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The University of Manchester

TransMaths Research Briefing

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Engineering in Higher Education: what would help the students

Summary findings

The literature on developing more inclusive and effective mathematics teaching practices in Higher Education has been strong in advocating more 'connected/connectionist' pedagogic practices. While there have been drives to develop a more connected pedagogic culture in Higher Education, the evidence suggests that take up of this has been slow. Our research shows that this reluctance to adapt to a more connected pedagogy may be particularly significant in the case of mathematics for engineering. In relation to developing mathematical understanding and relevant, mathematical modelling capability amongst engineering students, the dominance of transmissionist, lecture-focussed practices can provide a major barrier for many engineering students.

- Shortly after arrival at university, engineering students may take some form of diagnostic test to ascertain their 'present knowledge' of mathematics rather than their mathematical potential. Although students may be given prior warning of the test before they start at university some fail to recognise that how they perform on the test can play a significant role in putting them into ability groups for teaching, and what the consequences might be for their future development/opportunities.
- Due to economies of scale, one mathematics course may cater for more than one engineering discipline or indeed more than one 'problem'. (For example, overseas students with very good mathematics skills but poor English may be grouped with native English speakers with poor mathematical skills.) This does not always provide a good learning experience.
- Our surveys revealed that the majority of students report that their lecturers and tutors adopt mainly transmissionist practices in their teaching of mathematics. Students indicated that they would find it more helpful to be given interactive problem solving opportunities that are structured and guided by the lecturer rather than being expected to follow ready-prepared solutions/recipes.
- Many students do not recognise just how significant mathematics will be in their engineering course. Failure to do so from the outset can make the course extremely difficult for the less well-prepared student leading to a decline in mathematical confidence. Eventually, the mismatch of reality with expectations can lead to students becoming demoralized and resentful of others who are not finding the course similarly challenging.

Mathematics learning, identity and educational practice: the transition into Higher Education

The Transmaths research projects investigated students' transitions from school through college into mathematically demanding degree programmes in Higher Education. The focus was on transitional practices and the projects investigated the effects on learner identities, choices and learning outcomes. Using a mixed methods approach, quantitative survey data were analysed alongside a longitudinal series of student interviews and case study data.

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Summary findings

Diagnostic mathematics testing for engineering

'Diagnostic' testing at the start of the first year of university can be used to identify students' needs. Although often a blunt measure that does not provide the diagnostic feedback it might, it can be used to identify those requiring remedial support, sometimes leading to targeted workshops. Lecturers can also use these tests to become aware of 'what the students already know' which can inform 'setting' arrangements with groups of different attainments being taught by different staff and in different ways thought suitable for their different starting points.

In the following extract, the students are reflecting upon their experiences of the diagnostic test at our second survey point which took place during the second half of the students' first year at university. All students seem to be given prior warning of the test before they start at university and some do prepare themselves.

Ravi: So yeah, I went through the books and the questions and it helped me quite a lot really. I mean, like you know, just that few - one, two hours of that extra effort, it paid off a lot in that diagnostic. *EEE Student, Riverside*

In some cases, the timing of the test may prove problematic for students. For many, this is their first time away from home and at the time of the test they are struggling to come to terms with their new living and learning environments. That said, where 'setting 'by ability occurred, the majority of our case study students claimed to appreciate the need for 'setting' in mathematics that the diagnostic test had informed.

Owen: I don't think it was well placed in Freshers' Week to be honest... especially at nine in the morning. But, I think it's a good idea, putting us in sets to be honest because I've seen what the top set do and that's just...mad. Like I'd love to be able to do that kind of maths but I just know like I have to start at the bottom and work my way up. *EEE Student, Riverside*

Connecting mathematics and engineering

The connection of mathematics with its applications in engineering is not often clear as one mathematics course may need to serve students following courses in a range of engineering disciplines. Consequently mathematical principles can seem somewhat abstract and disconnected from engineering with students left to learn to apply mathematics in contexts meaningful to them at a later stage:

Ellie: It was like I may as well have been doing a maths degree. The maths felt completely separate. *EEE Student, Riverside*

Our surveys found transmissionist teaching practices to be dominant in many forms of teaching, not just in lectures but also often in workshops and tutorials. These do not support the development of deep understanding. Students benefitted more from ways of working that allows discussion and interactivity, and approaches that offer them insight into problem-solving using mathematics in engineering contexts. Interactive tutorials and workshops (and even such interactivity as was possible in lectures) often proved more successful in this regard.

George: Probably, we have some examples where we go through question sheets in a small group with a lecturer, and I find, I find those are really useful for helping your learning, because they help you apply what you've learnt in lectures, in labs to an example and see if your ideas are correct, and if your methods are correct, and that's...I find that really useful. *EEE Student, Northern*

Our survey data suggest transmissionist practices were in most frequent use on engineering mathematics courses, where there was little connection made between topics and there was seldom a reference to engineering problems. Students reported transmissionist teaching methodologies used 'most of the time' or 'almost always' (refer to Figure 1).

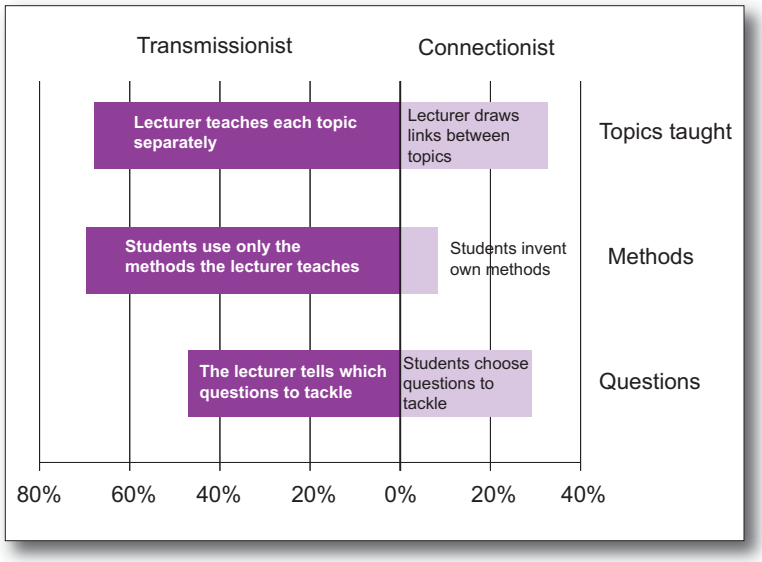
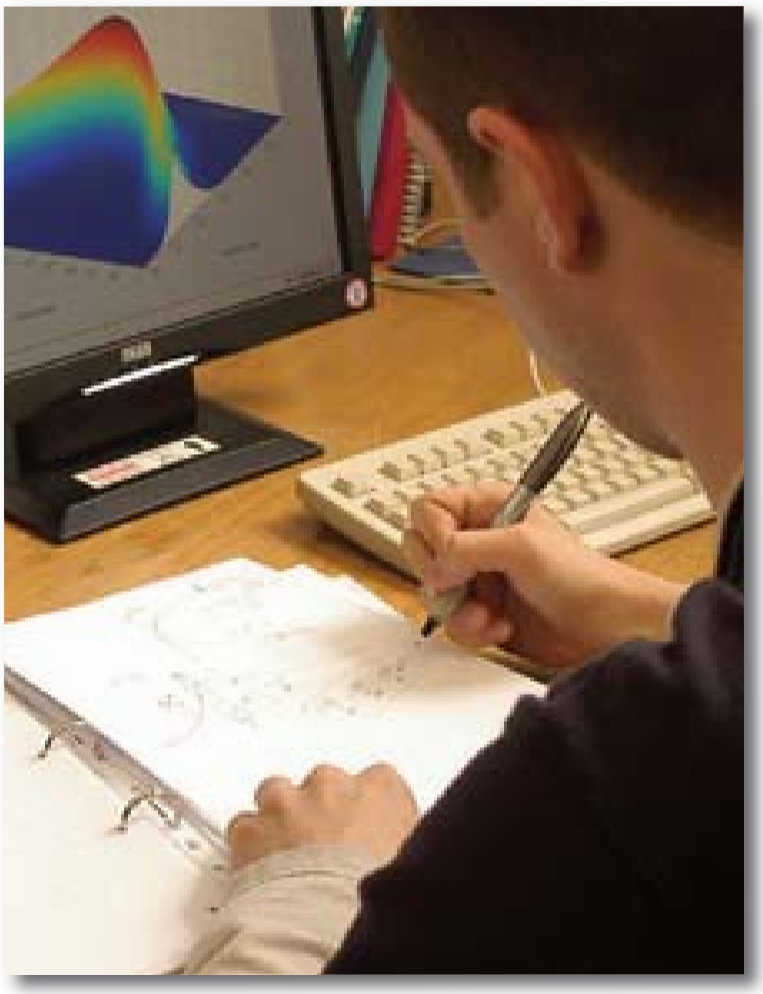


Figure 1: The rep orted use of transmissionist and connectionist teaching practices in EEE mathematics courses

At the outset of their studies some students do not recognise the key role that mathematics has to play in engineering. Those mathematics courses that are disconnected from engineering contexts do not help students understand this. Those who find mathematics difficult can lose confidence quickly and their studies across the board can suffer.

Olufemi: There's this guy that, you know, people know him as a 'geek' but at the same time he's really, really smart. Cos one thing I notice is, even the questions he ask at times, I say to myself, 'wow, how did he think of that?' *EEE Student, Riverside*

The way mathematics is taught may also have an effect on students' mathematical confidence. Engineering students surveyed from 'Northern' university at the beginning of their engineering degree had far less mathematical confidence than their equivalent students from the other universities, on average. However, by half way through their first year the survey revealed that the mathematical confidence of the students from Northern had risen and for the other universities it had fallen. This may be attributable to the fact that the majority of students at Northern are taught mathematics by engineers and as a cohort of engineers. The importance of mathematics is also particularly stressed on this programme, with considerable extra provision and attention given to those who come with lower mathematics grades and qualifications, or who fall behind in their weekly mathematics assessments.



Implications and recommendations

- The significance of the outcomes of any diagnostic testing needs to be made clear to students in good time, so that they do not find themselves unprepared for the test, for example. The timing of these tests also needs to be handled with sensitivity. For example, it may be better to defer the tests until after students have come to terms with the new living and learning environments.
- Although using some form of setting to support students can prove useful, more important is the formative assessment involved, i.e. the identification of the wide variety of learners' backgrounds and needs, and the dialogue with students about what needs to be done. Consideration then needs to be given to how courses and transitional practices can best cater for students with different prior experiences and learning needs, and how specific diagnosed needs are to be addressed. Sometimes there is little follow up as a result of such an assessment, or the students are expected to take the main responsibility for any follow-up.
- Students report that their lecturers and tutors adopt mainly transmissionist teaching practices and that they have little opportunity to solve problems under the guidance of lecturers/tutors. Students should be given more opportunities to explore mathematics and its place in engineering by rethinking the teaching and learning environment in ways that allow for more individual and collaborative working, with and without the tutors/lecturers/assistants.
- To avoid students becoming overwhelmed by the level of mathematical competence required by engineering courses, university prospectuses should make this aspect very clear. Also, at times, the students believe there is little coherence between their engineering courses and the mathematics they are taught separately. Our research suggests that good pedagogic practices, i.e. connected practices, can make a difference to students' confidence with regard to learning mathematics. We therefore suggest that efforts are made to fully integrate engineering examples within mathematics courses to give context to what otherwise seems to some students to be a mathematics degree course.

Where next?

During 2011 the team, with ESRC Follow-on funding, will work with key partners, including the National HE STEM Programme, the National STEM Centre and the National centre for Excellence in Teaching mathematics (NCETM) to promote participation and engagement in post-compulsory mathematics education for STEM. This work will draw on and synthesise findings across all three research projects that investigated students' trajectories in and through mathematics programmes from compulsory school, through college to Higher Education. Further details of our ongoing work can be found at the project website One HE STEM project entitled "Mathematical modelling and problem solving" is working with STEM departments including engineering at three universities to develop first year curricula that integrate the teaching of mathematical modelling. Additionally the team are involved with further research that builds on previous work. The ERSC funded project (grant RES-061-25-0538) 'Mathematics teaching and learning in secondary schools: the impact of pedagogical practices on important learning outcomes' will explore issues of teaching and learning in the secondary years of compulsory school.

Further information

The TransMaths projects have developed, and are continuing to work on, a range of publications and other dissemination resources that can be found at the project website: www.transmaths.org

Of particular relevance to the issues raised in this Research Briefing are:

Davis, P., Harris, D. & Jooganah, K. (2010) Transfer of mathematics learning to problems of electrical and electronic engineering during the first year of university. Paper presented at the British Educational Research Association Annual Conference, University of Warwick, 1-4 September 2010.

Davis, P., Harris, D. & Jooganah, K. (2010) Using mathematics to solve engineering problems and mathematical subjectivities. Paper presented at the European Conference on Educational Research, University of Helsinki, 25-27 August 2010.

Harris, D., Davis, P. & Jooganah, K. (2010) Mathematics as a 'tool': what does that mean for first year engineering students? Paper presented at the European Conference on Educational Research, University of Helsinki, 25-27 August 2010.

Royal Society (2011) 'State of the nation' – preparing for the transfer from school and college science and mathematics education to UK STEM higher education. London: Royal Society

Wake, G. (2010) Learning university mathematics: a case for expansive learning. Paper presented at the Psychology of Mathematics Education (PME34) Conference, Instituto de Ciências Exatas, Brazil, 18–23 July 2010.

Williams, J. S., Hernandez-Martinez, P. & Harris, D. (2010) Diagnostic testing in mathematics as a policy and in practice in the transition to HE. Paper presented at the British Educational Research Association Annual Conference, University of Warwick, 1-4 September 2010.

The warrant

One of the strengths of our project that investigated transitions into Higher Education is that it drew on a variety of methods. It used large-scale questionnaire surveys of students (n>1700) at the start of their university course and after the first semester, developed case studies of 13 university courses (mostly in STEM), and tracked a number of students in more depth through three longitudinal interviews (N>50). This provided a rich base of data for analysis.

In addition, we extended the conceptual framework already developed for our previous research project ESRC TLRP 'Keeping Open the Door to Mathematically Demanding Programmes in Further and Higher Education' which explored transition through college in much the same way.

Specially constructed instruments were developed and validated to measure important new affective learning outcomes in the transition into mathematically demanding (STEM) programmes in Higher Education.

The case studies were developed from mainly qualitative investigations and involved observations of lectures and tutorials with interviews of students and teachers. Triangulation was supported by the collection of other university degree course documents and data, and interviews with other stakeholders such as Heads of Departments. The series of longitudinal biographical style interviews about students' transitional experiences provided further deep description and insight into the transitional process.

Our methodological approach is imbued with the notion of generating practical knowledge in partnership with students and university 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 meetings with university teachers assisted in this respect. Finally, our warrant is also enriched by the project's advisory group, which consisted of academics and practitioners with relevant experience, and which met regularly with the project team.

Project website:

www.education.manchester.ac.uk/research/centres/lta/ltaresearch/transmaths/into-he/

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