Teaching and Learning RESEARCH BRIEFING

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Keeping Open the Door to Mathematically Demanding Programmes in Further and Higher Education

This project aimed to better understand how to extend and improve learning in mathematics, especially by those 'on the edge' of further participation. Our study surveyed students by questionnaire and interview through their AS year and studied contrasting Programmes and pedagogies. We conclude that Programme and pedagogy can make significant differences to learning outcomes for these students, especially in terms of drop-out and the disposition to continue to study mathematics, sometimes despite injurious policy and institutional influences.

• Programmes can make significant differences to drop out rate, and to the value of mathematics for students.	→ Programmes should be designed to engage students in meaningful uses of mathematics, e.g. via modelling coursework.
• 'Connectionist' teaching practices can make a significant difference to students' dispositions and understanding, especially for students with lower GCSE grades.	→ If we value inclusion, and outcomes such as understanding and disposition, more connectionist teaching should be encouraged.
• A culture of 'performativity' in Colleges reinforces teaching to the test that can be damaging to learners.	→ Policy should reduce the pressure to teach to the test by giving value to learning outcomes of deep understanding, and dispositions

T·L·R·P TEACHING & LEARNING RESEARCH PROGRAMME

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

The research

Background

The study drew on a large sample questionnaire survey of students reporting their dispositions and performance on three occasions, early in the AS course, at the end of the year of study before the AS exams, and in the second year of college when AS results were known and university subject decisions were being made. The sample was chosen in order to be able to compare outcomes for sufficient numbers of students following two contrasting Programmes, traditional AS Mathematics, and the AS "Uses of Mathematics" which was designed to widen participation in mathematical studies. Instruments were made to measure students' self-efficacy with mathematics, their disposition to study more mathematics in HE in the future, and to measure teachers' pedagogic practices.

This activity was supplemented by case studies in five 6th form FE Colleges, where we observed lessons, interviewed teachers and managers, and interviewed a select group of over 40 students on up to four occasions. The students' interviews tracked their view of mathematics, their aspirations for higher education and their future generally. The case studies sought to develop insights into learning and teaching processes and explanations for survey results. The whole study asked: how learners' engagement in different practices can develop a mathematical disposition or identity, and how teaching and learning practices are shaped by institutional and policy cultures.

Mathematics, institutional values and the marketplace

The value of mathematics can be seen in its 'use' and its 'currency'. The social value of mathematics rests ultimately in the fact that it provides a powerful, useful way of seeing and analysing the world, whether it be the natural or the social world. Mathematics provides access to an understanding of science and technology, but also to understanding big social ideas such as change, growth, risk and complexity. However, most of the talk of the significance of mathematics we captured, in classrooms and interviews, with teachers, students, and managers, spoke of different values. They regard mathematics as important mainly because it has 'currency' in getting the grades /UCAS points required for university entry (for the student), in getting the pass rate and grades required for performance management (for the teacher) and in acquiring league table reputations and funding (for institutional managers).

Sometimes our students addressed the usefulness of mathematics, and this was significantly more evident among 'Uses of mathematics' students, especially those also studying BTEC engineering. However, it was much more common to hear students talk of the currency of mathematics, in terms of 'looking good for the CV', or being 'needed' for getting into a chosen course at university, i.e. to 'become a success'. Indeed in this respect, the idea that maths is a hard subject makes it more valuable and 'worth the struggle.' Achievement in mathematics is 'evidence of being smart' and 'standing out'.

But for those who weigh up the value of an AS versus an A level, or a higher grade rather than a lower grade in the market, dropping maths in favour of an easier option may be the right decision in terms of maximising opportunities. Teaching and college policy play into the same market discourse. Teachers may urge students in their lessons to 'listen to this part because it is important in the exam', and colleges often choose to exclude students from maths unless their GCSE grade and tier is optimal. Other colleges persist with relatively open access policies. They may pay a price in the league tables and in terms of student drop out. Schools and colleges are therefore calculating strategies to optimise their yield. This may even lead them to encourage students to take options that are irrelevant to their career aspirations, and may turn out generally not to be helpful for mathematics.

Policy makers should be aware of the perhaps unintended effects of the market place in education, and look for ways to give value to what is important.

Students' aspirations and their learning approach

Analysis of students' interviews led us to conclude that there is a variety of distinct ways of aspiring mathematically. We have called these 'repertoires.' These tended to be adopted by students in specific interviews as an account of their current state of aspiration. They are contingent, situated, and subject to fluctuation. Nevertheless there were some patterns that were suggestive.

For example, mathematics sometimes forms part of an imagined path to becoming a success. Currency is important in this discourse, so it could be decisive whether maths is thought to be required for entry to study business, engineering, or medicine. This currency may not be associated with an appreciation of the use of mathematics in their future discipline. At other times, mathematics is associated with an aspiration for personal satisfaction. Here it is important for mathematics to be enjoyed, and to give satisfaction and some depth of understanding. Then there were those already perceiving themselves as being engaged on a vocational pathway (e.g. Engineering BTEC students with 'Use of Mathematics') who see mathematics as important in the here and now, not the distant future. Such students usually expressed a very distinct, tenacious aspiration for mathematics, even in the face of apparently significant challenges.

This might have important implications for engaging students with mathematics, especially those students who are currently turned off by it.

The effect of different AS programmes on inclusion

Our main finding was that the AS Use of Mathematics Programme did encourage students to persist in learning in a variety of ways. Coursework assessment encouraged students to explain their work and understand mathematical modelling rather than simply perform. Learning through uses and with the aid of technology also had positive benefits for some students. Additionally, the Uses of Mathematics students generally expressed their appreciation of mathematics as a useful subject, particularly for those doing BTEC engineering. For almost all traditional AS Mathematics students the only uses they recalled being relevant were drawn from everyday life, such as shopping.

Drop-out rates were high amongst students with low GCSE maths grades, especially for the intermediate tier GCSE.

The statistically significant differences between traditional AS Mathematics (AS Trad) and AS Uses of Mathematics (UoM) were seen in the relatively low drop-out from UoM when GCSE tier and grade are taken into account (see table 1), and in the added value in grades from GCSE to

Prog/ tier-grade	A* and A	B^{High}	B^{Inter}	C^{High}	C^{Inter}
AS Trad	9 % (16%)	18 (50)	31 (61)	26 (65)	46 (80)
UoM	12 % (13%)	18 (26)	9 (24)	27 (54)	18 (45)

Table 1: Dropout Rate by course and GCSE tier and grade (Maths Dropout or U-grade) as a % for c1300 students

AS, which was of the order of one grade higher for GCSE grade C and intermediate tiers for UoM. This difference diminishes to zero for the higher grades.

An interesting influence on drop-out, AS performance and future intentions was found for students with 'English language only.' On all indicators they did significantly less well compared to bilingual and 'other' language speakers when all other available factors are taken into account. We are still exploring this: we believe that these background effects are intersectional and complex.

The effect of different pedagogies and widening participation

The evidence of our research on pedagogy is that the bulk of teaching practices were 'transmissionist', encouraging test-orientated, 'surface' learning approaches, and that this practice is supported by institutional cultures that are responsive to the educational market place. On the other hand, we found some space for the development of 'connectionist' teaching practices that encourage more deep learning approaches, emphasising conceptual understanding and personal satisfaction and enjoyment in mathematics. Colleges with open access courses, which are responsive to supporting a community ethos, and where the teachers are committed to an inclusive approach to students, can provide such space.

We measured connectionist teaching practice simply by asking teachers how frequently they engage in certain activities in their teaching. Connectionist practices involve discussions, group work, and encouraging students' own methods, whilst transmissionist teaching practices involve routine practice of examples, teaching to the test, and sticking to the text book. The result was a scale, with transmissionist practice at one end and connectionist practice at the other. The majority of teaching practice reported was near the transmissionist end, with very few classrooms where connectionist practices were reported. It was these few classes that made a difference.

The survey found that connectionist pedagogy can significantly affect dispositions for further study for AS traditional students with low GCSE tiers and grades. While dispositions were declining as a whole during the AS course, connectionist pedagogy ameliorated this decline. However, we have no evidence that transmissionist practices have a negative effect on the performance of students with high GCSE grades, at least in the short term. It seems that connectionist pedagogy is principally a response by teachers to classes in which tiers and grades are low, and teachers perceive that learners need to build confidence through understanding.

Major implications

Current performance drivers focus on grades, but marginalise student dispositions and even 'value added'. If policy-makers want to encourage students to be well disposed to further study of science, technology, engineering and mathematics within a performance management environment, then the development of practical usable measures of disposition and affect are important to consider. The principle should be to try to measure what we value rather than to value what we can easily measure. The same is true of teaching practices.

The structure of the whole programme, including assessment, materials and technologies, is important to what is learnt. It needs to be designed and continuously monitored with great care for the full range of valued learning outcomes. Currently there is no sense of a design behind curriculum development nationally. Text books, for instance, are largely controlled by the same organisations that set the exams, both of which emerge from an economy in which these organisations compete for college business. It is unfortunate that impacts on drop-out rates and student enjoyment are not even monitored in this process.

We found that if the aim is to widen participation of students in mathematics, especially to those with lower GCSE grades, a 'Uses' approach can help significantly. But there is the danger that the 'Uses' course will be stigmatised as the course for the lower grade GCSE students, especially when there is no A2 course for these students to progress to. Again, we found that for many students, coursework was an important aid to developing understanding and was perceived as helping them persist with mathematics. However, coursework is not popular with teachers and examiners, and is relatively expensive. Policy could make a real difference here. The important features of good curriculum design need to be explained and communicated to teachers and policy makers.

Widening participation in and improving the conceptual understanding of mathematics also requires the development of more connectionist pedagogical practices, especially for the inclusion of less well prepared students. But for colleges, inclusion involves a risk in terms of league tables. Some Colleges prefer to exclude students with GCSE grade C from studying mathematics at AS level. Our data suggests that they maybe 'right' in their own terms to do so, as the commercial risks are great, particularly for the current traditional AS level mathematics.

There is a real danger that recent and planned changes in the curriculum will exacerbate this problem. For example, those who take Foundation level GCSE will almost without exception be excluded from AS study. We anticipate the need for a 2-year mathematics course to engage these students, but it has to be one that offers value to students to compete with other options.

Transmissionist teaching had a negative impact on less well-prepared students' learning outcomes, such as their disposition to study a subject they say they find hard, i.e. one that they do not understand. While transmissionist teaching appears to deliver exam grades in the short term for well-prepared students, it can have a negative impact on dispositions, and does not support conceptual understanding of mathematics or deep learning approaches. We may find that even for the high-grade students, this is not a good preparation for university, and other studies already suggest this.

Teachers' practices (mostly transmissionist in this study) were powerfully shaped by the culture of performance, and by institutional factors such as the College access policy. Tests, exam grades and league table performance were dominant in shaping practice, though in particular circumstances we found some space for teachers' professional identity to provide agency so that some connectionist practices were able to survive. Reducing the pressure for immediate test performance and league tables could make room for teachers' professional development.

Finally, widening the participation of young people in mathematically- demanding courses means recognising the diversity of learners 'repertoires' of aspiration. Dialogue with learners must address these distinct constituencies and must be multi-voiced. It is important that mathematics has economic value. However, regarding mathematics as a shortage subject can confirm for others that it is difficult and has little intrinsic worth. But for many of our students it is important that mathematics inspires interest and enjoyment. It is therefore important that mathematics should be seen as immediately useful because it is a powerful way of seeing the world.

Further information

A resource providing information about the project, its members and an overview of our work is at http://www.lta.education.manchester.ac.uk/TLRP/

Here you can find a selection of publications arising from this project.

- **Two related new projects just starting:**

ESRC (RES-000-22-2890) Mathematics learning, identity and educational practice: the transition into higher education (PI Williams: this project will follow the current study students into HE in 2008-2009)

ESRC (RES-000-22-2890) Mathematics learning, identity and educational practice: the transition into post-compulsory education (PI Hernandez-Martinez: this project will follow a cohort of students from schools into the Colleges that were case studies in the current study).

- **Selected publications downloadable from the website:**

Black et al (2007), *Imagined futures: mediation of the mathematical biography.* Submitted and under review to Ed Stud in Maths

Hernandez-Martinez et al (2008), Mathematics students' aspirations for higher education: class, ethnicity, gender and interpretative repertoire styles, in Research Papers in Education, 23(2), Routledge.

Davis et al (2007), Hybridity of maths and peer talk: crazy maths (ESRC seminar paper, to appear in edited book, Routledge)

Williams et al (2007), *Storying mathematical identities with cultural models*. Paper presented at Working Group 10 (Mathematics education in multicultural settings) of the Conference for European Research in Mathematics Education, Cyprus. (to appear in edited book, Sense).

- **Additionally to appear on the website soon:**

Wake et al (2008), the central role of the teacher - even in student centred pedagogies. Paper to be presented at PME 32, Morelia, Michoacán, Mexico, on July 17-21, 2008

The warrant

One of the strengths of our project is that it draws on a variety of methods. It used a large-scale questionnaire survey, case studies, and longitudinal interviews, providing a rich base of data for analysis. The survey involved 1800 students who have been carefully sampled to include a high proportion of students considered "on the edge" between engagement and disengagement.

Specially constructed instruments were used to measure important new learning outcomes including the mathematical self-efficacy of students, their disposition to enter higher education and their dispositions towards studying mathematically demanding subjects in higher education. Additionally, we constructed a self-report instrument that measures the degree of transmissionist/ connectionist practice used in each class. Validation of these newly constructed instruments suggested robust measures.

Our case studies take the form of mainly qualitative investigations and involve classroom observations with interviews of students and teachers. Triangulation is also supported by the collection of other college documents and interviews with other stakeholders such as Heads of Department or College Principals.

Our methodological approach is imbued with the notion of generating practical knowledge in partnership with students and teachers as informed and knowledgeable participants. This partnership approach also provides an ethical (and triangulating) basis for all the empirical, analytical and reporting work. A series of teacher conferences has assisted in this respect.

Finally, our warrant is also enriched by the project's advisory group, which consists of academics and practitioners with relevant experience, and which meets regularly with the project team.

Project website:
www.lta.education.manchester.ac.uk/TLRP/

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Project contact:
Julian Williams
julian.williams@manchester.ac.uk

Project team:
Principal Investigator: Julian Williams
Co-Investigators: Laura Black, Pauline Davis, Graeme Hutcheson, Su Nicholson and Geoff Wake
Research Assistants: Paul Hernandez-Martinez, Maria Pampaka
Admin: Tim Millar

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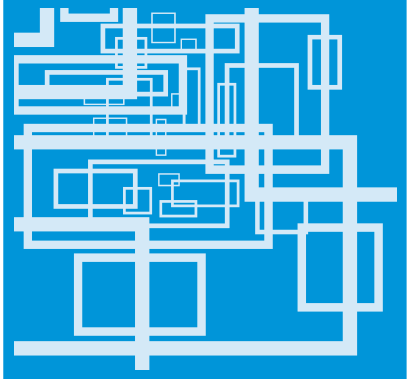
Teaching and Learning Research Programme



TLRP involves some 90 research teams with contributions from England, Northern Ireland, Scotland and Wales. Work began in 2000 and the Technology Enhanced Learning phase will continue to 2012.

Learning: TLRP's overarching aim is to improve outcomes for learners of all ages in teaching and learning contexts across the UK.

Outcomes: TLRP studies a broad range of learning outcomes, including the acquisition of skill, understanding, knowledge and qualifications and the development of attitudes, values and identities relevant to a learning society.

Lifecourse: TLRP supports projects and related activities at many ages and stages in education, training and lifelong learning.

Enrichment: TLRP commits to user engagement at all stages of research. It promotes research across disciplines, methodologies and sectors, and supports national and international co-operation.

Expertise: TLRP works to enhance capacity for all forms of research on teaching and learning, and for research informed policy and practice.

Improvement: TLRP develops the knowledge base on teaching and learning and policy and practice in the UK.

TLRP Directors' Team
Professor Andrew Pollard | London
Professor Richard Noss | London
Professor Miriam David | London
Professor Alan Brown | Warwick
Professor Mary James | London

TLRP Programme Office
Sarah Douglas | sarah.douglas@ioe.ac.uk
James O'Toole | j.o'toole@ioe.ac.uk
tlrp@ioe.ac.uk

TLRP
Institute of Education
University of London
20 Bedford Way
London WC1H 0AL
UK

Tel +44 (0)20 7911 5577