resulted in a much increased level of response from students. Of particular interest is that the developmental research approach enabled the teachers involved to learn about what engaged students and how they experienced the innovative approaches.

### **Supporting Undergraduate Engagement and Achievement in STEM Disciplines**

In this project an innovative, engaging and practical mathematics blended learning 'bridging' course was introduced for new students enrolling onto Higher Education Engineering programmes. The focus here is on the move away from entirely face-to-face delivery to a combination of online and face-to-face delivery.

The feedback from the students has been extremely positive with, for example, students highlighting the ability to watch videos ‘as many times as I want’ as being particularly helpful. This enabling of students to shape and structure their own learning has proved valuable for the students involved, who are mainly from non-traditional backgrounds.

The report details some of the issues arising when creating online mathematics materials and how these have been addressed. It is interesting to note that students are strongly in favour of keeping the mix of online and face-to-face teaching and would oppose a move to fully online provision. Additionally of interest is the finding by the project team that the time spent monitoring and emailing students has been larger than initial predictions. They noted that there seems to be a perception that creating online material, once done, would reduce the amount of hours a lecturer has to dedicate to the module but this is not necessarily the case.

### **A Pilot for a Shared Online Statistics Advisory Service**

Students undertaking a final year undergraduate or Masters project or engaged in postgraduate research often require individual tailored support with statistics and Statistics Advisory Services (SASs) have recently been established at several universities to meet this need. The objectives of this project were to identify the practical and pedagogical issues associated with universities sharing an online SAS resource, and to elicit the opinions of students using the service in order to understand their expectations and experience of using this type of online support.

A statistics advisor was employed as part of the project, working remotely from her home and the students met with the statistics advisor using an Elluminate online learning space/web meeting tool<sup>1</sup>.

The report highlights that while students are very appreciative of this online support, there can be many problems with ensuring that the technology is working well. However this pilot study has demonstrated that an online SAS is able to offer a practical alternative to an institution specific face-to-face SAS if suitably experienced staff are not available locally.

### **Good Practice on Inclusive Curricula in the Mathematical Sciences**

A workshop in February 2011 brought together those with different perspectives on the issues involved in inclusive design and proactive adjustments regarding disability. The focus was on what is required, what is best practice and what are the challenges involved which are specific to the mathematical sciences. The resulting guide (Cliffe and Rowlett, 2012) is an excellent resource for all departments involved in the teaching of mathematics. It identifies common challenges for inclusive practice and explores technical and pedagogical barriers. It provides strong evidence of the need for collaboration between the MSOR community and the support professionals. This latter point also comes across very strongly in the report which follows it in this booklet.

### **Methods to Produce Flexible and Accessible Learning Resources in Mathematics**

Disabled students are often disadvantaged by mathematics learning resources which are in inaccessible formats. It was noted that many staff tend to provide students with handwritten or PDF documents. This project explored the essential topic of what methods can be used to produce flexible and accessible learning resources for mathematics. This includes formats accessible via speech and/or some form of Braille, large print and editable formats.

The report highlights some of the technical issues which were encountered and provides details of the processes involved in converting mathematics learning resources into accessible formats. Of particular note is the guide which has been produced for staff in HEI to enable them as individuals to create flexible resources efficiently and robustly (Maths and Stats Help Centre, 2012). This guide is a clear and comprehensive document which I am sure will be invaluable for those endeavouring to produce accessible mathematics learning resources. However the report concludes that, due to the technical nature of the methods, staff specialising in accessible mathematical document preparation will be best placed to produce the master documents

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<sup>1</sup>Note that Elluminate is now known as Blackboard Collaborate (see [www.illuminate.com](http://www.illuminate.com))

initially and then advise teaching staff on how to update master copies, highlighting the need for collaboration between these two staff groups.

### **Autism spectrum disorders (ASD) and group work in mathematics**

This report presents the outcomes from two workshops which were organised to bring together interested parties to investigate the particular difficulties that a student with ASD may experience in mathematics group work and to share current practice of organising and supporting group work.

The outcome is a very useful suggested framework for minimising barriers to group work in mathematics. This framework includes: using a carefully designed group allocation method; ensuring that explicit rules of engagement are either provided or must be produced; ensuring transparent and fair marking.

Clearly these would be of value for students in all disciplines but, as noted in the report, in a systematic subject such as mathematics the added structure is also likely to benefit all students as the learning and assessment will sit more naturally within their experiences of degree studies.

### **Using social media to engage students**

This report presents an overview of discussions at a workshop themed around using social media to engage students. As is pointed out, this is an emerging area of practice with no clear information on or evidence of good practice. The focus is not primarily on what media are available but, more importantly, what might be done using these. Three very interesting case studies are presented, all involving Twitter and one also using Facebook. It is clear that, as well as potential value, there are many issues for lecturers and institutions to consider. This is very much a preliminary discussion in an area which is likely to become much more important in years to come and it is hoped that further investigations will follow in this area.

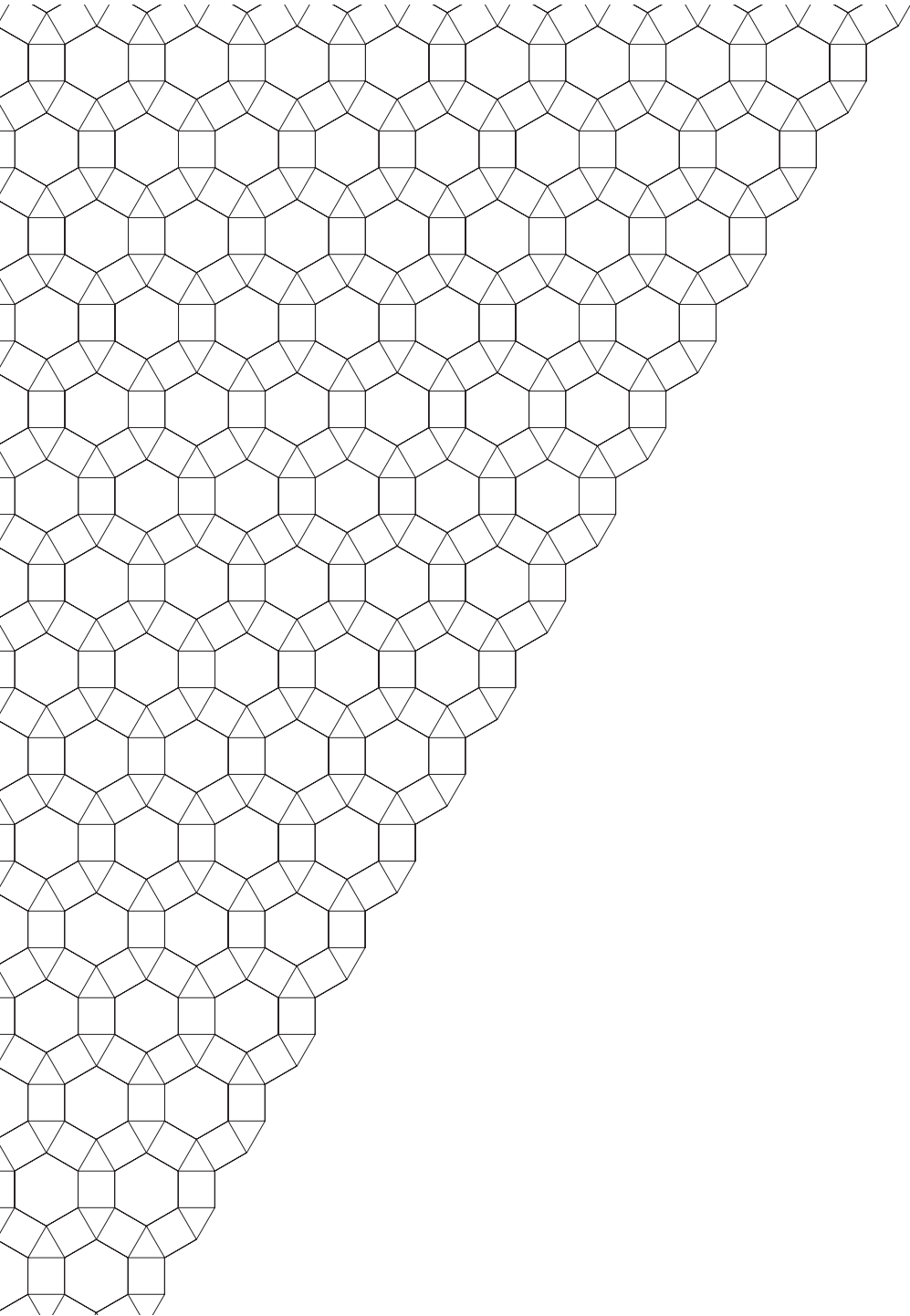
### **Concluding Remarks**

I trust that you will have as much enjoyment reading about these projects as I have had in editing them and that the lessons learnt from these projects will assist you in developing approaches in your own institution which enable student-centred learning to take place.

Carol Robinson  
Mathematics Education Centre  
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July 2012

## References

- Bradshaw, N., 2012. *Maths Arcade – start-up guide*. Available via: [http://www.ima.org.uk/viewItem.cfm?cit\\_id=384191](http://www.ima.org.uk/viewItem.cfm?cit_id=384191) [last accessed: 19/07/2012].
- Cliffe, E. and Rowlett, P. (eds.), 2012. *Good Practice on Inclusive Curricula in the Mathematical Sciences*. MSOR Network.
- Gosling, D., 2003. Encouraging student motivation. In: H. Fry, S. Ketteridge and S. Marshall, eds, *A Handbook for Teaching and Learning in Higher Education*. Second edn. London and New York: RoutledgeFalmer, pp. 162 - 181.
- Gravestock, P., 2011. *Inclusive Curriculum Practices*. Available via: [http://www.heacademy.ac.uk/resources/detail/subjects/psychology/Inclusive\\_Curriculum\\_Practices](http://www.heacademy.ac.uk/resources/detail/subjects/psychology/Inclusive_Curriculum_Practices) [last accessed: 11/07/2012].
- Kember, David., 2009. Promoting student-centred forms of learning across an entire university. *Higher Education*, 58(1), pp. 1–13.
- MacBean, J., Graham, T. and Sangwin, C., 2001. *Guidelines for Introducing Group Work in Undergraduate Mathematics*. Learning and Teaching in Mathematics, Statistics and Operational Research. [http://www.mathstore.ac.uk/headocs/MacBean\\_Book.pdf](http://www.mathstore.ac.uk/headocs/MacBean_Book.pdf) [last accessed: 11/07/2012].
- Maths and Stats Help Centre, 2012. *Methods to produce flexible and accessible learning resources in mathematics*. Available via: <http://www.bath.ac.uk/study/mash/maths-access> [last accessed: 19/07/2012].



# Building on the Maths Arcade: supporting mathematics learning

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## Abstract

The Greenwich Maths Arcade was initially set up in September 2010 following a successful internal University bid for funding for curriculum innovation. Support from the MSOR Network as part of the National HE STEM Programme has enabled the project to be enhanced in 2011-2012 with more equipment and more sessions. Staff have had further training and a workshop was also carried out for those interested in the School of Engineering.

## Background and Rationale

This project has been designed to support mathematics students, particularly at the transition between school or college and University. Students are reluctant to attend 'help sessions', since there is a perception amongst their peers that these are for the weaker students and they don't wish to identify themselves as such. The Maths Arcade, offered at a convenient time for first-year students, provides a venue for mathematical talk, games and problem-solving, with a range of mathematical games available, and weekly puzzles contributing to a termly competition. Academic staff who are free at the time attend, and students can get help with tutorial work from colleagues or teachers. The sessions were popular in 2010-2011, attracting both stronger and weaker students: some attended to play games whilst others attended to work through exercises and talk to staff. The Arcade has helped to motivate students which in 2011 resulted in better retention and progression levels than in previous years.

The objectives for this project were as follows:

- Improve existing facilities so these can be used by more students
- Continue to target improved retention and achievement
- Increase students' confidence in their mathematical ability
- Produce a guide for other HEIs to setting up a Maths Arcade, including a list of suitable resources [1]
- Run a training session for staff and PhD students at Greenwich
- Run a workshop on the Maths Arcade at the Medway campus for the University's School of Engineering

## Implementation

A staff development training session was delivered at Greenwich for all teaching staff and PhD students who might help out with this activity. This was attended by eight teaching staff and five PhD students.

Room bookings for 2011-12 were successful and we obtained a suitable room for two hours on a Monday and one hour on a Friday as requested. More equipment was purchased.

The work of 2010-2011 was evaluated and various conference presentations were given [2], [3], [4], [6] resulting in interest from other HEIs, others in HE STEM and two schools within the University.



In September 2011 the enhanced Maths Arcade began with 70 first and second year students turning up for the first session. Twice weekly sessions have continued all year and there has been a weekly puzzle posted each week. More students have entered the puzzle competition this year than last and there is again evidence that more are doing the puzzle than are actually entering the competition.

## Evaluation

In 2010-2011 pass rates for two first year courses rose from 70-90%. This increased progression and retention rates for the year as a whole.

It is too early to comment on this for 2011-2012 except that it was noticed that in the coursework assignments for the second year course STAT1026 Operational Research, which particularly requires strategic thinking, those students that had attended the Maths Arcade regularly were the ones that obtained the highest marks. However, this could be because they naturally like these activities and so attend rather than because attendance improved performance.

At the start of the year we set very ambitious targets for engagement with the Maths Arcade and did not sufficiently strategise for meeting these. In part this was because of other responsibilities allocated to members of staff – the tutor responsible for the Maths Arcade was appointed Admissions Tutor and Induction Coordinator for the School of Computing and Mathematical Sciences - and late changes to personal tutoring arrangements for first year students which meant that the Maths Arcade was not promoted as strongly in Week One as had been intended.

Our plans to engage a higher proportion of students were in retrospect over-ambitious. There are students who, perhaps because of family or work engagements, choose not to engage with University beyond the core activities of lectures and tutorials. Attempting to overcome their reluctance to engage with an optional activity was unsuccessful, but these students are often mature and well-motivated, and are on course to succeed in their studies. So one lesson is that the Maths Arcade should not expect to engage the whole cohort and that the focus should be on promoting it to the students who are likely to benefit.

Target for attendance

- 60% of first year students attend the Maths Arcade at least twice in the year
- 20% of them attend regularly

Results

- 30% of the first year has attended at least twice (and most of them more than this).
- 10% of them have attended regularly

This level of student engagement has been similar to last year, despite a 25% smaller first year. On average on Mondays in the first term we have had 15 first years and 8 second years attending, giving an average attendance of 23. There have been occasional attendees from among the final year and PhD students. On Fridays, when the timing is perhaps less convenient for students, we have had a smaller attendance. Often different students attend on different days giving an average across the week of 30 including staff which is what we found last year. There was considerable variation in attendance depending on students' coursework load.

In the second term attendance dropped (as last year) with an average weekly attendance, including staff, of 20.

Those students that have attended have found it beneficial and tutors believe that there are some students that would not be on track for passing this year without this facility. Staff have also used the sessions successfully to discuss project work with students.

On the occasions where numbers have been low there has been good mathematical discussions taking place with students and staff and PhD students.

Student feedback this year has included:

*'Maths Arcade sessions are a good part to the course as it improves our thinking skills. It's a good way to socialise and meet fellow maths students from not just our year but also years above us.'*

*'What is also good about the Maths Arcade is that you can ask your teachers questions about anything you didn't understand in a lecture or about anything else relevant to your degree such as careers you can undertake with your maths degree. Going to the Maths Arcade also improved my social skills as I got the chance to meet other people and make new friends.'*

### **Discussion, Learning and Impact**

- We advertised as previously whereas in retrospect our high target needed different strategies for encouraging attendance and engagement.
- Sessions were run on two days / week this year due to feedback from last year's students. However the Friday session has not been so well attended although this has been used by final years wanting help with projects and there have been worthwhile mathematical discussions.
- The Monday session lasts for two hours – again as the result of a student request. This meant that second years often attended the first hour and first years the second which did not enable the hoped for level of interaction between first and second year students.
- Last year the Maths Arcade sessions were used for MathSoc activities such as the Pie Day Party and for an origami session led by Colin Graham. It was felt at the time that these special events rather detracted from the work of the Arcade but in retrospect it is likely that sessions like this helped to bring in extra students and thus boost subsequent attendance by raising awareness of the facility, as new students realised that it was there and began attending.
- The Maths Arcade has had more impact elsewhere in the University than we expected. As a result of Bradshaw and Lakin presenting the project at the University's Teaching and Learning conference in June 2011 [6] two weekly sessions were instigated in different departments in the Business School. These provided a focus for employability as well as strategy games. This presentation is published in [7].
- The University's partnership division became aware of the project and has rolled this out to schools. This has involved training 15 University STEM Ambassadors in using the games and several schools have asked for these sessions.
- As a result of Bradshaw presenting the work at an HE STEM SW spoke seminar (June 2011) [3] and at the Ideas Exchange (July 2011) [4] the project has been rolled out to six other HEIs. This work is documented in an MSOR Network publication [8].

### **Further Development and Sustainability**

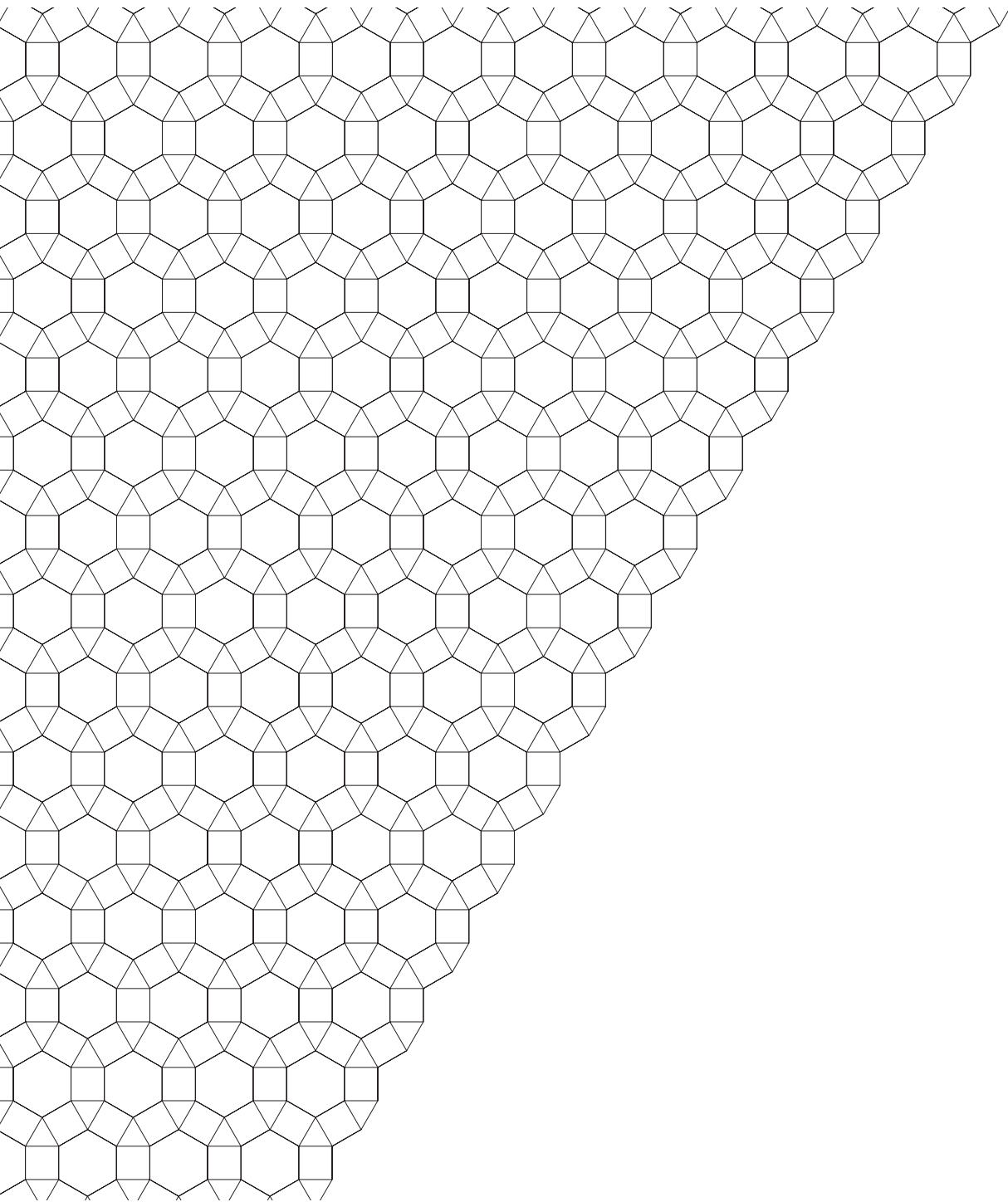
We have discussed the possibility of using the Maths Arcade as a focus for employability sessions. The large quantity of games and puzzles that we now have means that the Arcade is sustainable. There will be some depreciation on equipment but this is not costly. Staff time is more of an issue but if staff are asked to use one of their office hours for the Arcade then the resource is not substantial and members of staff appreciate the value of the sessions in building relationships with students.

More information can be found about the Maths Arcade on the Institute of Mathematics and its Applications website [1].

## References

- [1] Bradshaw, N. (2012). *The Maths Arcade Start-Up Guide*. Available via: [http://www.ima.org.uk/viewItem.cfm?cit\\_id=384191](http://www.ima.org.uk/viewItem.cfm?cit_id=384191) [last accessed: July 2012].
- [2] Bradshaw, N. (2011). The University of Greenwich Maths Arcade. *CETL-MSOR Conference*, Coventry, 6 September.
- [3] Bradshaw, N. (2011) The University of Greenwich Maths Arcade, in *seminar for the Transition, Induction and Peer-Assisted Learning project of National HE STEM South West Spoke*, University of Exeter, 7 June
- [4] Bradshaw, N. (2011). The University of Greenwich Maths Arcade. *Ideas Exchange 2011*, Birmingham, 9 July.
- [5] Bradshaw, N. (2011).The University of Greenwich Maths Arcade. *MSOR Connections*, 11 (3), pp. 26-29. ISSN 1473-4869
- [6] Bradshaw, N. and Lakin, S. (2011). The Mayhematics Maths Café: a tool for nurturing the inquiring mind. *Redefining the Student Experience: directions for learning, teaching and assessment*, University of Greenwich, London, 5 July.
- [7] Bradshaw, N. and Lakin, S. (2012). The Greenwich Maths Arcade: A Tool For Nurturing The Inquiring Mind. *Compass: The Journal of Learning and Teaching at the University of Greenwich*, 5, pp. 5-9.
- [8] Bradshaw, N. and Rowlett, P. (eds.) (2012). *Maths Arcade: stretching and supporting mathematical thinking*. MSOR Network.





# Engineering Students Understanding Mathematics (ESUM)

**Barbara Jaworski, Janette Matthews, Carol Robinson and Tony Croft**, Mathematics Education Centre, Loughborough University

*This article first appeared in MSOR Connections 11(3), pp. 47-48.*

ESUM (Engineering Students Understanding Mathematics) is a developmental research project at a UK university. The motivating aim is that engineering students should develop a more conceptual understanding of mathematics through their participation in an innovation in teaching. A small research team (the authors) has both studied and contributed to innovation which included small group activity, a variety of forms of questioning, an assessed group project and use of the GeoGebra medium for exploring functions. The main study took place in the academic year 2010-11, but development is ongoing.<sup>1</sup>

## Background to ESUM

A mathematics module for Materials Engineering students in a UK university has run for three years over two semesters with the same lecturers, a different one in each semester. In ESUM we focus on the first semester in which the lecturer has modified teaching each year, intending to create a more student-participative approach and encourage students to develop more conceptually-based understandings of mathematics. Modifications in previous years have had limited success [2] and the innovation in the third year was designed to be more coherent and far-reaching, encompassing changes to how the module was delivered and the ways in which students interacted with the mathematics, the lecturer and each other. Innovation was undertaken by a research team of three teachers of mathematics (two with extensive experience of teaching engineering students and one, the lecturer, with extensive experience of mathematics teaching and teacher education at secondary level) who designed, conducted and reflected on teaching (the insiders), and a research officer (outsider) who collected and analysed data as agreed with the teaching colleagues.

The module was taught by one of the team (the lecturer) over 13 weeks with two lectures and one tutorial per week. The cohort of 48 students mostly had A-level mathematics with grades A to C, with just a few alternative qualifications; two students had no mathematics since GCSE. Lectures were timetabled in tiered lecture theatres. The weekly tutorial was held in a large computer laboratory with individual computer tables in squares of four, each set of tables accommodating one group of students. For the tutorials, students were grouped in threes and fours and expected to work together on set tasks and an assessed project. Tasks and project were designed for the module by the teaching team and formed a part of the innovation; both included inquiry-based questions designed to encourage exploration in mathematics using GeoGebra<sup>2</sup>. In addition, inquiry based questions were used in lectures along with more traditional questions to encourage student involvement and provide feedback on understanding. Question design drew on a range of published resources.

## Developmental Research in ESUM

The project had four phases: a design phase (of questions and tasks) preceded teaching and continued in parallel with the teaching phase of 13 weeks; a phase of data analysis followed involving the research officer and two members of the teaching team; a fourth phase (which is still

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<sup>1</sup>This report is necessarily short. See Jaworski & Matthews, in press [1], for further details.

<sup>2</sup>GeoGebra: <http://www.geogebra.org/cms/>

ongoing) involves dissemination of findings and their use in the (re)design of the module for the subsequent year which is now underway.

Research was designed both to *promote* development and to *study* it [3]. Promotion was achieved by feeding back to teaching as data was collected and by creating an inquiry approach to teaching. The research studied the entire process through a rigorous analysis of data collected. The lecturer acted as a practitioner-researcher, reflecting on all activity and feeding back from observations and other data to ongoing teaching design and practice. The outsider researcher observed lectures and tutorials, with audio-recordings of lectures. She designed and administered two questionnaires for student data and feedback from teaching sessions and, with another member of the team, held one-one and focus group interviews with students at the end of the teaching semester. All research instruments and activity were agreed first with the teaching team.

## Research Findings

Findings have come from both insider and outsider analyses. Insider analysis has involved reflective consideration of day to day activity, often with feedback to ongoing practice. Outsider analysis has involved a rigorous analysis of data collected from events. We summarise here the key findings of the project.

Compared with previous cohorts we have observed a much greater engagement in lectures. Inquiry-based questions have contributed to this, and the lecturer's deliberate use of a questioning approach has resulted in a much increased level of response from students (over previous cohorts). The lecturer in the second semester found remarkable responsiveness (over previous years), and the students' lecturer at the start of their second year has remarked similarly. Marks in tests and examinations were at a higher level (approximately 10%) than in previous years. Of course, this might have been a specially responsive and able group of students compared to previous years. We were not able to compare intake qualifications since the data from previous years was not available.

Students held mixed views about the values of the innovation to them. Analysis of focus group data revealed that:

1. While they could see that GeoGebra helped them to consider a wider range of functions and fit functions to data (as evidenced by their project reports), the need to draw by hand in an examination required more practice of graph sketching without GeoGebra. Dynamic use of GeoGebra in lectures was seen as sometimes interrupting lecture flow and taking unnecessary time.
2. Computer-based work in tutorials led to temptations to engage with social networking sites. Students would have preferred more opportunity to practice solving test or exam style questions.
3. Group activity worked well for some groups but was problematic when some students contributed little to the group. It was extremely valuable for some of the weaker students when their peers helped them to understand mathematical ideas. Some students felt that the group project could have been more demanding.
4. Students felt that too much time at the beginning of the module was spent on functions which they 'knew' already from A-level work. They would have preferred to spend more time on matrices and complex numbers which were relatively new for many of them.

It seemed clear that students came to the module with both traditional views on learning mathematics (e.g., wanting clear explanations and opportunity for practice) and a strategic approach to their studies (what is needed to pass the exam). We set out to create opportunity for more conceptual understanding of mathematics. We observed greater engagement and higher summative results than with previous cohorts. However, we were not able to measure

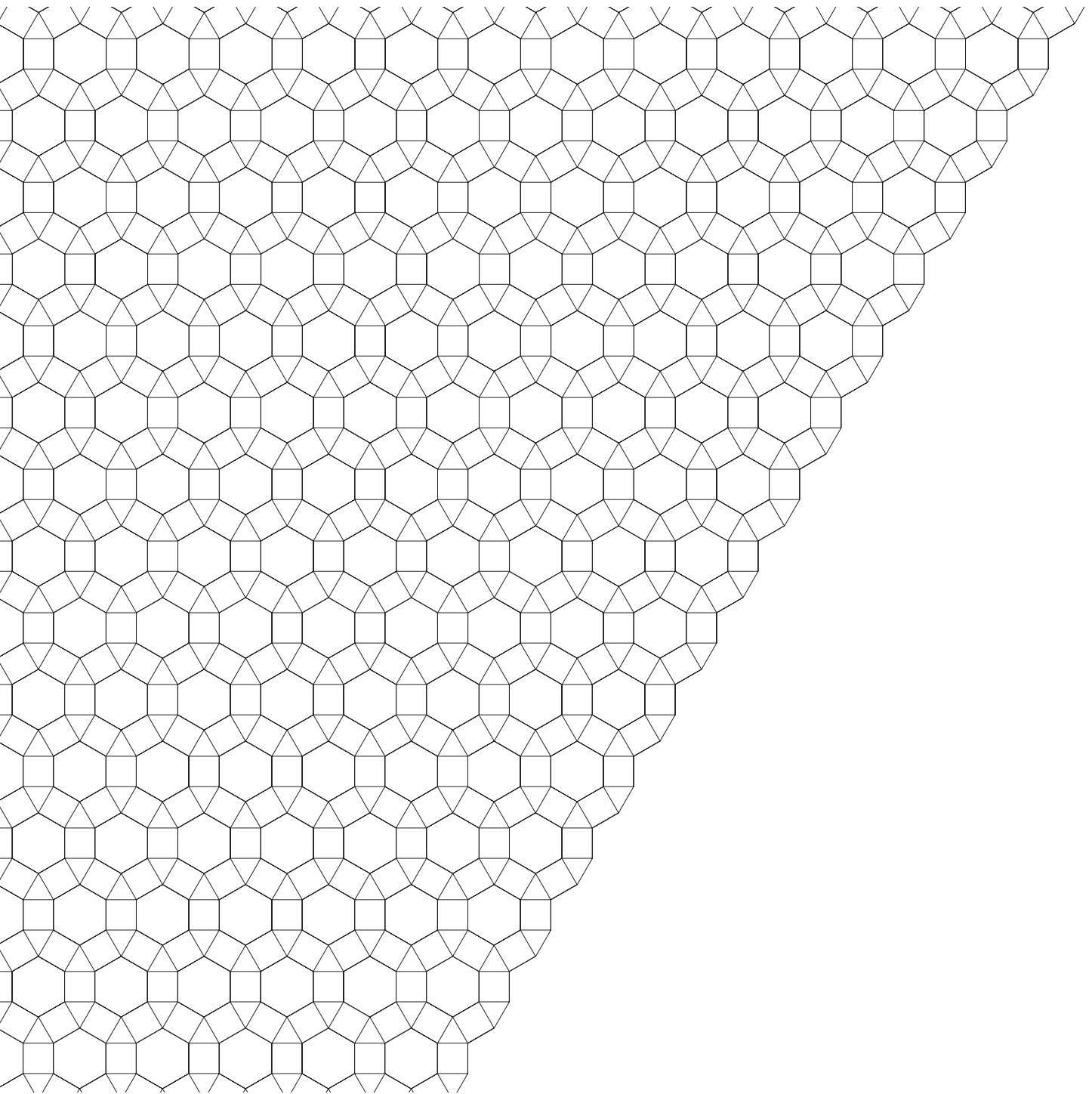
conceptual understanding directly through our approach. An instrument to achieve this is being trialled with the new cohort.

Student perspectives are being fed into the new design: for example, starting the year with a focus on matrices and including practice-based work in tutorials alongside exploration with GeoGebra. The group project is being redesigned. The overwhelmingly positive outcome from ESUM is what we have learned as teachers about what engaged students and how they experienced the innovative approaches we have used. We are becoming more knowledgeable about the balance of activity, about specific elements of innovation and about the issues in developing conceptual understanding of mathematics. These feed into the overall module design; they also inform day to day practice in interacting with students and discerning their quality of understanding.

## References

- [1] Jaworski, B. & Matthews J. (2011). Developing teaching of mathematics to first year engineering students. *Teaching Mathematics and its Applications* 30 (4), pp. 178-185.
- [2] Jaworski, B. (2010). Challenge and support in Undergraduate Mathematics for Engineers in a GeoGebra medium. *MSOR Connections* 10 (1), pp. 10-14.
- [3] Jaworski, B. (2003) Research practice into/influencing mathematics teaching and learning development: towards a theoretical framework based on co-learning partnerships. *Educational Studies in Mathematics* 54, pp. 249-282





# Supporting Undergraduate Engagement and Achievement in STEM Disciplines

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## Abstract

With support from the MSOR Network as part of the National HE STEM Programme, the University Centre at Blackburn College has developed an innovative, engaging and practical Mathematics ‘bridging’ course for new engineering students enrolling onto Higher National programmes.

The project team have developed an online resource to not only to reduce contact time within College, but more importantly to introduce a blended learning approach to make mathematics engaging and relevant to learners in engineering disciplines.

Videos, written resources and assessments have been created by the team which are available for student access within the College’s Virtual Learning Environment, Moodle. There have been many issues with adding mathematical formulae to the VLE, but most have been resolved with the use of LaTeX.

Student feedback during trials has been extremely positive and, while there is still much more to be added to the online course material, the benefits of this blended delivery approach are being witnessed by all stakeholders.

## Background and Rationale

The project objective has been to develop an innovative, engaging and practical mathematics blended learning ‘bridging’ course for new students enrolling onto Higher Education Engineering programmes.

A significant majority of applicants to our programmes do not formally possess a level 3 (equivalent to an A-level) in mathematics. Historically a conditional place onto a Higher Education (HE) programme has been offered subject to successful completion of an intensive six day course comprising level 3 mathematics. Previously the course has been delivered through face-to-face (f2f) traditional lectures and has utilised paper resources.

The ‘bridging’ course is a centre-devised module and does not result in a stand-alone qualification; the syllabus was designed to contain the essential building blocks for learners to develop their mathematical skills required to complete technical modules at Higher National (HN) level.

At the University Centre at Blackburn College (UCBC), a number of delivery modes are adopted for its engineering programmes. One mode allows for year-round enrolment and therefore the bridging course is offered a number of times during the academic year, attracting approximately 50 students. The majority of these students (non-traditional) are not local to the College and therefore have to seek accommodation during the course, which can have an impact on their study during the intensive week.

As the module is not accredited, students are constantly requesting for it to be made shorter, as accommodation costs are high for those learners that are not local to the area and organising leave from work can be difficult. Before this project began it would have been impossible to reduce the course to less than six days without removing vital material.

This project has allowed the School to produce online resources, which will act as a permanent point of reference for students and will also reduce the contact time with lecturers in College. It has also provided the opportunity to develop more engaging and engineering-relevant material via a blended learning approach.

## Implementation

The College has an e-learning strategy that is heavily biased towards using Moodle, the Virtual Learning Environment (VLE). Although the project was not restricted solely to Moodle, it seemed a sensible choice of platform, as the learners would be able to access the material from outside of College and also Moodle will play a large role in their future studies on the HN programme.

The project team (the authors) initially reviewed the existing syllabus, as it was deemed a good opportunity to include topics below level 3 which are known to cause difficulties and involve misconceptions. After review, the syllabus was split into 14 topics ranging from negative numbers to calculus. The project team also conducted searches into existing material available freely on the internet, including YouTube (1), Khan Academy (2), BBC Skillswise (3) and mathcentre (4). Although the standard of this material was excellent, it was not deemed suitable for a number of reasons: The team could not find material that was fully relevant in terms of the topics outlined on Moodle and the depth into which a topic was explained. Another reason to develop material in-house is that external material could not be relied upon to be available in the future. Further, as this online module would constitute the first interaction with the College and the teaching staff, it was considered important to personalise the dedicated Moodle pages. It was assumed that a learner would feel a sense of 'being a student at UCBC' if they had been 'taught' by the lecturers, albeit via video, and they would also feel more at ease during online tutorials.

The team wanted to create a mixture of written text, videos and assessments for each of the 14 topics within Moodle. We wanted the development of the material on the VLE to be very much guided by the learners, and therefore their input was sought on the three remaining courses that were to be delivered during the project timescale. These three remaining bridging mathematics courses were delivered from January to May to non-traditional students only, as on-campus students had already commenced their HN studies and therefore had done the bridging course in September.

Out of the 25 students involved in the three remaining bridging mathematics courses, 23 were non-traditional students and 2 were on-campus students wishing to commence HN studies in September 2012. Student input and feedback was mainly gathered during the taught days spent in College, after they had completed the online material. Comments were also sought from students during their online studies via weekly emails sent by the lecturer.

In terms of input, students were not involved in the initial selection of topics listed on Moodle and they did not contribute to designing any material. However to-date their input has been invaluable and will have a significant impact on the material produced for the incomplete Moodle topics.

It was decided that the informative text should be kept to a minimum, so that the VLE did not look cluttered. The majority of the information would therefore be delivered via recorded video. Two members of the team used different media to record videos, in order to provide variety. Some material was recorded using screen capture software called Camtasia; information was prepared on PowerPoint and voice was added as the recording was made. Other videos were filmed live using a video-recorder focused directly upon the hand-written demonstrations. All the videos are approximately 10 minutes, or under, in duration and there has been at least one video produced per topic.

Adding text to Moodle has proved to be the biggest challenge of this project; the typing of the Latin alphabet is not an issue, however the VLE is limited to a handful of fonts and sizes which allows for little creativity. The problem has been the typing of mathematical formulae. Although Moodle has an in-built equation editor, it is restricting and cumbersome. The team experimented with a number of alternative solutions without success. The solution that has been adopted is saving text and formulae as images and uploading them to Moodle; the former using Word 2010 to allow for flexibility of font and size; the latter using a type-setting language called LaTeX which allowed for ease of typing mathematics and formulae. Uploading images rather than text would cause issues for visually impaired students and possibly those with dyslexia, due to text reader not being able to read images.

The team felt it was important to assess the students' progress through the online material, in terms of engagement and also in terms of understanding the material. At least one assessment appears in each topic and they are categorised as formative and summative. The tutors are able to see student attempts, grade on each attempt, what answers were given and the duration of each attempt. However, the inclusion of assessment proved difficult because of the lecturer's need to input mathematical formulae and the solution used for general text (detailed in the previous paragraph) could not be applied within the in-built Moodle assessments. Instead a LaTeX equation editor, available on the web (5), was used to convert LaTeX into HTML which could be pasted directly into Moodle.

To-date six out of the fourteen topics are completed on the VLE and the material has been trialled with three cohorts of students and feedback has been obtained from each one. The f2f element of the course has now been reduced to three days. The topics are listed in order of difficulty and students are expected to complete them in order. The first six topics cover concepts that are deemed level 2 (equivalent to GCSE) and therefore the project team felt it reasonable that a student would be able to complete one topic per week. Currently login details and instructions are sent to students six weeks prior to the f2f sessions. It is possible to monitor student access to the VLE, but it is not currently possible to determine if they have read the material or for how long. At the start of the f2f sessions an overview of the online material is given by the lecturer for approximately five hours.

## Evaluation

This project is still very much a work-in-progress and therefore evaluation has been targeted towards improving the content already developed and not particularly on immediate impact. The team did design an online questionnaire for the group which the majority of learners completed, however the most useful feedback came from f2f discussions with the group as the students gave honest and constructive feedback.

All of the students (25 involved in the project) liked both types of videos and commented that they were extremely helpful in terms of the content and also that they could be watched repeatedly and paused. Some suggested that captions of important formulae could be added when editing, which will be done on future videos. The fact that some students watched the videos repeatedly is important as it demonstrates how the individual needs of students can be met by this approach.

The first cohort of students all commented on the assessments; they wanted more feedback within the solutions rather than just the answer. Therefore full worked solutions were provided upon the submission of assessments in time for the second cohort of learners.

It was initially assumed, by the project team, that the online course would eventually replace the need for any f2f lecturers in College, however the students objected strongly to this advising at least one consolidation and tutorial day within UCBC.

Online tutorials, using Adobe Connect, have been offered to all students prior to attending the College, however none have accepted to-date. It is envisaged that as more of the topics are completed, and get progressively more challenging, online regular tutorial sessions will be scheduled.

All of the students have continued onto either a HNC or HND programme at UCBC, and to-date eight of the students have completed a mathematics module at that level. Each of these students has received at least a Merit for the module, which implies that completing the bridging maths module through a blend of online delivery and f2f sessions has not had a negative impact upon grades obtained in further mathematics modules, rather the experience has left a positive and hopefully lasting mark on their future studies.

## Discussion, Learning and Impact

Although the VLE is not complete, we believe that the project has successfully achieved the initial objectives of creating an engaging bridging mathematics course via a blended learning approach.

As all the material (written text, videos and assessments) was developed in-house the advancement of the VLE course has been a slow process, further delayed with amendments made to material resulting from student feedback.

The actual concept of creating an online course was not daunting; however, the practicalities of adding mathematical text and creating assessments posed many initial problems. In the main these issues were alleviated using LaTeX, but some problems still remain that lie with the VLE. The College are currently in the process of upgrading to the latest version of Moodle, so it is assumed that some resolution can be achieved.

The feedback from the students has been extremely positive, giving comments such as:

*'The videos are great because I can watch them as many times as I want'.*

*'The feedback on the quizzes helps because I can see where I have made mistakes'.*

*'I found the online material extremely useful in preparing for the course itself. The videos where worked examples were shown were useful.'* and

*'Having not studied this subject for some time, I was concerned about how this would affect my understanding. However, both the pre-course and especially the tuition throughout the week got me well up to speed. I did find the online material useful but i would not like to sacrifice the tuition for this, as the tuition is where my questions could be answered and different teaching methods could be used to solve some the mathematical problems.'*

The tutors are able to monitor the students closely as they carry out their online study; features in Moodle allow for the display of time spent by each student on particular tasks and of grades achieved in assessments. This is a really useful tool as tutors can send individual emails to students who are either having difficulties or are successful in tasks to offer encouragement or extra guidance and praise.

The team have also discovered that it is not just the bridging mathematics students who are accessing the material online; existing students on the HN programmes are also finding the module useful for revision purposes.

There seems to be a perception that creating online material, once done, will reduce the amount of hours a lecturer has to dedicate to the module. Although the online learning has clear benefits for the student, we have found that the time spent monitoring and emailing students has been larger than initial predictions. As the topics on Moodle increase and become more challenging, online group tutorials will become mandatory.

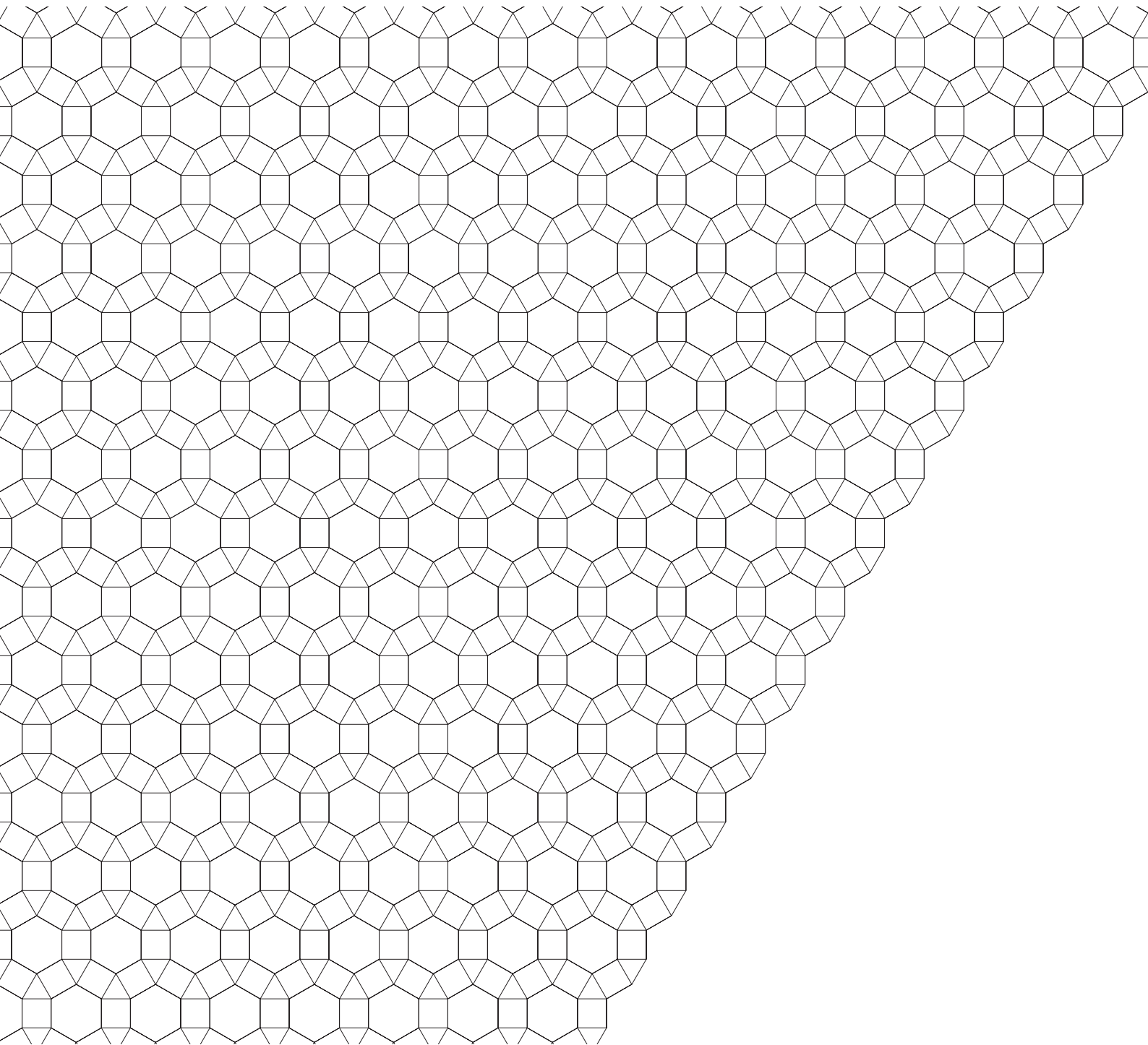
## Further Development and Sustainability

Although the project is not complete, in terms of the Moodle resources, the College are able to see the benefits of the blended delivery and have allocated further development hours in the next academic year for the project team. One member of the team is currently learning Flash animation in order to create interactive resources that would allow for 'experimentation' with certain mathematical concepts.

Currently, some of the resources from the bridging course are being adapted for use for Computing and Construction Summer School programmes.

## **Bibliography**

1. YouTube. YouTube - Broadcast Yourself. *YouTube*. [Online] 2012. <http://www.youtube.com/>.
2. Khan Academy. Khan Academy. *Khan Academy*. [Online] 2012. <http://www.khanacademy.org/>.
3. BBC. BBC - Skillswise - Maths. *BBC Skillswise - English and Maths for Adults*. [Online] 2012. <http://www.bbc.co.uk/skillswise/maths>.
4. MathCentre. Mathematics Resources. *MathCentre*. [Online] 2012. <http://www.mathcentre.ac.uk/>.
5. CodeCogs. Online LaTeX Equations Editor - create, integrate and download. *CodeCogs*. [Online] 2012. <http://www.codecogs.com/latex/eqneditor.php>.



# A Pilot for a Shared Online Statistics Advisory Service

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## Background

Statistics Advisory Services (SASs) have recently been established at several UK HE institutions [1], offering statistics help and advice to students undertaking a final year undergraduate or Masters project or engaged in postgraduate research. A SAS is appointments based and is normally provided in addition to drop-in support offered via a mathematics support centre. Typically it offers statistics advice in relation to aspects of study design, questionnaire design, data analysis, use of statistics software, and the interpretation and reporting of results.

However, not all UK HE institutions currently offer this type of SAS, possibly due to a lack of suitably experienced personnel or financial resources. In response to this, a National HE STEM Programme pilot project operated an online SAS shared between several HE institutions.

The objectives of the project were to identify the practical and pedagogical issues associated with sharing an online SAS resource, and to elicit the opinions of students using the service in order to understand their expectations and experience of using this type of online support.

## Implementation

The project facilitated a total of 68 appointments taken up by 46 students from the three partner institutions (Birmingham City University, De Montfort University and the University of Sunderland). A statistics advisor was employed as part of the project, working remotely from her home.

The students met with the statistics advisor using an Elluminate<sup>1</sup> online learning space/web meeting tool. The Elluminate learning space was provided by Loughborough University which has recently adopted Elluminate as its primary online learning space. For the last two years this tool has been used to provide online access to the SAS for Loughborough University students who are studying or researching part-time or via distance learning.

## Evaluation and discussion

Students' opinions were sought via a follow up online questionnaire. In addition, more in depth opinions were gathered from three students via follow up case study interviews.

The over-riding picture that emerged from the study was that the students found Elluminate easy to use and both the students and the statistics advisor felt that this tool has many advantages for use in the provision of this type of online support, particularly in view of its easy to use application sharing facility. This means that statistical software such as SPSS or Minitab, or indeed Excel, can be shared simultaneously by both the student and the statistics advisor. This allows the statistics advisor to see the student's data during the appointment.

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<sup>1</sup>Note that Elluminate is now known as Blackboard Collaborate (see [www.illuminate.com](http://www.illuminate.com))



However, many students did experience some technological issues during their appointments. These were reported across all institutions and related mainly to either difficulties with the audio or to connectivity problems. The occurrence of both of these problems does, however, depend very much on the computer hardware and type of connection being used by the student. These problems could be removed to a large extent if the student had access to a PC at their host institution, which was known to have a good wired internet connection and a headset that functioned correctly using Elluminate.

Some students also displayed a lack of confidence with using this type of online tool. This may be partly due to a lack of previous experience with the technology. Where the student's first language was not English, communication difficulties may also have been a contributory factor to this lack of confidence. Some of these problems with lack of confidence can be overcome to some extent by giving one-to-one instruction on using Elluminate before their online appointment. Note that all students were given written instructions on using Elluminate prior to their appointment and also pointed to a video providing further instruction if required. Some of these students did also receive one-to-one instruction in the use of Elluminate by a local contact at the host institution.

If such a shared SAS resource is being considered in the future then it seems clear from this pilot that a local contact at each partner institution forms a vital component of the success of the service. This same person could also provide a screening function, similar to that undertaken at some of the host institutions during this pilot, to ensure that their needs could be satisfied via the online SAS.

In terms of the pedagogical value of the service to the students, 85% of the students completing the survey reported that they were able to obtain help with "Most" or "All" of their statistics problems and the remaining 15% reported that they were able to obtain help with "Some" of their statistics problems. Furthermore, all but one student in the survey considered their overall experience of the service to be "Good" or "Very Good" and these same students said that they would use this service in the future if there was no alternative source of support and would also recommend this service to a friend.

### **Further work and sustainability**

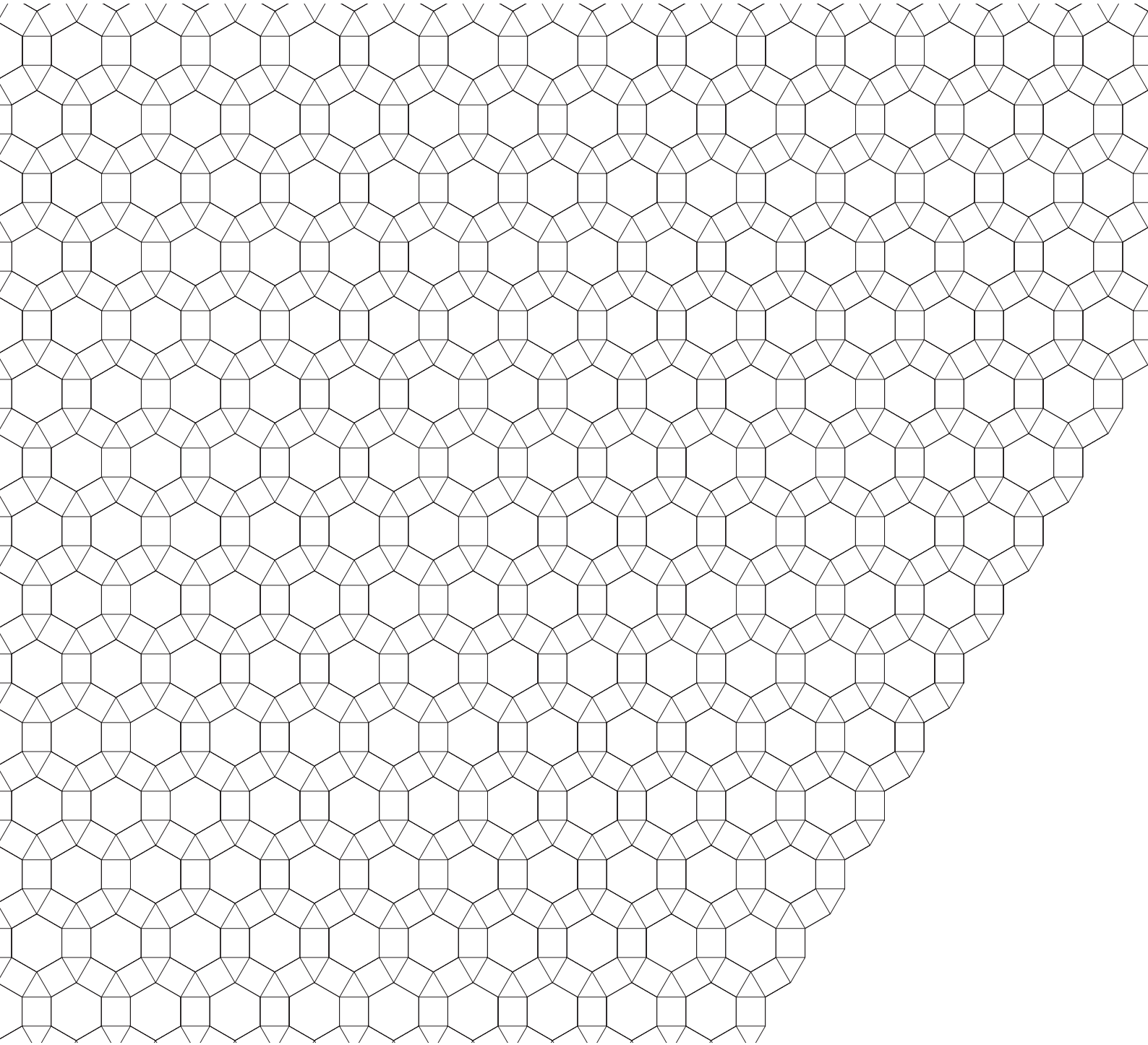
This pilot study has demonstrated that an online SAS is able to offer a practical alternative to an institution specific face-to-face SAS if suitably experienced staff are not available locally. In addition, it has shown that it is feasible for this type of service to be shared by a number of institutions and that this might offer a viable option in order to share the financial costs of providing such a service.

This work was reported at the CETL-MSOR Conference 2011. A full report is available [2] to disseminate what was learned in conducting this pilot, with details of the implementation, case studies from the institutions involved and recommendations for running an online SAS service.

We believe that this type of shared service would offer universities a viable alternative means of providing a SAS without incurring the financial costs of resourcing a SAS solely dedicated to their own institution. Given the new climate of student access to information relating to learning support and the proposals set out in the UK Government's Higher Education White Paper on "Students at the Heart of the System" [3], it would seem sensible to further consider this type of support provision and we look forward to being able to take this idea forward.

## References

- [1] Patel, C., De Jager, B.G. and Zou, L. (2010). Approaches to extra-curricular statistics support for non-statistics ug and pg: facilitating the transition to higher education. In: C. Reading (ed). *Data and context in statistics education: Towards an evidence-based society; Proceedings of the Eighth International Conference on Teaching Statistics (ICOTS8), Ljubljana, Slovenia*. <http://www.stat.auckland.ac.nz/~iase/publications.php?show=icots8> [last accessed 10/10/2011].
- [2] Owen, A. et al. (2011). *A Pilot for a Shared On-line Statistics Advisory Service*. Loughborough University. Available via: [http://mathstore.ac.uk/headocs/OnlineSAS\\_FinalReport.pdf](http://mathstore.ac.uk/headocs/OnlineSAS_FinalReport.pdf) [last accessed July 2012].
- [3] Department for Business, Innovation and Skills (2011). *Higher Education: Students at the Heart of the System*, Cm 8122, London: The Stationery Office.



# Good Practice on Inclusive Curricula in the Mathematical Sciences

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Inclusive curriculum practice refers to “the process of developing, designing and refining programmes of study to minimise the barriers that students may face in accessing the curriculum” [1]. In addition to reacting to the needs of individual students through reasonable adjustments, potential barriers should be anticipated and resolved in a proactive manner. Both aspects are part of the legal requirement [2]. Courses with substantial mathematical content pose specific accessibility challenges beyond those usually considered in general inclusive curricula good practice advice.

A workshop in February 2011 brought together those with different perspectives on the issues involved – academic staff, professional support staff, disability researchers and students – to consider inclusive design and proactive adjustments regarding disability, what is required, what best practice might be and the challenges involved which are specific to the mathematical sciences.

Workshop attendees and members of the Maths Stats & OR (MSOR) Network ‘Accessing MSOR’ working group were invited to submit case studies or reports relevant to the theme for a guide. The resultant guide, ‘Good Practice on Inclusive Curricula in the Mathematical Sciences’, seeks to complement and extend, rather than replace, general good practice advice.

Contributions address the experiences of students with visual impairments, dyslexia and Asperger syndrome and issues relating to making mathematical content accessible to disabled students. The guide concludes with a collection of references to resources, sources of further information and key papers with short annotations. This list is provided to assist departments seeking mathematics specialist information to discover resources more effectively.

Common threads that run through the contributions indicate common challenges for inclusive practice in mathematical sciences. Contributions explore technical and pedagogic barriers and the way these may be formed by the modes in which mathematics is communicated. Evidence is provided of the need for collaboration between the mathematical sciences community and the support professionals in dissolving barriers and moving together towards the goal of inclusive curricula.

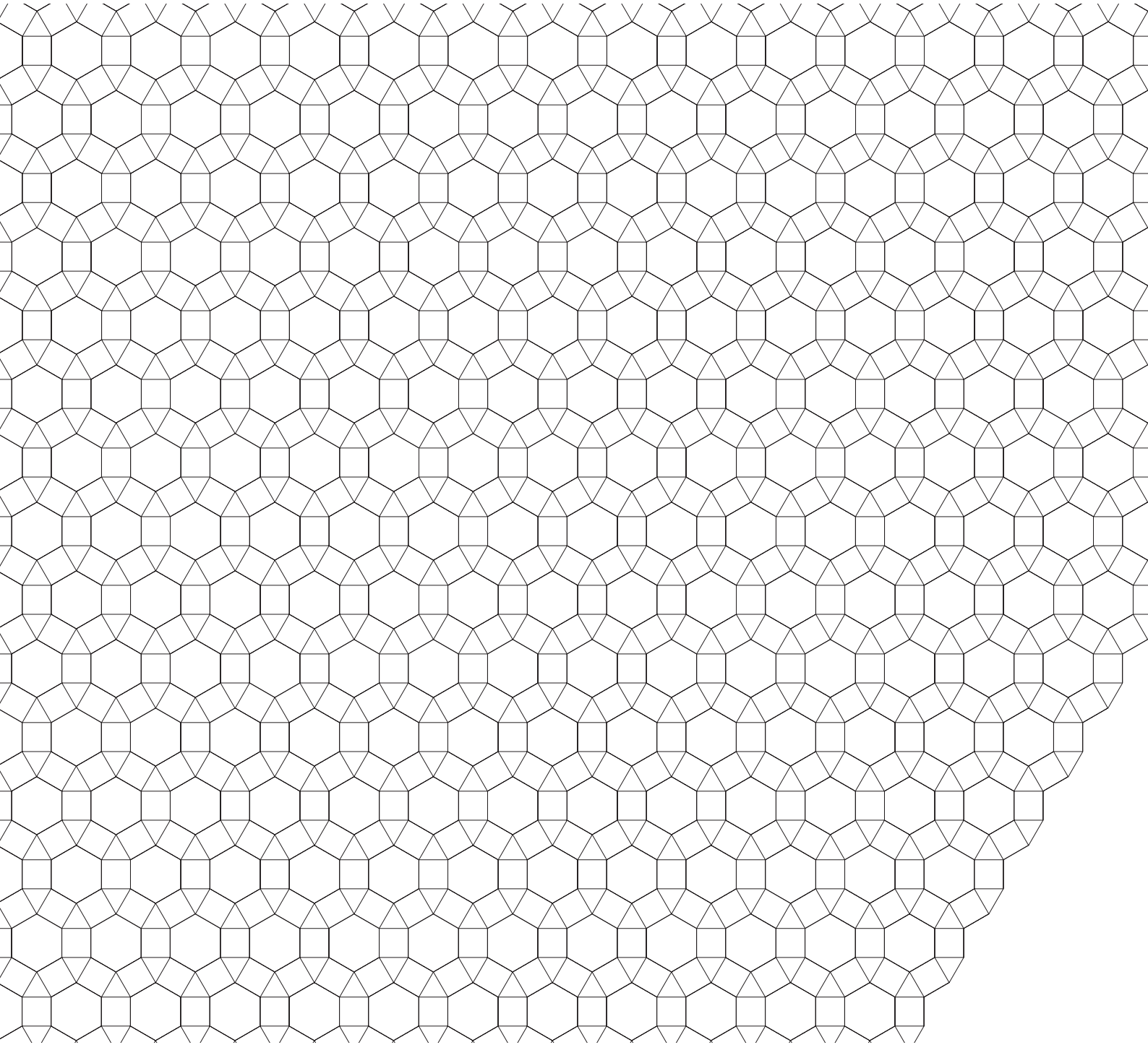
## Output

Cliffe, E. and Rowlett, P., eds., 2012. Good Practice on Inclusive Curricula in the Mathematical Sciences. MSOR Network.

Available via: [www.mathcentre.ac.uk/resources/uploaded/InclusiveCurricula.pdf](http://www.mathcentre.ac.uk/resources/uploaded/InclusiveCurricula.pdf)

## References

- [1] Gravestock, P., 2011. Inclusive Curriculum Practices. Available via: [http://www.heacademy.ac.uk/resources/detail/subjects/psychology/Inclusive\\_Curriculum\\_Practices](http://www.heacademy.ac.uk/resources/detail/subjects/psychology/Inclusive_Curriculum_Practices) [last accessed: 09/06/2012].
- [2] Equality and Human Rights Commission, 2010. Codes of Practice. Available via: <http://www.equalityhumanrights.com/advice-and-guidance/information-for-advisers/codes-of-practice/> [last accessed: 09/06/2012].



# Methods to Produce Flexible and Accessible Learning Resources in Mathematics

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## Introduction

A significant barrier for disabled students is the delivery of mathematical learning resources in inaccessible formats. Due to the mathematical nature of the text, teaching staff may not be aware of the formats required to enable use of assistive software or have experience in the production of resources which can be modified to individual requirements. This has an impact on departments' ability to design and deliver inclusive curricula. In this project we explored methods to produce flexible and accessible learning resources for mathematics with a focus on producing a guide for staff in HEI to enable them as individuals to create flexible resources efficiently and robustly. This includes formats accessible via speech and/or some form of Braille, large print and editable formats.

## Overview of the literature

A review of the literature and available technologies confirmed the formats that we might need to produce but also furnished us with extensive lists of technologies which might assist us. We present an overview of this literature here.

The provision of partial notes in mathematics courses is perceived by students as beneficial to their learning and is strongly related to high academic performance [1]. However, a significant barrier for disabled students is the suitability of the learning resource format provided. Many of the contributions to the Good Practice on Inclusive Curricula in the Mathematical Sciences guide [2] highlight the need for full notes in specific formats to be provided prior to classes. Some case studies covering inclusive curricula in mathematical subject areas also confirm the need for full notes, sometimes in specific formats [3, 4].

Some students require full notes in Braille [5, 6, 2] and may use a Braille display [7, 2] either for Braille mathematics or direct access to the LaTeX code [8]. Other students require large print and authors highlight that large print is not simply a matter of using a larger font but also requires changes to some or all of spacing, page layout, layout of the mathematics, font or colour [9, 8]. However, students (and staff) are likely to have difficulty creating a large print version even if provided with the LaTeX source [10], the lack of line-breaking in the equations in standard LaTeX being a primary issue, and the MathType format is highlighted as being useful [2]. The RNIB Clear Print guidelines are a useful starting point [11] and note the minimum font size etc. considered advisable for general resources. For students reading in Braille or large print, access to full notes in class acts as an alternative to the board and permits the student to follow the lecture content.

Students who are d/Deaf are not able to lipread, watch a BSL/English interpreter or lipspeaker while also taking notes, so would require a note-taker to write down what is written on the board. For a student lipreading, all verbal information given while facing the board will be lost [12]. Some practices known to be beneficial include the provision of visual organisers, using a collaborative, case study, problem-solving approach (where possible) and pre-teaching (or, at least, enabling preparation) of specialised vocabulary [13]. This suggests that notes which clearly highlight terminology, use visual organisers and include examples are likely to be helpful.

Some disabled students experience difficulties copying precisely, knowing what to write down, maintaining concentration or their place in text or retaining definitions in memory. This might include some students with specific learning difficulties (e.g. dyslexia, dyspraxia), students with

Asperger syndrome, mental health and fatigue conditions. Access to full notes in a suitable format enables the main activity in class to be the desired engagement with concepts and logical arguments. Formats reported as being of assistance are: those presented in sans serif fonts; clearly structured documents; coloured backgrounds; formats which can be adapted by the students to their font, spacing and colour requirements; formats with colour or structural highlighting of equation scope; audio formats or formats which can be read loud; video formats of real time manipulation; visual organisers such as mind-maps and flow diagrams; notes which can be annotated in class; and, formats from which formula can be copied and pasted or notes electronically annotated [2, 14, 15, 16, 17, 18].

In summary, the use of visual organisers helps some students as does the provision of editable formats. Other students might require quite specific formats which may include clear print, large print and formats accessible by text-to-speech (e.g. literacy support software used by dyslexic students), screenreader or Braille technologies. Word or PDF documents containing mathematics cannot easily be produced in these formats.

In order to provide such a range of formats we require a method to produce a single master version, which can be updated over time, from which the multiple required formats can be produced automatically. Using a single master is not a new idea [19, 20, 21] but we require viable methods which specifically produce accessible formats.

Cooper [22, 23, 2] neatly captures the technical challenges and general approaches which we might need to take. The use of MathML [24] is a key technology as this enables speech to be produced and equations to scale with the surrounding text and reflow, linebreaking as necessary. Scalable graphics can also be used to permit scaling of equations [25]. Automated linebreaking, while possible for some equations in LaTeX, requires the use of non-standard mathematics environments which have a substantially different syntax from standard LaTeX and are not in widespread use [26].

MathML is not designed for humans to read and write directly. The World Wide Web Consortium (W3C) maintains extensive lists of technologies which produce MathML or convert between MathML and other formats [27] and these formed a starting point. However, guidance from the literature [28, 29, 30, 31, 32, 33, 34, 35, 36] greatly facilitates comparisons between and understanding of these technologies.

MathML is not the only format we considered. The TeX User Group (TUG) maintains lists of converters between LaTeX and word processor formats [37, 38] and the American Mathematical Society (AMS) maintain a list of TeX related resources [39].

Finally, the many reference documents on LaTeX hosted by the Comprehensive TeX Archive Network [40] and the bug trackers of all the software we worked with sometimes gave insights as to the likely cause of misbehaviours of the transform technologies in the face of the author's freedom to use and abuse LaTeX [41].

## Student views

Disabled students in mathematics had previously provided input on their requirements, their use of assistive technology and given feedback on the notes already in production. We invited further input for this project and one student updated us on how his use of notes had changed over time.

Students reported that lecturers either provide handwritten notes or PDF output from LaTeX which has normally been encoded in 10pt, 11pt or 12pt default spacing and fonts. The following formats have been produced for students:

- Clear print (A4, single sided, 12pt Helvetica font for English, extra white space between paragraphs, extra spacing in maths – extra space is to enable annotation) is provided to students who are dyslexic or dyspraxic, who have Asperger syndrome, mental health difficulties, conditions causing fatigue and to some students with mobility difficulties. Such notes are also provided to students with temporary conditions.

- Large print (A4, single sided, Helvetica font for English, extra white space between paragraphs and in mathematics, enlarged diagrams and a variety of sizes – 14pt, 17pt, 20pt and 26pt – with adjusted spacing and adjustments to emphasis, underlining and line spacing).
- LaTeX source, either ‘as is’ for one student who could no longer take their own notes but wished to continue to annotate the course notes, or ‘human readable’ with commands present solely for visual layout removed for a student who needed a format that could be read by a screenreader.

Editable formats for students who don’t know LaTeX have been requested but could not be provided. These are needed because the students often prefer to adjust the materials to their own requirements and are best placed to do so, if we can enable this. Some students report their frustration that text-to-speech does not work or ask if it is possible. Since equations are interspersed with text this even impedes students who primarily wish to hear the English text aloud rather than the equations themselves.

It is important that students are given access to notes. One student said *“Without the lecture notes there is no point in being there [in lectures]”*. It is also important that alternative versions are kept up-to-date. Students said *“the confusing part is when lecturers change the order of things round completely”* and *“the lecturer often strays from the official course notes”*. In this case, students can lose track in lectures quite rapidly if they are not able to read the board clearly or at all.

### Staff views

Whether staff and departments are willing to use a method to create learning resources is a key concern. To increase the uptake of any proposed methods it is ideal if they reflect those already in use and provide much of the same functionality. We sought input from teaching staff but also from staff employed in producing accessible versions of mathematical documents.

### Teaching staff

A survey was directed at teaching staff in mathematics at three institutions to ascertain the type of mathematical resource they typically produced, the underlying format in which they worked (and their minimum requirements for this), the formats in which they provided resources to students and their experience, if any, of supplying accessible notes. We additionally asked if staff would be willing to share representative samples of their resources for use in this project. We received 45 responses, 16 of which also provided representative samples.

The majority of staff are using a mixture of LaTeX, handwritten and Microsoft Office formats for their resources. Staff used a very wide range of methods to create images (with little duplication). A variety of LaTeX packages were in use for learning resource production. One respondent uses his own packages and class files. Staff tend to provide students with handwritten or PDF documents; this latter appears to include resources which were created in Word.

In response to the question *“Have your mathematical learning resources been converted into/produced in any output formats specifically for a disabled student by you or your department?”*, 15 respondents said yes, 9 were unsure and the rest had not. Only one respondent was able to create the resource format required automatically from their usual production format.

### Support staff

A small group of ‘expert users’ employed in producing accessible mathematical documents at two institutions were identified. The ‘expert users’ could not produce the required output formats from a single master though each could produce some of the specific formats to



requirements. The cost of producing inflexible learning resources was noted. These require costly adjustments to be made in reaction to individual requirements and this may be the work of specialist support staff.

In the Department of Mathematical Sciences at the University of Bath, over the last seven years, support staff have produced full notes of courses in a variety of accessible formats. Support staff found it difficult to reuse resources from year to year though sometimes they found it possible to produce a single version which was acceptable to all the students requiring notes on a specific module. However, this was not always the case and new versions of resources were sometimes produced for each specific set of requirements. Support staff found that the versions they created for particular students and shared with teaching staff for their future use were not updated when staff updated their standard copy. As a result new formats for some modules were produced three times in the seven year period. There were examples where students accepted a format that was not completely to their requirements because a better format could not be created. For example, students who would have benefitted from electronic notes they could edit, but who did not know LaTeX, instead accepted reformatted hard copy notes which they could less easily annotate.

### **Process used to produce the methods**

We used a set of documents each capturing a single component of structure e.g. a list, an equation array, an image or a table. The equations used were chosen to cover a range of one and two dimensional layouts e.g. symbols mixed with relations, sub- and super-scripts, matrices, roots or fractions. We transformed each document with each technology and evaluated the results (see figure 1 opposite for an example transformation).

We next used representative sample documents provided by survey respondents as complex inputs to test the identified transform technologies such as LaTeX to MathML convertors TeX4ht, LaTeXML and PlasTeX (a full technology list is given in the project output documents). Often no output was produced as structures within the input document could not be transformed and caused the transform to fail. The cause of the transform failure was recorded as a constraint on the structures permitted in input documents and the problematic structure removed to produce a new test document. If output could eventually be produced this was evaluated. We discarded document transform technologies if they were too constrictive or unstable for our purposes or if the results were difficult to realistically evaluate. For instance, we chose not to use LaTeXML as TeX4ht was less constrictive and more often produced output. In some cases we identified missing functionality or problems which we felt could be overcome, for instance that of producing large print reflowable LaTeX automatically. These problems were recorded as barriers to general use but proof of concept work rounds were produced and evaluated.

We produced integrated test documents formed of structural components which the transform technologies could all successfully convert. We then extended these to include a range of mathematical symbols and commands (those available in LaTeX with limited packages on the one hand and in Word on the other; similar documents form part of the project outputs). The remaining transform methods were applied simultaneously to these and each output evaluated. We iteratively adjusted the symbol, command, style and working process constraints until all output formats were correct within certain tolerances. For instance, equation numbering, while internally consistent within each output may not be identical or even equivalent between different formats and this was tolerated but not ideal. Such tolerances were recorded as possible barriers to uptake of the methods.

Finally, the constraints and methods were documented and a member of staff not so far involved trialled the process.

### **Evaluation**

Evaluation had two objectives: to measure the progress in attaining correct output documents and to evaluate the impact of using the final method in document production. The evaluation

Figure 1: example document transformations

$$\sqrt{\frac{1}{10} \sum_{i=1}^{10} i^2} = \sqrt{\frac{1^2 + 2^2 + 3^2 + 4^2 + 5^2 + 6^2 + 7^2 + 8^2 + 9^2 + 10^2}{10}}$$

$$= \sqrt{\frac{1 + 4 + 9 + 16 + 25 + 36 + 49 + 64 + 81 + 100}{10}}$$

$$= \sqrt{\frac{385}{10}}$$

*LaTeX original*

```
\begin{eqnarray*}
\sqrt{\frac{1}{10}\sum_{i=1}^{10} i^2}
&= \sqrt{\frac{1^2 + 2^2 + 3^2 + 4^2 + 5^2 + 6^2 + 7^2 + 8^2 + 9^2 + 10^2}{10}}\\
&= \sqrt{\frac{1 + 4 + 9 + 16 + 25 + 36 + 49 + 64 + 81 + 100}{10}}\\
&= \sqrt{\frac{385}{10}}
\end{eqnarray*}
```

$$\sqrt{\frac{1}{10} \sum_{i=1}^{10} i^2}$$

$$= \sqrt{\frac{1^2 + 2^2 + 3^2 + 4^2 + 5^2 + 6^2 + 7^2 + 8^2 + 9^2 + 10^2}{10}}$$

$$= \sqrt{\frac{1 + 4 + 9 + 16 + 25 + 36 + 49 + 64 + 81 + 100}{10}}$$

$$= \sqrt{\frac{385}{10}}$$

*reflowable LaTeX for large print*

```
\begin{dgroup*}[compact,spread={1.000000\baselineskip}]\begin{dmath*}
\sqrt{\frac{1}{10}\sum_{i=1}^{10} i^2}
\ = \ \sqrt{\frac{1^2 + 2^2 + 3^2 + 4^2 + 5^2 + 6^2 + 7^2 + 8^2 + 9^2 + 10^2}{10}}
\end{dmath*}\begin{dmath*}
\ = \ \sqrt{\frac{1 + 4 + 9 + 16 + 25 + 36 + 49 + 64 + 81 + 100}{10}}
\end{dmath*}\begin{dmath*}
\ = \ \sqrt{\frac{385}{10}}
\end{dmath*}\end{dgroup*}
\end{document}
```

*MathML output from TeX4ht*

```
<!--tex4ht:inline--></p><!--1. 8--><math
xmlns="http://www.w3.org/1998/Math/MathML"
display="block" >
<table class="eqnarray-star" columnalign="right center left" >
<tr><td class="eqnarray-1">
<msqrt><mrow>
<mfrac><mrow><mn>1</mn></mrow><mrow><mn>1</mn><mn>0</mn></mrow></mfrac>
<munderover accentunder="false" accent="false">
<mrow><mo>mathsize="big"> \sum_{i=1}^{10}</mo></mrow>
<mrow><mi>i</mi><mo class="MathClass-rel">=</mo><mn>1</mn></mrow>
<mrow><mn>1</mn><mn>0</mn></mrow></munderover>
<msup><mrow><mi>i</mi></mrow><mrow><mn>2</mn></mrow></msup></mrow></msqrt></td>
<td class="eqnarray-2">
<mo class="MathClass-rel">=</mo></td>
```

goal was to locate and record defects in the output (or, if no output was produced, to determine the cause). Output was checked visually and with relevant assistive software, for correctness by comparison and for usability via a heuristic inspection.

The baseline for document production was established from staff input. None of the sample documents could be used to automatically produce multiple formats and most could not be transformed at all successfully without alteration. Recall that, of the 45 survey respondents, 15 had had resources produced in an output format specifically for a disabled student and 9 were unsure whether this had occurred; only 1 had been able to produce the required format without assistance.

To evaluate the impact of using the methods we asked an expert user to encode a series of handwritten sample documents following our guidelines for LaTeX. The experience of the expert user and the integrated document evaluations confirmed that while production of correct documents is possible the methods are technically exacting (even the smallest deviations can lead to no or incorrect output). She felt she would eventually learn the restrictions and, asked to disregard the overhead of learning, stated *“I believe this is as long as it would have taken me working in the usual way [to create one specific format]”*. On reaching full understanding of the methods, she concluded they were flexible enough and saw they could be expanded in the future. She noted that *“establishing a common standard for producing notes is the best way to not only produce accessible notes but to ensure easy transition between lecturers for a course”*.

## Conclusions

The project has positively impacted practice by:

- increasing the knowledge and expertise of staff who produce and advise on the production of accessible learning materials in mathematical sciences; and,
- providing a method to reduce resource production and maintenance costs, helping to ensure sustainable access for disabled students to formats suited to their needs.

We have derived and documented structure, command, style and symbol constraints which permit multiple formats to be produced. Due to the technical nature of the methods we conclude that staff specialising in accessible mathematical document preparation will be best placed to produce the master documents in the first instance and to transform the documents as required for individual students. Specialist staff may also need to advise teaching staff on the rules they must follow when updating master copies.

Staff specialising in mathematical document production for disabled students will be able to produce, from a single master, formats including large print PDF, also suitable for small screens such as some e-book readers, browser independent formats, formats accessible to text-to-speech technologies, editable formats and formats suitable for screenreader use (speech and/or some form of Braille).

## Outputs

The following outputs are available from <http://www.bath.ac.uk/study/mash/maths-access>

- Instructions and examples of methods for producing master copies in LaTeX and Word and hence the above listed accessible formats.
- A project guide giving further detail of: the literature identifying required formats and the available technologies for transforming mathematical documents; the staff survey; the development process; the costs and remaining barriers.

## Next steps

Staff producing mathematical resources for disabled students will embed the use of these methods in their own practice and in their advice to teaching staff. We did not approach

students to provide feedback on the documents. In most cases they would have needed to learn new facets of an assistive technology and would have derived no immediate benefit from this time-consuming experience. As 'live' learning resources become available in multiple formats we will provide guidance for students and their support staff on how to read and use the formats effectively. Feedback from staff and students can then be used to develop the methods further. Dissemination of the methods may also result in further feedback and adjustments. As the methods are developed further or should new software functionality become available the online resources can be updated.

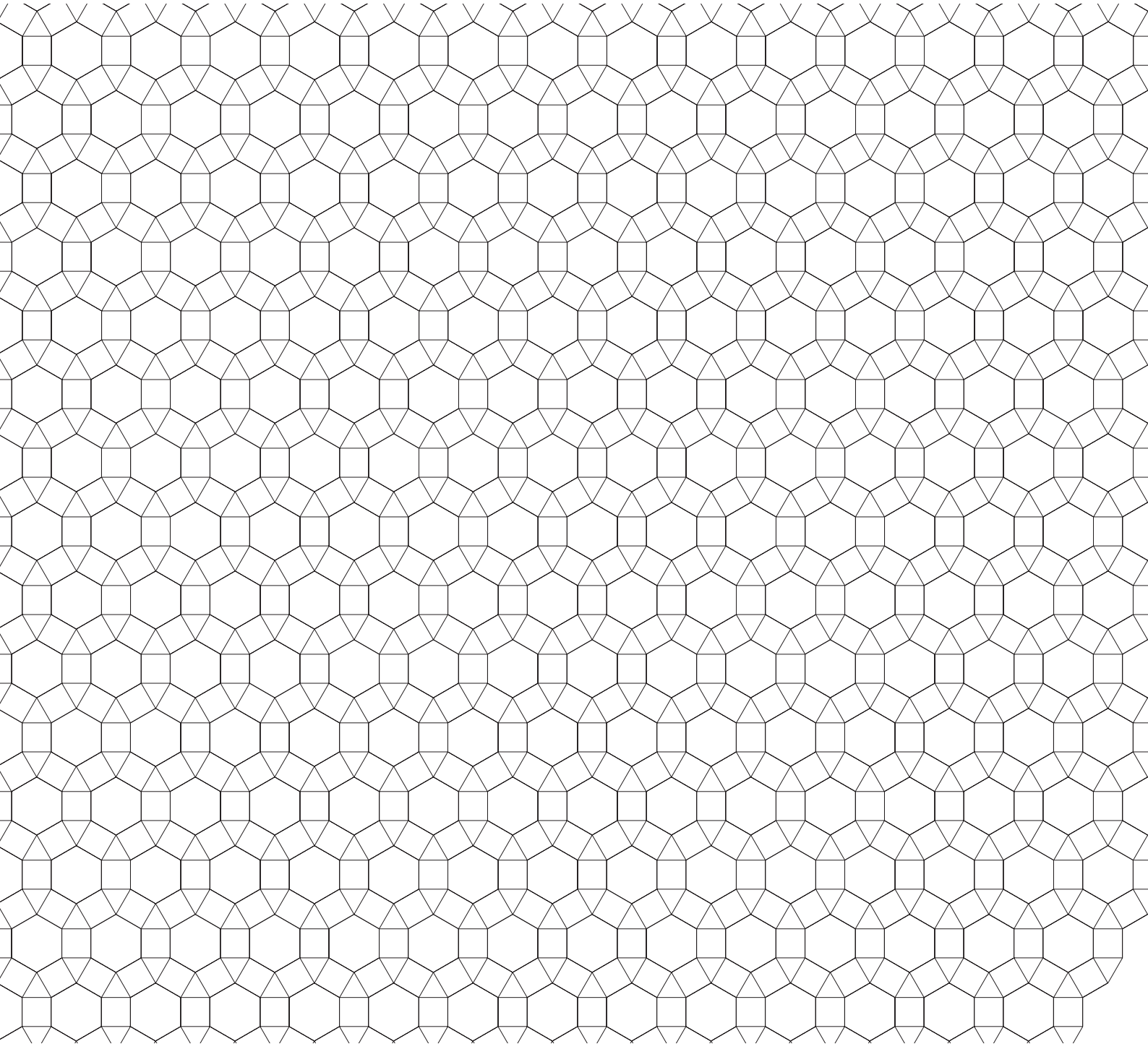
A second avenue for further development, which is required for sustainable use, is to work with the various software publishers and open source communities to patch bugs, improve functionality and ensure long term viability of the required software. Such work would eventually widen the viable user group of the proposed methods and improve the sustainability of them.

## References

- [1] Cardetti, F., Khamsemanan, N. & Orgnero, M. C., "Insights regarding the Usefulness of Partial Notes in Mathematics Courses", *Journal of the Scholarship of Teaching and Learning*, vol. 10, no. 1, pp. 80-92, 2010.
- [2] Cliffe, E. & Rowlett, P., eds., "*Good Practice on Inclusive Curricula in the Mathematical Sciences*", National HE STEM Programme: Mathematical Sciences HE Curriculum Innovation Project, 2012. Available at: <http://mathstore.ac.uk/node/2095> [Accessed 27-May-2012].
- [3] Chapman, V., "*Strategies for Creating Inclusive Programmes of Study (SCIPS)*", 2005/7. Available at: <http://www.scips.worc.ac.uk/> [Accessed: 28-Oct-2011].
- [4] Loughborough University, "*Disabilities: Academic Resource Tool (DART)*", 2005. Available at: <http://dart.lboro.ac.uk/tool/index.html> [Accessed: 01-Nov-2011].
- [5] Whapples, M., "Obtaining Braille mathematical documents", *MSOR Connections*, vol. 7, no. 3, pp. 18-21, Oct. 2007.
- [6] Maddox, S., "Mathematical equations in Braille", *MSOR Connections*, vol. 7, no. 2, pp.45-48, 2007.
- [7] Stanley, P., "Assessing the Mathematics Related Communication Requirements of the Blind in Education and Career", in *ICCHP '08 Proceedings of the 11th international conference of Computers Helping People with Special Needs*, pp. 888-891, 2008.
- [8] Cliffe, E., "Accessibility of mathematical resources: the technology gap", *MSOR Connections*, vol. 9, no. 4, pp. 37-42, Nov. 2009.
- [9] Rowlett E. & Rowlett, P., "Visual impairment in MSOR", *MSOR Connections*, vol. 9, no. 4, pp. 43-46, 2009.
- [10] Rowlett, E. J., "Accessibility in MSOR: one student's personal experience", *MSOR Connections*, vol. 8, no. 1, pp. 27-30, Apr. 2008.
- [11] RNIB, "*Clear Print*", 2011. Available at: [http://www.rnib.org.uk/professionals/accessibleinformation/text/pages/clear\\_print.aspx](http://www.rnib.org.uk/professionals/accessibleinformation/text/pages/clear_print.aspx) [Accessed May 27, 2012].
- [12] Mole, J. & Peacock, D., "*Learning, teaching and assessment: A guide to good practice for staff teaching d/Deaf students in science and engineering*", University of Wolverhampton, 2005.
- [13] Easterbrooks, S., Stephenson, B. & Mertens, D., "Master Teachers' Responses to Twenty Literacy and Science/Mathematics Practices in Deaf Education," *American Annals of the Deaf*, vol. 151, no. 4, pp. 398-409, 2006.
- [14] Perkin G. & Croft, T., "The dyslexic student and mathematics in higher education", *Dyslexia*, vol. 13, no. 3, pp. 193-210, Aug. 2007.

- [15]Graves, L. & Plant, S., “An Attitudinal Study of Pen Technology and Web-based Recordings to Accommodate Students with Disabilities in Post-Secondary Science, Technology, Engineering, and Math Courses”, *The Impact of Tablet PCs and Pen-based Technology on Education: Going Mainstream*, 2010, pp. 39-46, 2010.
- [16]Webb, S. D., “Accessibility of University Mathematics”, *MSOR Connections*, vol. 11, no. 1, pp. 42-47, 2011.
- [17]Freda, C. et al., “Dyslexia: Study of Compensatory Software Which Aids the Mathematical Learning Process of Dyslexic Students at Secondary School and University”, *Computers Helping People with Special Needs*, LNCS 5105/2008, pp. 742-746, 2008.
- [18]Iansyst, “*Technology For Supporting Dyslexic Students Using Mathematical Notation And Scientific Language*”, 2007. Available from: <http://www.dyslexic.com/articlesearch.asp?type=Technology>. [Accessed: 31-May-2012].
- [19]Sojka, P. & Růžička, M., “Single-source publishing in multiple formats for different output devices”, *TUGboat* vol. 29, no. 1, XVII European TeX Conference, pp. 125-131, 2007.
- [20]Godfrey, A. J. R., “*Putting it all together — A blind person’s perspective on developing a toolbox for document preparation*”, Inftyreader.org, 2012. Available from: <http://inftyreader.org/18GodfreyPutting.pdf>, [Accessed 15-May-2012]
- [21]Sojka P. & Plich, R., “Technological challenges of teaching mathematics in a blended learning environment”, *International Journal of Continuing Engineering Education and Life Long Learning*, vol. 18, no. 5, pp. 657-665, Jan. 2008.
- [22]Cooper, M., “Making Mathematics Teaching Inclusive – Access for Disabled Students to Symbolic Languages in Electronic Media”, *MSOR Connections*, vol. 6, no. 4, pp. 29-37, 2006.
- [23]Cooper, M., Lowe, T. & Taylor, M., “Access to mathematics in web resources for people with a visual impairment: Considerations and developments in an open and distance learning context”, *Computers Helping People with Special Needs*, vol. 5105/2008, pp. 926-933, 2008.
- [24]W3C, “*Mathematical Markup Language (MathML) Version 3.0*”, 2010. Available at: <http://www.w3.org/TR/MathML3/>. [Accessed 31-May-2012]
- [25]Stanley, P. B., Bledsoe, C. & Karshmer, A. I., “Utilizing Scalable Vector Graphics in the Instruction of Mathematics to the Print Impaired Student” in *Computers Helping People with Special Needs*, 2004, pp. 626-629.
- [26]Downes, M., “Breaking equations”, *TUGboat*, vol. 18, no. 3, 1997.
- [27]W3C, “*The W3C MathML software list*”, 2012. Available at: <http://www.w3.org/Math/Software/>. [Accessed: 31-May-2012].
- [28]McKain, D., Talk:“Translation of TeX to XML and MathML” given at *Technical Aspects of Mathematical Content workshop, Open University, 9th Sept. 2009*. Video and slides available via: <http://stadium.open.ac.uk/stadia/preview.php?whichevent=1393>, [http://stadium.open.ac.uk/webcast-ou/documents/mc09\\_david\\_mckain\\_conversion.pdf](http://stadium.open.ac.uk/webcast-ou/documents/mc09_david_mckain_conversion.pdf).
- [29]Stamerjohanns, H. et al., “MathML-aware article conversion from LaTeX. A comparison study”, *Towards a Digital Mathematics Library, Grand Bend, Ontario, Canada, July 2009*, pp.109-120, 2009.
- [30]Gurari, E., “TeX4ht: HTML Production”, *TUGboat*, vol. 25, no. 1, 2004.
- [31]Arnold, T., “plasTeX: Converting LaTeX Documents to Other Markup Languages”, *The PracTeX Journal*, TeX Users Group, vol. 3, 2008.
- [32]Stamerjohanns, H. et al., “Transforming Large Collections of Scientific Publications to XML”, *Mathematics in Computer Science*, vol. 3, pp. 299-307, Feb. 2010.

- [33]Ginev, D. et al., “The LaTeXML Daemon: Editable Math on the Collaborative Web” in *Intelligent Computer Mathematics*, vol. 6824, J. H. Davenport, W. M. Farmer, J. Urban, and F. Rabe, eds., Berlin, Heidelberg: Springer Berlin Heidelberg, 2011, pp. 292-294.
- [34]Cervone, D., “MathJax: A Platform for Mathematics on the Web”, *Notices of the AMS*, vol. 59, no. 2, pp. 312-316, 2012.
- [35]Soiffer, N., “MathPlayer: web-based math accessibility” in *Proceedings of the 7th international ACM SIGACCESS conference on Computers and accessibility, New York, NY, USA*, 2005, pp. 204-205.
- [36]Gillan, D. J. et al., “Cognitive Analysis of Equation Reading: Application to the Development of the Math Genie” in *Computers Helping People with Special Needs*, 2004, pp. 630-637.
- [37]Hennings, W., “*Converters from PC Textprocessors to LaTeX — Overview*”, 2011.  
Available at: <http://tug.org/utilities/texconv/pctotex.html>. [Accessed: 31-May-2012].
- [38]Hennings, W., “*Converters from LaTeX to PC Textprocessors — Overview*”, 2011.  
Available at: <http://tug.org/utilities/texconv/textopc.html>. [Accessed: 31-May-2012].
- [39]AMS, “*TeX Resources*”, 2012. Available at: <http://www.ams.org/publications/authors/tex/tex>. [Accessed: 31-May-2012]
- [40]CTAN, “*The Comprehensive TeX Archive Network*” at <http://www.ctan.org/>. [Accessed 31-May-2012]
- [41]Gregorio, E., “*Horrors in LaTeX: How to misuse LaTeX and make a copy editor unhappy*”, TUGboat, vol. 26, no. 3, pp. 273-279, 2005.



# Autism Spectrum Disorders and Group Work in Mathematics

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## Introduction

Students with autistic spectrum disorders (ASD) including Asperger's syndrome can experience difficulties engaging with group work. This forms a barrier to accessing the benefits that group work can deliver, particularly in terms of graduate and employability skills development. As a body, students in mathematics who complete the National Students Survey report relatively weak agreement, compared to all other disciplines, with the statements "*the course has helped me present myself with confidence*" and "*my communication skills have improved*" (Hewson, 2010). In addition, students studying mathematics may experience relatively little group work during their studies which tend to be assessed overwhelmingly via unseen timed examinations (Iannone & Simpson, 2012). Hence, in mathematics, it is arguably more important that those rarer experiences of group work which are provided are accessible, positive and that the skills learnt can be transferred by participants to other contexts.

Two workshops were organised to bring together interested parties in this area to investigate the particular difficulties that a student with ASD may experience in mathematics group work and to share current practice of organising and supporting group work. This paper reports briefly on these topics, notes commonalities in successful practices and suggests a framework based on these.

The authors would like to thank the following speakers for sharing their expertise in order to inform and promote discussion: Mark Brosnan (Chartered Psychologist and Director of Research, Department of Psychology, Bath), Barrie Cooper (Mathematics Teaching Fellow, Exeter), Ruth Fairclough (Mathematics Senior Lecturer and School Student Enabling Coordinator, Wolverhampton), Joanna Hastwell (Asperger Syndrome Project Officer, Cambridge), as well all those who attended.

## Overview: Autism spectrum disorders, mathematics and group work

Autism spectrum disorders affect "*the way a person communicates and relates to people around them*" (Pike, 2005). Typical challenges include a difference in understanding of verbal communication, difficulties with social relationships and less flexibility of thought. Barriers to group work noted included: anxiety regarding how to approach the situation, establishing a group with which to work, understanding the 'rules of engagement', the unpredictable nature of other group members, understanding other members' motivations, intentions and possibly unclear communication and being misinterpreted by others.

Baron-Cohen (2003) describes the cognitive style of people with ASD as usually systematic rather than empathic. Systemising is the ability and drive to build or analyse rule systems including those of an abstract nature. This cognitive style can bring strengths such as logical and systematic thought, areas of deep, narrow interest, attention to detail, accuracy and ability to focus. Mathematics might be described as a 'perfect system' and Baron-Cohen (2007) notes links between mathematical talent and ASD and, as noted by several attendees, a student's area of specialist interest is often their chosen subject at university. Hence, mathematics students with ASD may have areas of particular mathematical strength and a strong dedication to facets of their subject – which their peers might not necessarily share. This may further hinder communication within groups and may also drive anxiety that working in a group will negatively impact on marks.



## Discussion of practice: group work in mathematics

Hastwell (2011; 2012) highlights that an explicit and systematic approach to motivation, group allocation, organisation, marking and reflection is likely to enable ASD students' participation. Some subject specific pedagogic challenges discussed included the need for a subject evidence base that group work supports employability; whether, in mathematics, there is any teaching of group work skills; whether group work was ever integral to the set task, and whether we enable students to reflect on their experiences and transfer them to other contexts including the wide range of employment contexts which mathematics graduates enter.

A new group allocation method developed over several years with maths students at Greenwich is detailed by Bradshaw (2009). Students are asked to form triples, should they wish, which are combined into larger groups by staff based on the strengths and challenges experienced by individuals in the cohort. It was noted by attendees that some students with ASD will be able to identify peers with whom they have a rapport or shared mathematical interests. Allocation methods which provide all students with an opportunity to say who these people are, may reduce anxiety and improve communication. Appointing group leaders / facilitators who have an understanding of these issues can be beneficial.

Exeter employ structured group work on a first semester 100% group work module (Cooper, 2011) including the use of rules and group wikis to structure communication and guide progress. Attendees agreed that the use of rules (e.g. all communication must be followed up in writing) and explicit guidance on running groups, determining roles, timescales, action points etc. seemed to alleviate difficulties for some students. However, attendees had experienced problems when other group members viewed 'rules' as merely 'expectations'. The need for clarity in distinguishing rules from expectations was noted, as was the need for access to a mentor or advisor with whom the breaking of rules or the failure to meet recorded expectations could be discussed. At Exeter, the wiki record of group interactions and progress was also used to evidence mark allocation when group members reported an unequal burden of work. This method of guiding and recording communication was positively received by other attendees who expressed intentions to explore the mechanism. However, attendees did note the inherent difficulties of using e-mail, wikis and forums to communicate mathematical content.

Students on some mathematics degrees have few opportunities to work in groups until their final year of study. It was noted that this aggravates anxiety by placing an expectation on students to develop their group working skills while concentrating on maximising their final year grade.

## Commonalities: A possible framework for group work

The discussion of barriers and examples of practice uncovered many commonalities. We summarise these as a starting point for a possible framework for minimising barriers to group work in mathematics.

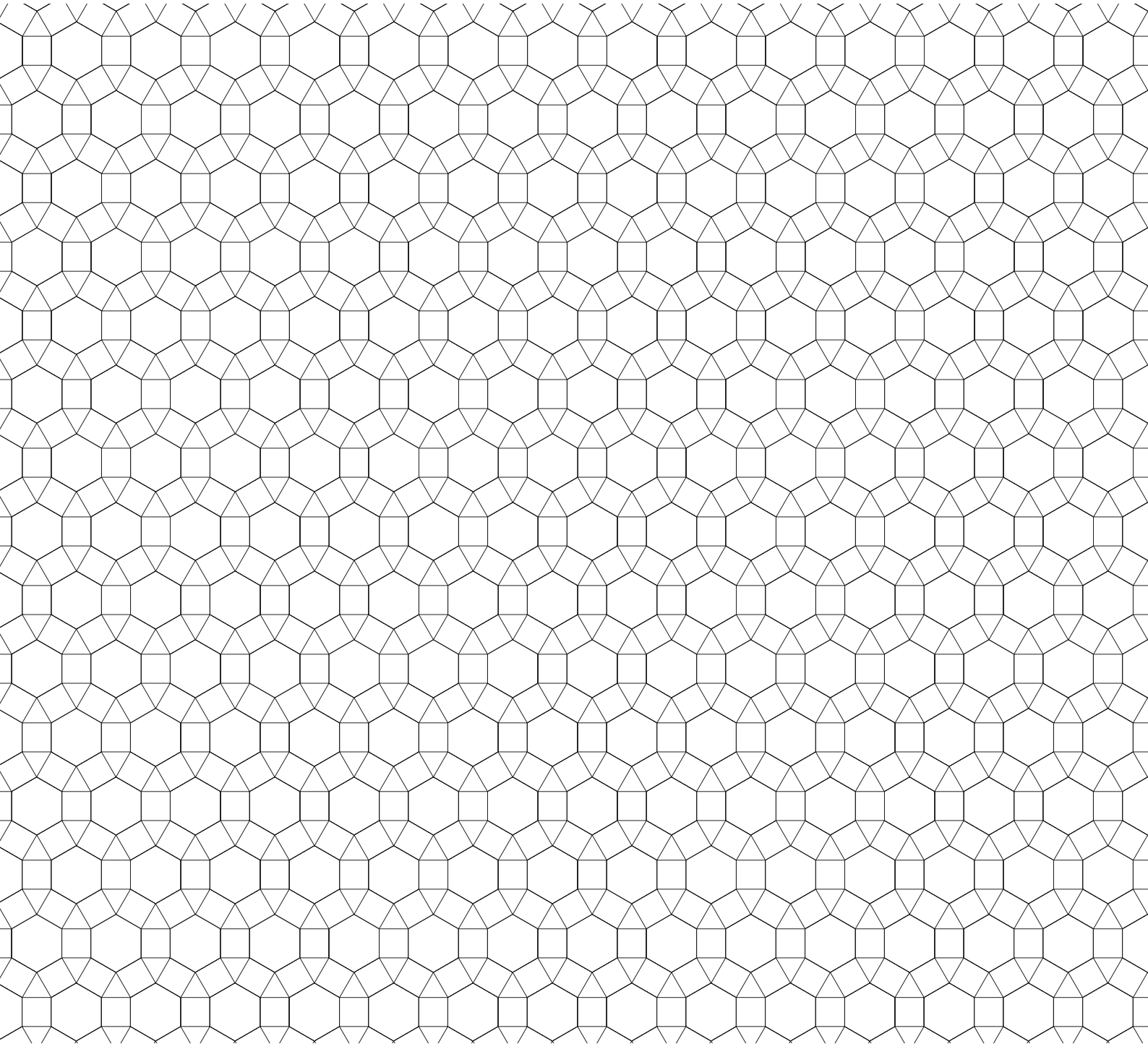
- **Provide explicit educational rationales** including a subject evidence base that group work is important to employers. Ensure group working is integral to coursework tasks: In many subjects group work has a more natural rationale, it is important that we do not tack group work on to the 'real' coursework (the mathematical content!) as an afterthought.
- **Provide scaffolding** opportunities to build group work skills over time in a 'safe' environment. This might include formative / low-mark assessment or structured activities where participation is driven by interest, such as sessions guided by peer mentors and problem solving activities such as the Maths Arcade (Bradshaw, 2011, Martin & Cliffe 2012). Such provision would not rely on changes to core mathematics assessment practice which is a wider question for the community.
- **Use a carefully designed group allocation method** which permits input from students on groupings but does not require students to form groups.
- **Include group working skills as learning objectives** and approach this skill acquisition as a systematic process. Models for group working can be taught and explored before being assessed – as in subjects where group working skills are core content.

- **Ensure that explicit rules of engagement** are either provided or must be produced, agreed and recorded by the group perhaps using **technology to support communication**. This might include roles, responsibilities, a work schedule, agreements that all agreements are recorded in writing etc. Clarity as to what extent each group member must provide input to different tasks, mathematical and otherwise, should be provided. The difference between *rules* and *expectations* should be explicit. In the event of rule breaking or failure to meet expectations the group should be able to contact **a group mentor/advisor** to assist communication for all members.
- **Transparent and fair marking** might include methods for group members to report on the sharing of the work. The use of **technology to support communication** will enable staff to substantiate such claims and hence increase transparency.
- **Explicit reflection** on group work is likely to assist all students to transfer their experiences to future contexts including employment. This is arguably important for all students since experiences of mathematics group work may appear to have little resemblance to group working in the employment routes which mathematics graduates enter.

Such a structured and systematic approach may be less important in subjects, unlike mathematics, where group work is embedded throughout the curriculum delivery and assessment. In a systematic subject such as mathematics the added structure is also likely to benefit all students as the learning and assessment will sit more naturally within their experiences of degree studies.

## References

- Baron-Cohen, S., 2003. *The essential difference*. Penguin, London
- Baron-Cohen, S., Wheelwright, S., Burtenshaw, A. & Hobson, E., 2007. *Mathematical Talent is Linked to Autism*. *Human Nature*, 18(2)
- Bradshaw, N., 2009. *Tribute to triplets: A model for successful group work*. *Compass: The Journal of Learning and Teaching at the University of Greenwich*, [http://web-dev-csc.gre.ac.uk/conference/conf64/docs/compass\\_journal\\_%20edition%20one.pdf](http://web-dev-csc.gre.ac.uk/conference/conf64/docs/compass_journal_%20edition%20one.pdf)
- Bradshaw, N., 2011. *The University of Greenwich Maths Arcade*. *MSOR Connections*, 11(3) [http://mathstore.ac.uk/headocs/Connections\\_11\\_3\\_Bradshaw.pdf](http://mathstore.ac.uk/headocs/Connections_11_3_Bradshaw.pdf)
- Cooper, B., 2011. *Reflective writing for first year mathematicians*. Developing Writing in STEM Disciplines, SW HE STEM Project Conference, University of Bath, 12th September 2011. Presentation and circulated paper.
- Hastwell, J., 2011. *Listening to students with Asperger syndrome and best practice in higher education*. *Adolescence to Adulthood with Autism, Making the transition from education to employment*, 3rd National Conference, September 2011. [http://embed.policyreview.tv/media/documents/SH282\\_JOANNA\\_HASTWELL.pdf](http://embed.policyreview.tv/media/documents/SH282_JOANNA_HASTWELL.pdf)
- Hastwell, J., 2012. *Placements & Students with Asperger syndrome*, HE STEM project. <http://www.hestem-sw.org.uk/project?id=23>
- Hewson, P., 2010. *Bayesian analysis of the National Student Survey*. <http://mathstore.ac.uk/headocs/nssresults.pdf>
- Iannone, P. & Simpson, A., 2012. *How do we assess our students?* *MSOR Connections*, 12(1) [http://mathstore.ac.uk/headocs/Connections\\_12\\_1\\_Iannone.pdf](http://mathstore.ac.uk/headocs/Connections_12_1_Iannone.pdf)
- Martin, N. & Cliffe, E., 2012. *Assisting mathematics students who have Asperger syndrome*. *Good Practice on Inclusive Curricula in the Mathematical Sciences*, <http://mathstore.ac.uk/node/2095>
- Pike, R., 2005. *Supporting students with Asperger syndrome in higher education*. The National Autistic Society



# Using Social Media to Engage Students

Report of a workshop which took place on  
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## Introduction

Having seen several people trying to use social media to engage their students, I was interested to discover what people were trying, what worked and what didn't. I asked various people if they would run a workshop on the topic and got a common response: "Oh, I'm just playing around. I don't know enough about it to run a workshop".

Seeing several people trying out an emerging area of practice and no clear information on or evidence of good practice, I felt the opportunity was open for a preliminary discussion. I invited a small group to an open discussion meeting at the University of Birmingham themed around 'Using social media to engage students'. This paper is a report from that workshop. I don't want to claim that everything in this paper represents my view or a consensus of everyone at the meeting but I hope I have presented a fair account of the issues raised and the discussions which took place. I hope it will serve as an aide to discussion of approaches in this emerging area of practice.

## Uses of social media

In the opening introduction to the workshop I gave a list of examples of services which might be included in a discussion of social media. It is difficult to know whether to include areas where students or lecturers create content such as blogging, photo or video sharing sites, but we decided to use a broad definition. In case these are of interest, they are (in no particular order): social networks such as Facebook, Twitter, Google+ and LinkedIn; photo sharing sites such as Flickr and Pinterest; video sharing sites such as YouTube and Vimeo; blogging through various platforms including Tumblr. In discussion, we added services which allow users to share links to interesting web content and tag these with appropriate keywords, for example Delicious.

In common with all technology, what services are available is not as interesting as what might be done using these. I suggested aims for using these technologies might include the following.

- Classroom engagement  
e.g. to encourage discussion and feedback in lectures. Students use phones, laptops or tablets to send messages to the lecturer or class, avoiding anxiety over speaking in front of a large group. Some services would allow students to use a pseudonym for anonymity.
- Building a community  
e.g. to share links and interesting content, to keep students in discussion outside of lectures.
- Doing or organising project work  
e.g. putting students in groups on a social network so they can share content relevant to projects they are working on.
- Students sharing content they had produced  
e.g. asking students to produce a video for YouTube when you might previously have asked them to produce a poster.
- Careers awareness or job hunting  
e.g. students using a network like LinkedIn to increase their professional profile and investigate potential employers.

- Making wider connections  
e.g. reaching professionals through a social network to gain different views on a discussion. As an example, before the workshop I had asked on Twitter for teachers and lecturers to send examples of their use of social media with students and reviewing these aided this discussion greatly.
- Outreach  
e.g. reaching potential students and applicants online and receiving feedback from attendees at open days.
- Lecturers' professional development  
e.g. accessing a professional network to gather ideas for teaching or discussion of teaching practice. For example, maths teachers on Twitter have #mathchat [1].

In discussion of this list we added two-way communication with individual students, which was to be a feature of the talk by Ed de Quincey.

Several Twitter users who contributed remotely make use of various social media technologies to share content with their students, either extracurricular (videos, cartoons, jokes, competitions, news) or course related (coursework reminders, information about cancelled lectures). Several made use of course hashtags on Twitter. This is a way for all students on the course to find each other and talk to one another about the course and is a system that works well at conferences. For example, "#hestemsoc" in figure 1 is a hashtag used to collect tweets from our workshop.

We got the impression from reviewing some of the examples of use that a lot of use is broadcasting to students with little evidence that students are reading or responding.

In what follows I will summarise the use of social media by three speakers and then offer, combined, a summary of the discussion that took place.

### **Case study: use of Twitter in digital media at the University of Greenwich, Ed de Quincey**

Ed de Quincey intended to use Twitter for three purposes:

1. As an alternative method for posting useful course specific information to students e.g. links to articles, emergency changes to lecture times etc.;
2. To enable students to ask questions about courses e.g. clarifying something from a lecture, asking about coursework specifications etc.;
3. To encourage students to help each other and create a community of practice.

Ed had produced some summary statistics on his and his students' use of Twitter. He found that most students were willing to sign up and sent at least one message but few continued to make use of the service if they weren't already active users. His Twitter account had around 80 students as followers out of 102 students on the two modules with which he used Twitter. Ed suggested hashtags for students to organise their contributions. However, he found that most use of hashtags came from his own account rather than from the students.

Ed's account had sent 289 tweets during the modules. 56% (161) of these were @mentions, meaning in response to other users. Ed said he didn't send an @mention to students who hadn't first sent him one, so this means over half of his tweets involved two-way interaction with individual students. Ed received 93 public @mentions from 32 Twitter users, about 30 of which were students (the others being staff), and 40 private direct messages from 11 students (with some overlap between the 30 and the 11).

Ed concluded that Twitter was a good method for communicating with individual students to resolve issues quickly and this was the main benefit. Of course, email could also provide this function but Ed regarded Twitter as having several advantages. A limit to length of messages of 140 characters means that messages sent via Twitter are concise and replies can be quick

also. There is no need to follow email etiquette such as salutations and sign-offs, making this an efficient method of communication. In addition, apart from private direct messages, replies sent to students are public so all students can see the question and its answer. Ed reported an absence of duplicate questions on the same topic and wondered if the public forum was a reason for this.

### **Case study: use of Facebook and Twitter in mathematics at Greenwich, Noel-Ann Bradshaw**

Noel-Ann Bradshaw talked about use of Facebook and Twitter at Greenwich with current students and prospective students.

With current students, use of Facebook evolved out of the undergraduate Maths Society Facebook group. Noel-Ann interacts with students and the site is used as an online community for current undergraduates and staff to interact. Noel-Ann said that if she notices it is a student's birthday she would make a point of wishing them "Happy Birthday". She said a good relationship as personal tutor with students can result from this and sending messages like "I'm looking forward to seeing the student presentations today".

With prospective students, there is a university policy that Facebook and Twitter should be used and the School has a communications officer to assist with this. Noel-Ann said it was a useful way to get feedback from attendees at open days. She also reported applicants using Twitter to ask questions such as "What's the weather like there?" or "How do I do ... [something about applying]?" She said this can be labour-intensive but it is useful to deal with small queries.

### **Case study: use of Twitter in mathematics at Chester, Jason Roberts**

Jason Roberts reported that there seemed to be a general shift towards making more use of social networking tools within other departments of the University. After a module in which students created videos, YouTube was investigated as a method to distribute these. Jason started using Twitter with one module to share news involving applications of mathematics with the aim of encouraging career aspirations among mathematical modelling students. Later this expanded to the student cohort generally so anything to do with careers and news relating to mathematics was shared.

Jason warned of the risk of secondary purposes expanding use of this service. He resisted the university listing his Twitter account for applicant enquires due to time restraints. He is considering asking students to look into what mathematicians are doing with social networking as an 'experiential learning' project.

### **Putting mathematics online**

One key obstacle to using these services is when the need arises to include mathematics notation in communications. To this end, Christian Perfect gave a presentation on technologies which could be used to put mathematics on the web.

MathJax is "an open source JavaScript display engine for mathematics that works in all modern browsers", requiring no font installation or browser plugins and designed to be compatible with screenreaders [2]. To install MathJax just requires a piece of code added to the header of a webpage. Christian demonstrated MathJax working on his blog and gave information about easy installation on most popular blogging platforms [3]. This may also work on university VLEs, for example Moodle.

However, most social networking services do not allow users to edit the page header and so MathJax cannot be installed on sites like Twitter and Facebook. In this case, Christian offered a 'bookmarklet' [4]. This piece of code can be added as a button on your web browser and will run MathJax on any page. As an example, he asked me to post some LaTeX code to Twitter and ran the bookmarklet. I tweeted "#hestemsoc @christianp is asking us to tweet LaTeX to this hashtag.  $y = ax^2 + \frac{1}{b}x + c$ ". The result is shown in figure 1.

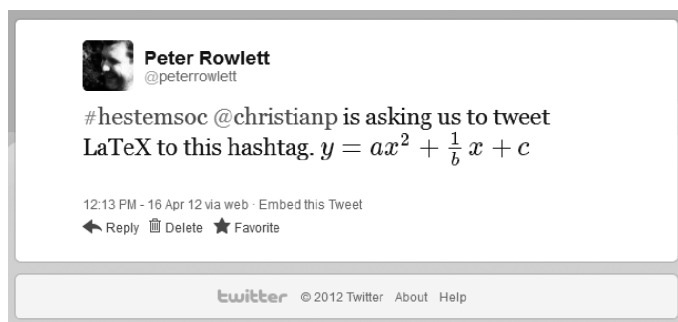


Figure 1 – The result of running the MathJax bookmarklet on a tweet containing some LaTeX

We discussed the use of these approaches. For the second method, the user is required to click a button to turn the LaTeX into formatted mathematics. Although we hope students, seeing the LaTeX code, would remember what they needed to do, this is a barrier to overcome when using this method. The first method is preferable because it requires nothing of the user.

If one wishes to encourage students to ask questions about the mathematical content of their work then comments on a blog which displays LaTeX code as formatted mathematics may be considerably preferable to email. We discussed the advantages this would have in collecting all answers given to student queries, to make sure no student is getting privileged information.

## Issues discussed

### Style

We discussed style. Some Twitter accounts seem to be focused around broadcasting messages and not interaction but some, despite being from large organisations, manage to adopt a chatty, informal style and engage well with other users (for a discussion of the approach taken by the Times Higher Education Twitter feed, see [5]). We felt this approach might encourage a greater level of engagement than formally broadcasting links and course reminders.

We discussed the need to just be factual on professional accounts, for example when informing students about news involving mathematics. There are issues in starting to offer opinion on subjects for a broad audience and in any case it is desirable for students to be given the facts and left to form their own opinions.

### Students creating content

Some services offer more specialist use than the general services such as Facebook or Twitter. For example, LinkedIn can be linked to graduate skills development and might be used to build an online portfolio. We wondered whether LinkedIn could be used for PDP portfolio-type tasks, so that the students would be creating something that lasts beyond university. LinkedIn users can request ‘recommendations’, public references that are placed on their profiles. The suggestion was that lecturers could do this for students but that this can create added workload. However, the potential for keeping in contact with alumni has advantages.

Students need to be aware that what they say on these networks is public and often permanent. Since we hope students might go onto careers, we should be careful about developing their awareness of managing their online profile using these services that we may have encouraged them into using.

### Whether to keep personal use of social networks separate

Ed de Quincey and Jason Roberts both have separate personal and professional accounts on services such as Twitter. This can be confusing but helps to keep personal and professional lives separate.

An alternative would be to have an account for each module. However, this was seen as more impersonal and Ed reported the advantage of having students connected to your own account in terms of keeping in contact with alumni, while students are likely to disassociate a module account when they finish the module.

### **University policy and related issues**

Concern was raised over whether we could expect all students to own a smartphone capable of using some of this technology, for example for sending messages to Twitter while in class.

Some universities have a policy that the university systems (VLE, internal email, etc.) should be the primary method to communicate with students. In discussion we agreed these third party services should never replace university systems but that duplicating messages in multiple locations might improve their chances of being read.

We discussed guidelines for using these services. Some universities are encouraging staff to use social media but do policies exist for use of these and, if so, are such policies realistic? Additionally, some universities have policies regarding contact with applicants that might be relevant.

In common with most innovative curricula and new technology use, the concern was raised whether this technology was only being used by the students who are already engaged, and therefore whether it is widening the gap between students.

Time for doing this is an issue. There was a sense that people are generally not getting credit (say, against workload allocation models) for engaging with students and applicants in this way. If you are the only person in a department who is doing this you might attract a lot of extra work because students would rather send a message this way than email the correct person for their query.

There is a tendency for policy to lag behind fast-moving technology and a need for those compiling policy to have an understanding of the technology involved.

### **Pastoral care and access to student personal information**

There was a discussion about what responsibility the lecturer might hold by being more aware of the students' personal circumstances. At the less serious end, what should a lecturer do about students who are giving their location online when they should be in lectures? More seriously, students might reveal personal issues that could cause a duty of care for the lecturer. We discussed whether the lecturer had a responsibility to follow up on such cases and whether this placed an additional pressure on lecturers. Noel-Ann Bradshaw said that where she sees from postings on Facebook that a student has problems she would follow this up with a brief enquiry sent as a private message along the lines of "I know this is none of my business but I saw on Facebook that you said ... and wondered if you are okay". She said this approach has certainly saved several students from dropping out of university and, though she is aware that this is a sensitive issue, to date no student has responded negatively to such an approach.

In a related issue, we heard about a circumstance in which students were believed to be cheating via a Facebook group. Lecturers could see which students were members of the group but not what messages were being exchanged. In that case you at least have a list of students whose work you may examine for evidence of plagiarism, which is more information that one might expect if the students were conducting this activity in person or via email.

We discussed whether using social networks to broadcast and deal with direct student queries while making a clear policy not to look at students' general messages would avoid this issue but decided this removed the social aspect that was one of the valuable features.

We discussed the issue of invading students' personal environment. Generally, the advice that emerged was to not connect with a student on a social network site uninvited but to let the student make the approach. Students can benefit by using a social network and engaging with peers without interacting at all with staff and we should be encouraging such informal interaction and peer support. Taking this further, one might decide not to send a message to a student except in response to a direct query, although this might lose something of the social spontaneity of the system.



## Next steps

We felt there was certainly value to be had from using social media with students. We heard about services being useful for short message interaction with students, perhaps more so than email. Much use of Twitter is broadcasting information the lecturer believes is of interest to students but we felt further investigation was needed to determine whether students were engaging with such content. We also heard about the value of these services for engaging with potential applicants and applicants, and for students to create and publish content that will help them build an online profile that will persist beyond university.

However, with all the potential value there are plenty of issues for lecturers and institutions to consider. This was a fruitful initial discussion on this topic but certainly further investigation is recommended.

## Acknowledgements

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## References

1. #mathchat. See: <http://mathschat.wikispaces.com/> [Accessed: 29/05/2012].
2. MathJax. See: <http://www.mathjax.org/> [Accessed: 29/05/2012].
3. Perfect, C., 2012. How to get beautifully typeset maths on your blog. *cp's mathem-o-blog*. Available via: <http://checkmyworking.com/2012/01/how-to-get-beautifully-typeset-maths-on-your-blog/> [Last accessed: 29/05/2012].
4. Perfect, C., 2011. A bookmarklet which typesets TeX on any page using MathJax. *cp's mathem-o-blog*. Available via: <http://checkmyworking.com/2011/09/a-bookmarklet-which-typesets-tex-on-any-page-using-mathjax/> [Last accessed: 29/05/2012].
5. Joly, K., 2011. Twitter Done Right: Times Higher Education #highered. *collegewebeditor.com* [online]. Available via: <http://collegewebeditor.com/blog/index.php/archives/2011/05/18/social-media-done-right-times-higher-education-highered/> [Last accessed: 29/05/2012].







The UK Higher Education system has moved increasingly in recent years to a 'mass' system. At the same time there is a drive to implement a teaching and learning environment which puts the student at its heart. These two factors would appear to be in contradiction with one another and yet, as teachers in HE, this is the dilemma that we all face. What does it mean to adopt student-centred approaches in mathematics and how can this be done in the current climate?

The projects highlighted in this booklet have as their key concern the student and have introduced initiatives which recognise the diverse needs of students. All have some element of support tailored to the needs of students, although the projects themselves are quite distinct. The first is focused on supporting mathematics students and the next three focus on student-centred approaches for students from other disciplines. The focus then changes, with three reports on inclusive curricula and students with additional needs. The final report presents an overview of how one might use social media to engage students.

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