Engineering - the barriers

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25th April 2018

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REFINE
Researching Futures in Engineering

Futures in Engineering: Informing policy and practice and developing future research agendas via existing research

Lead Project Investigators:

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Previous Research Informing the Project:

1. **Decision-Making for Degree-Taking:** Who or what influences students to study for a degree in engineering at a Russell Group university?
2. **Futures in Engineering:** Engineering-Related Aspirations and Anxieties
3. **Teleprism:** "Mathematics teaching and learning in secondary schools: the impact of pedagogical practices on important learning outcomes" (www.teleprism.com)
4. **TransMaths:** "Mathematics learning, identity and educational practice: the transition into Higher Education" (www.transmaths.org*).*
5. **TLRP:** 'Keeping open the door to mathematically demanding programmes in Further and Higher Education'. (www.transmaths.org)
6. **Maths Anxiety Review:** A systematic review and meta-analysis of existing research related to maths anxiety, including a case study of engineering. (www.mathsisok.com)
7. **Learning Gain:** This ongoing project is piloting alternative measures of students' learning gain at university, and includes students' attitudes, dispositions, their transitional experience from school to university, reasons of choosing particular subjects and their expectations of their university and studies. (http://www.hefce.ac.uk/lt/lg/projects/uni-manchester/)

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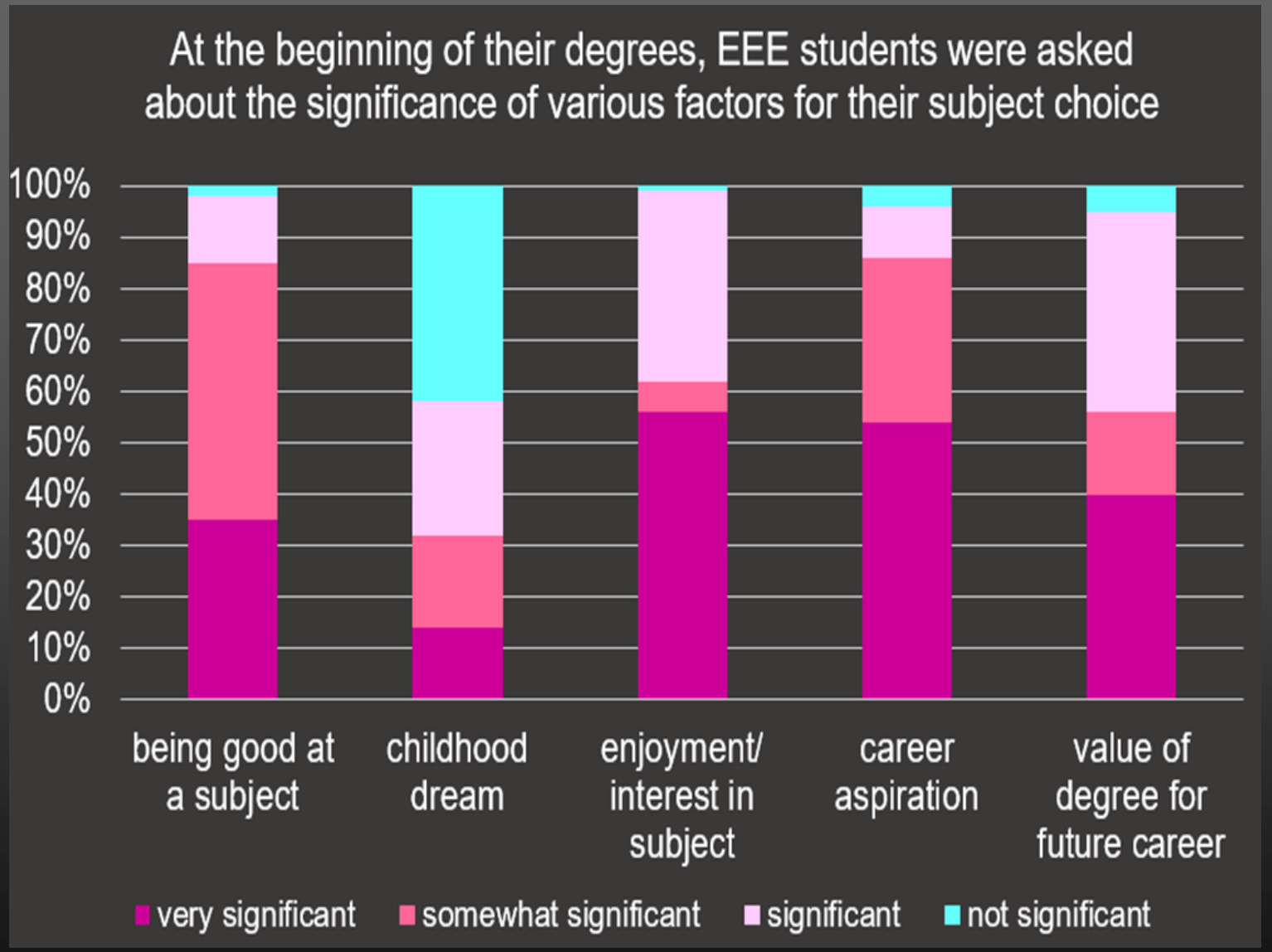
Evidence from

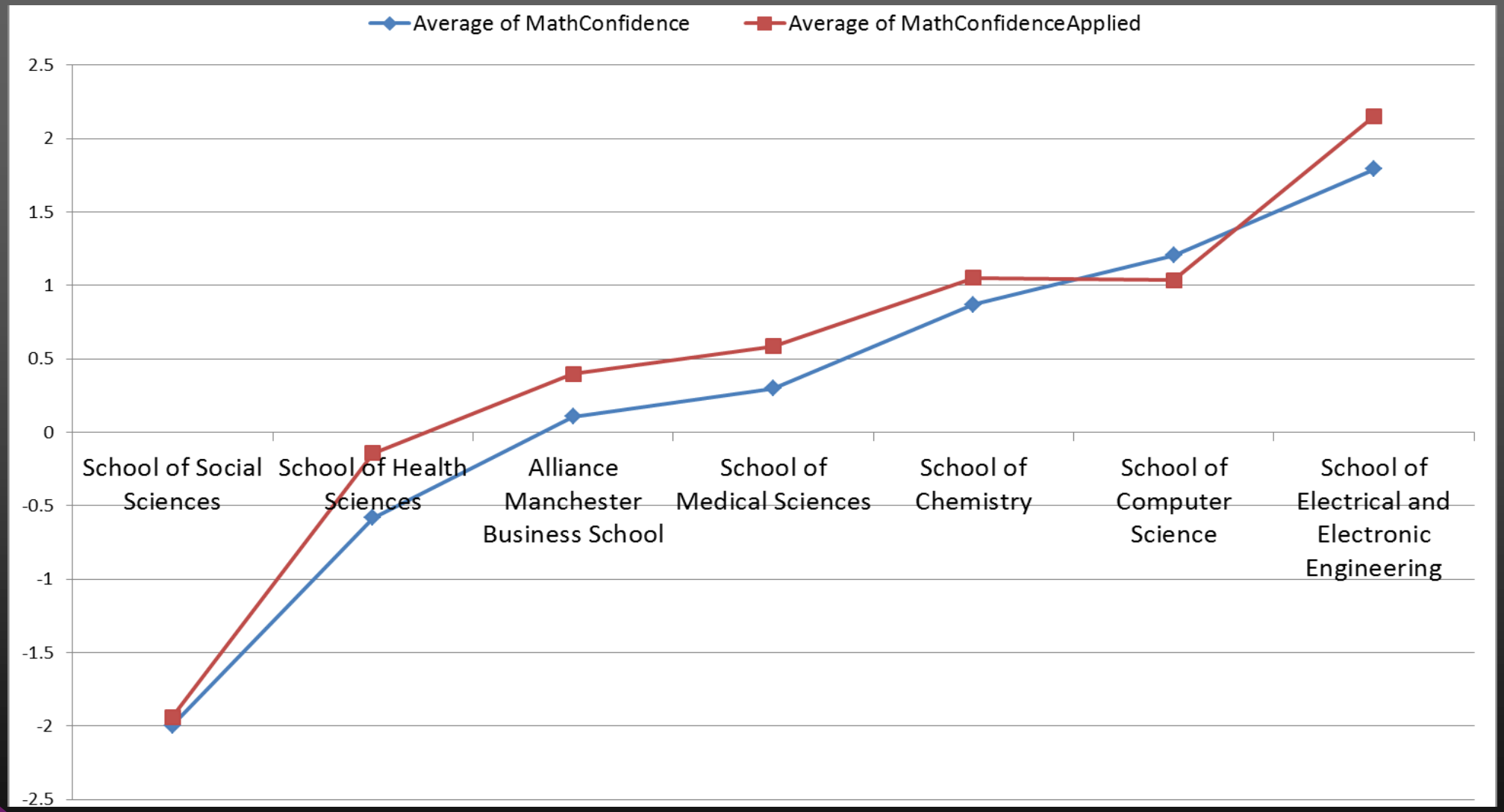
- Students and their teachers (from Year 7 into University) Studying various topics (STEM, not-STEM, Engineering)
- Surveys (usually longitudinal) of attitudes/emotions and perceptions of teaching practices
- Interviews with students and teachers
- Observations
- Systematic literature review (and meta-analysis)

Aspirations / Choosing Engineering

The aim of the TransMaths Project was to follow students' experiences of and engagement with mathematics and to investigate how these shape their developing dispositions towards mathematics during their transition to and whilst at university.



Example of attitudinal measures (math confidence)



First Year UG students, Learning Gain Project

The Barriers to Engineering

1. How much people know about engineering
2. The amount of mathematics and the way it is taught
3. Mathematics anxiety
4. Gender and stereotype threat

1. How much do people know about engineering?

Only 30% of parents know what professional engineers do. (Engineering UK, 2015)

A recent poll revealed that 49% of engineering students asked their teachers for advice about engineering but only 17% of those students said subsequently they had found this advice helpful. (Finegold, 2015)

Suitably qualified first year undergraduates who chose not to study engineering explained that they had no previous experience of 'professional engineering' which is why they did not consider studying the subject at university. (Harris, 2014)

Other suitably qualified first year undergraduates had somewhat more understanding and equated it with Design and Technology in general or with "building activities" using various unlikely materials (Harris, 2014).

This lack of an 'imagined identity' in engineering is further compounded by widespread false/negative images and stereotypes as Tonso (2014) explains: "In the popular imagination, engineers mistakenly tend to be considered (at least in the US) as socially inept sorts who are fascinated with gadgets and fixing things, more practical than scientists, and somehow brainier than technicians." (p.26).

Socio-demographic/Family Influences

- Parents/family were highly influential in pupils' decisions about what they wanted to do after Year 11
- Who will influence or inspire your decisions about what you want to do after Year 11?

	Year 7	Year 8	Year 9	Year 10	Year 11	All 5 years
My parents	79%	78%	74%	71%	67%	75%
My teachers	41%	36%	37%	34%	37%	38%
My friends	29%	27%	26%	24%	27%	27%
My siblings	34%	30%	29%	26%	23%	29%

Harris & Pampaka, 2016

Teleprism (Year 7-11 pupils i.e. 11-16 year olds)

Socio-demographic/Family Influences

Parents remain influential although not always in a positive way.

Those students who have relatives (fathers, uncles, grandfathers) who are/were engineers are more knowledgeable about the subject and are also more prepared to go into engineering than their peers.

Anxiety over A-level maths and/or the maths they may need in the future to pursue a career in engineering are a cause for concern for some students and may therefore negatively influence their aspirations to study engineering.

TLRP **(Sixth form students i.e. 16-18 year olds)**

We were encouraged to go into engineering but everyone was like "what's engineering?" It is encouraged already but there's too little information. I was at a girls' school where I was fine doing physics but when I talked to anyone else they were like, "What, physics, that's unexpected?" I really didn't like that. I think it should be just more of a "Fine, let people do what they want" rather than, "Oh, you're actually doing engineering".

Female non-engineering student

Decision Making for degree taking (First year university students: engineering and those with suitable qualifications to have studied engineering)

2. The amount of mathematics and the way it is taught

For many STEM subjects, mathematics will play a significant role in the students' overall success or failure on these degree programmes.

Many STEM subjects (e.g. physics, engineering, etc.), the necessary mathematics is often taught as a service subject by lecturers of mathematics, rather than of the subject concerned.

To economize on the use of resources, a service mathematics course may cater for more than one subject discipline or indeed more than one 'audience', e.g. overseas students with good mathematical abilities/skills but poor English may be grouped with native English speakers with poor mathematical skills.

Maths and engineering

Student 1:

Interviewer: So what about engineering? Do you think you have to do maths in that?

Sergio: I don't know. I don't want to do maths. If the engineering I choose has maths, then I'm not going to choose it because I want engineering that's more doing, not writing. I don't want to write anything in engineering.

Student 2:

Matthew: I dropped maths to do 'Use of Maths'. But if I could go back and did one thing differently in the whole of college I would have stuck with maths. 'Cos now, thinking about it, I would have done accountancy, maths and physics and now that I've… I would've had to do further maths this year. I think that was the big, big influence on why I didn't end up doing, pursuing a career in physics, or engineering, or anything …

Interviewer: Do you regret that?

Matthew: That is a huge regret.

- TLRP Interviews (Further and HE)

TransMaths interviews about maths & engineering

- Ellie, Engineering, Riverside
- I don't think like, in the first semester it was emphasised how important maths is to the engineering subjects. I think it was treated far too, treated far too separate. I know like obviously maybe for like numbers and things, they have to put us in with the [other engineering disciplines] for maths but I don't know if that's a very good idea, because it's like, I think it should be much more combined. I didn't expect when I came here that my maths would be like, it's just a separate subject. I thought it would be completely applied to what I was doing and it wasn't.
- Halim, Engineering, Modern
- First of all, I wouldn't explain things in such a complicated manner, it doesn't need to be explained in such a complicated way; you know, break it down, make it a bit easier. Yeah ok, they're clever people but the way I see it, the easier you make it the better it'll be.

- George, Engineering, Northern
- As I said, the lecturers are assuming we know more in lectures, and part of the thing that they're assuming is that we know a lot more maths, so already the lecturers are starting to apply maths that we've learnt in the last few months. So you can definitely see where the applications are . . . you can tell the importance of it. You can definitely see where the maths is gonna apply.

- Owen, Engineering, Riverside
- Engineering- there's a shortage of engineers. I don't know I just enjoy it more. I don't know why, because it's not just maths, in engineering it's loads of other things as well, there's circuit analysis, there's, you've got to learn all the digital logic which is completely different and you're learning like working in different number bases and algebra and stuff like that.

Peter, Lecturer in Maths and Engineering, Northern

I think it's a shock for some students. I think some students think they're going to come and spend a lot of time in the laboratory and make things with flashing lights and transistors, and that's all they're going to do, but actually electronic engineering is very deep, mathematically difficult, you know, rock hard engineering course, and it's getting harder, not easier. The breadth of the curriculum gets constantly wider and the impact it has on society is only growing year by year, not diminishing. [Northern teaches both engineering and mathematics,]

Students transition into HE

students studying engineering and mathematics courses perceived a large gap in their transition and they seem also to be less positive about it compared to other groups, especially the students studying medicine who reported larger gap but also significantly more positive feelings.

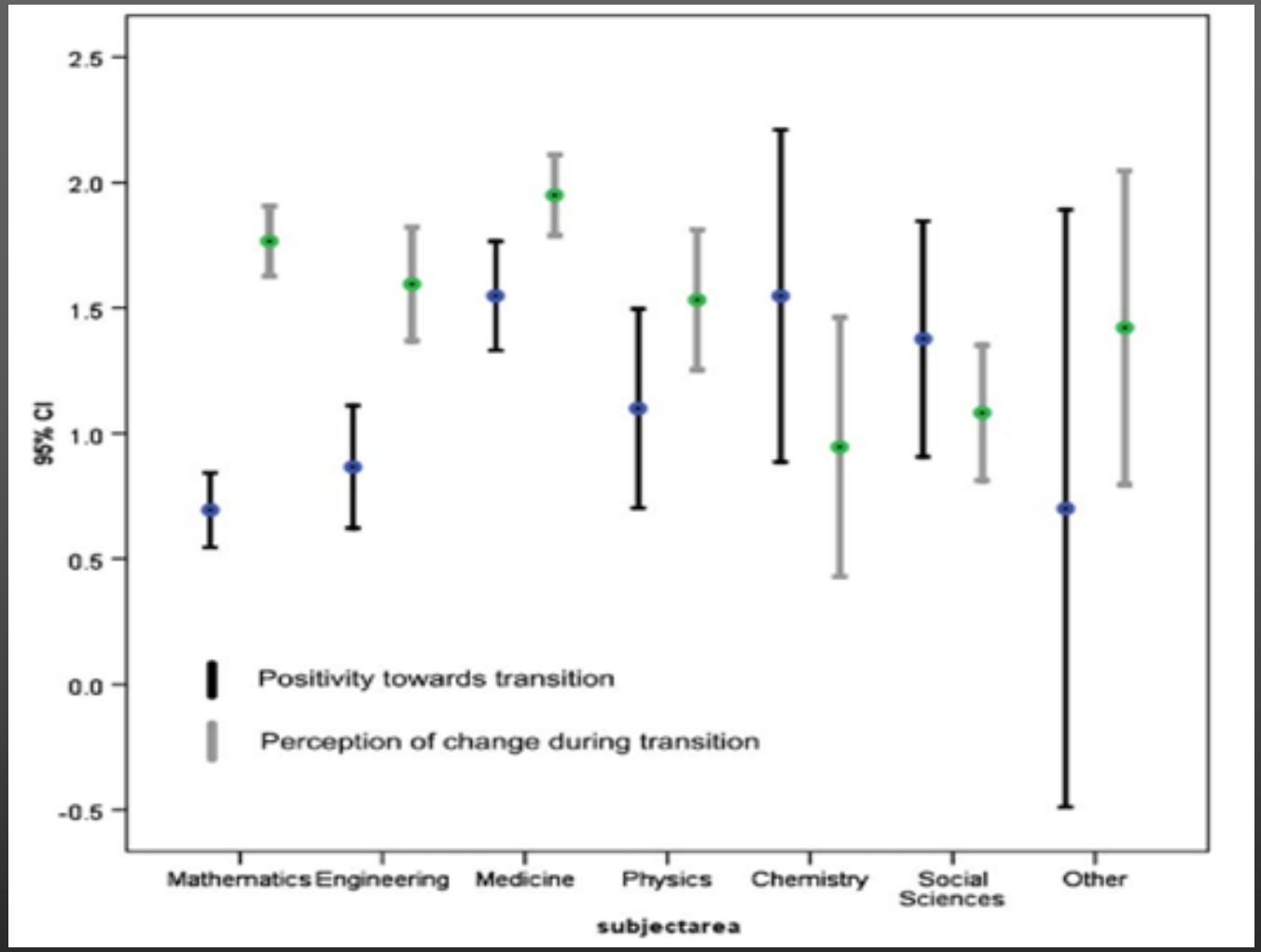


Figure: mean-error plots for the measures of 'perception of change/ gap' and 'positivity of feelings' towards transition by course

Teaching and Learning experience at University

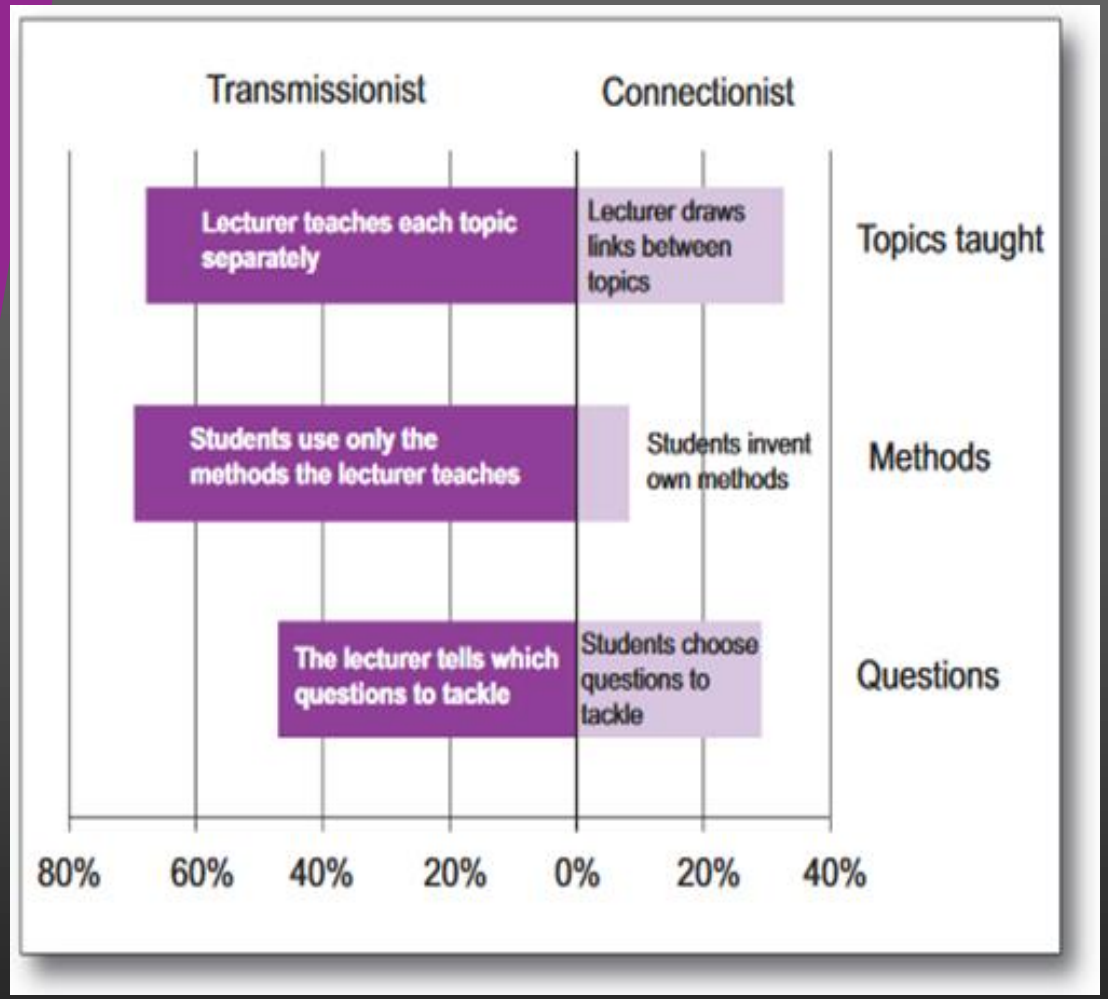
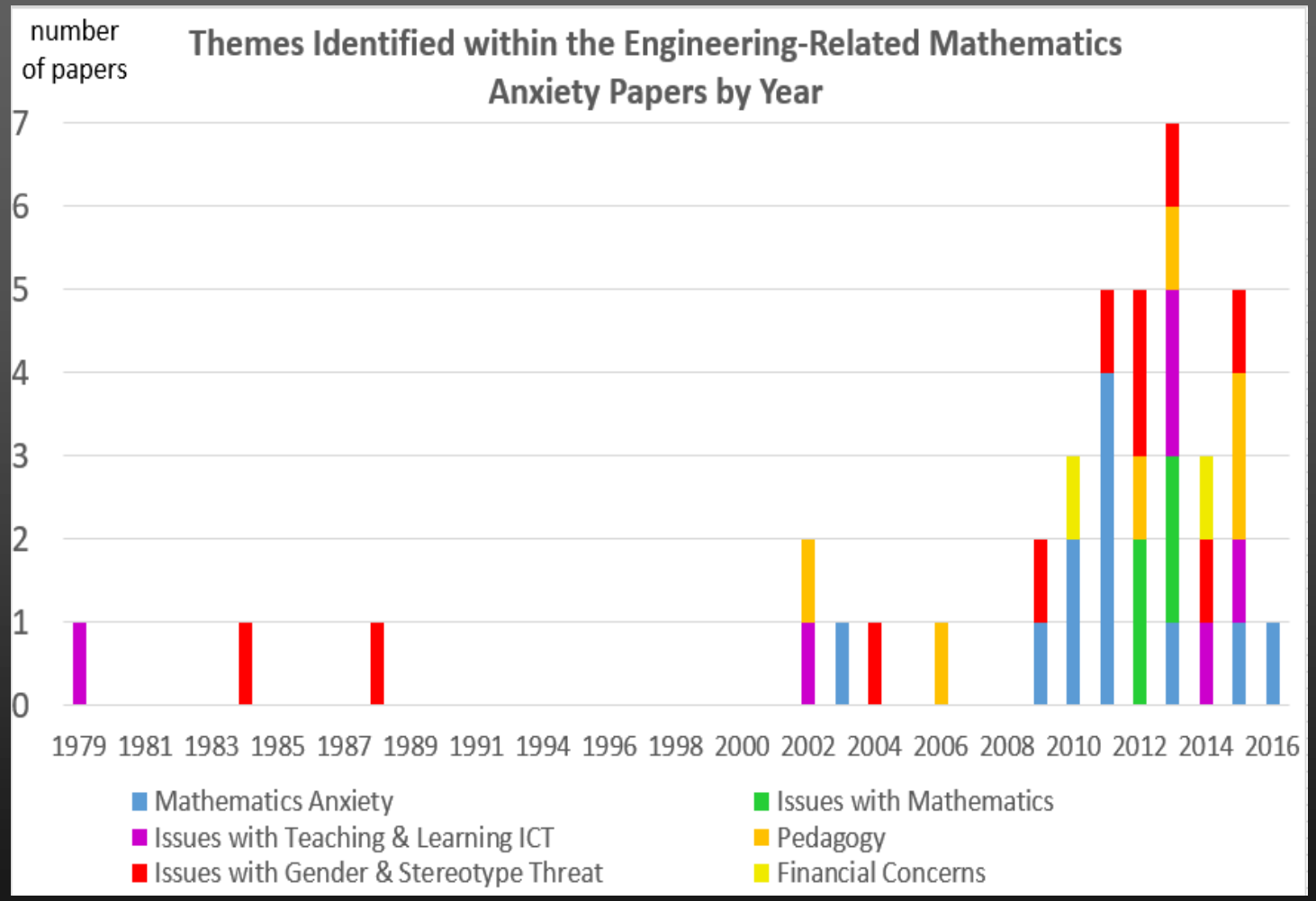


Figure: The reported use of transmissionist and connectionist teaching practices in EEE mathematics courses

The most difficult aspects of the transition between school and university for students to feel positive about are those related to teaching. Engineering students reported that their lecturers and tutors adopted mainly transmissionist (teacher-centred) teaching practices and the figure shows students' responses to a question about the frequency of teaching practices adopted by their lecturers and tutors (i.e. % of 'most of the time' or 'almost always' response options). Our research found that when a more transmissionist pedagogy is adopted, students tend to be less positive about their transition and this generally negative association is also consistent with our qualitative work.

3. Mathematics Anxiety

Our systematic review of almost 800 mathematics anxiety papers for the British Academy identified ways to reduce or alleviate maths anxiety for students at various educational levels, and in various fields of study.



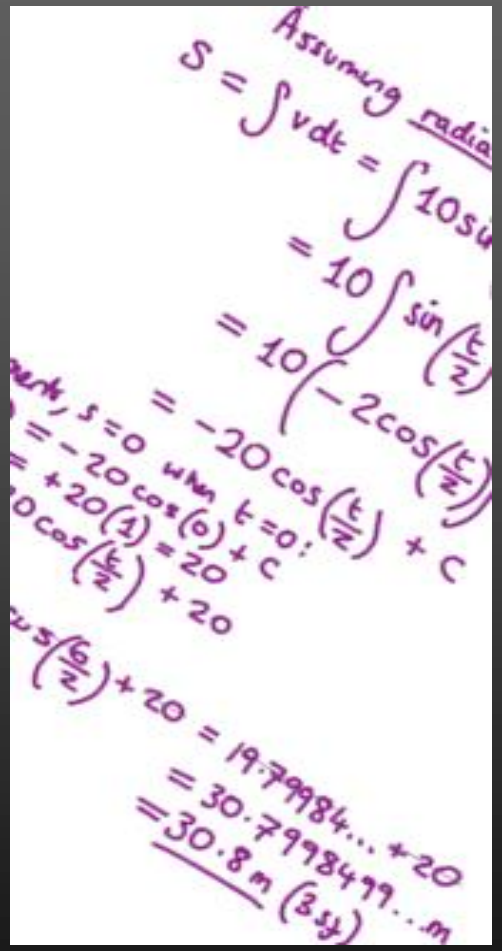
Engineering Students & Maths Anxiety

Level of Maths Anxiety

Has a significant negative impact on students' maths scores (Gonzalez-Nucamendi et al., 2015)

Can be interpreted as moderate among diploma engineering students (Jamil et al., 2011)

Is similar for men and women with the average scores being just beyond the uncertain/undecided range (Whigham, 1998)



Level of Maths Anxiety is related to:

Students' performance in electromagnetics (Ulaby & Hauck, 2000; Leppavirta, 2011)

- the feeling that maths is difficult
- always failing in maths
- always writing in maths
- lack of understanding
- loss of interest in maths

(Vitasari et al., 2010)

Students' overall achievement at the end of their first year (Maree, Pretorius & Eiselen, 2003)

Level of maths anxiety can be reduced via

developing courses designed to improve skills

developing courses designed to increase interest and

developing courses to engage students in critical thinking

Evidence from Maths Anxiety review

4. Gender and Stereotype Threat

Educational, professional and life opportunities may be limited by the influence of gender stereotyping.

So how does this happen?

Undeniably, women are equally as capable as men at performing well in mathematics but they can be adversely affected by the negative gender stereotype i.e. preconceived ideas which arbitrarily assign characteristics and roles to women (and men) that are determined and restricted by their gender (e.g. that men have better spatial awareness than women and are better at reading maps).

Gender stereotyping also applies to engineering itself with the outcome that only 9% of professional engineers in the UK are women and so a lot more work needs to be done.

TransMaths interviews about engineering

Ellie, Engineering, Riverside

I thought like whenever everyone said, 'oh you're going to do engineering, you're gonna be the only girl there', and I was like, 'oh don't be so stupid there'll be loads' but it's like there's not. There's three other girls and they are all from other countries but I think people perceive international students as being much, much cleverer and maybe that's why they're surprised at me. Cos they know I've come from the same [background], you know, they probably compare me to their friends, like girlfriends from home in their life, who did whatever at uni, you know, just girlier subjects.

George, Engineering, Northern:

I didn't think it would be a very female; an attractive course for females just from experience. I didn't think there'd be many girls in my class. I just think it's a male dominated area I would say. I don't think, I don't think it's difficult. I just don't think it's very attractive to them.

Owen, Engineering, Riverside

No. I don't know why, it's daft. They get like, women in engineering and science, they get like £4,000 a year just for doing engineering. It's daft.

- When asked if he knew why the one female student in his tutor group had chosen to study engineering James (Modern) replied:

- James: Because she wanted to join RAF and she had to do something before. So it wasn't really her choice. It was just something to do. To kill time I guess, definitely.
- Interviewer: Oh right, I see. So it's normal for a person like you, if he's a boy, to do engineering but not if somebody is a girl?
- James: Yeah, I think so, yeah.

- Halim (Modern) provided an example of unconscious bias towards the female interviewer:

- Halim I'm looking forward to my course, I definitely am looking forward to my course. I'm looking forward to what it's going to bring me, erm, what I'm going to learn. Because I find that it's like I don't know if you, if you were to like it because it's with automotive. I'm going to be learning car, car technologies. Erm I'm, you know, I'm a typical sort of boy. I like cars, I like football, you know.

Men at Riverside experience stereotype threat too:

Keith:

Yeah? I mean I normally sit, I normally try and sit behind, behind wherever it's coming from so that it's harder for them to actually chuck it at me and I see it coming when it is but, I can't find my glasses this morning and had to sit right at the front to see the board.

Keith:

But I don't think really it's anything to do with maths. Possibly because I ask a few more questions in lectures and they actually pay attention some of the time - not always, they tend to sleep. But you know, either pay attention or sleep, don't just sit around nattering. It's up to them.

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 asks at times… I say to myself, 'wow, how did he think of that?' You know, you're like, that is unbelievable. When he asks a question, those are the kind of questions you would not really ask. Or, when he asks it and the teachers answer, you definitely know that yeah, I've gained something out of him. Like, wow, thank God he asked that question.

Owen:

Turn up to all the lectures and ask stupid questions and, like, we're in the lecture like…can you just ask, can you please, can you just interrupt the lecture to ask stupid questions constantly, which have nothing to do with anything that's going on…and it's, it's really irritating and I don't think the lecturers like it either.

- Ellie, Engineering, Riverside:
- Oh, it's been awful. It's been really awful. I've hated it. It's been really, really horrendous erm and I didn't think, like I started doing engineering and I just thought I would love it because I'm such a 'lad' girl, not a 'girlie' girl and none of my friends are 'girlie', but I just like get talked down to. Respect, they don't really respect me.

Where next?

Futures in Engineering: Informing policy and practice and developing future research agendas via existing research

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Futures in Engineering: Informing policy and practice and developing future research agendas via existing research

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

Background

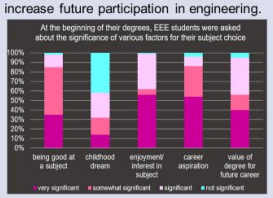
Currently, only 9% of practising professional engineers in the UK are women (WES, 2016) as compared with 21% across all Science Technology, Engineering and Mathematics (STEM) subjects (WISE, 2016). This is the lowest percentage of women engineers of the 28 European countries, over half of which have at least 20% (Perkins, 2013). When considering ethnic minority women, the percentages fall still further since the data show that men and women together only represent 6% of this workforce (RAEng, 2015). For over thirty-five years there have been incentives and initiatives to encourage women into engineering courses and careers but the problem of low recruitment remains. Although more acute in engineering, the problem exists across STEM and it is often referred to as the leaky STEM pipeline.

The issue is one of culture and there is a need for cultural change/transformation that will open up both recruitment and subsequent employment in engineering industries and STEM more generally.

Aims and Objectives

We aim to inform policy and practice to facilitate changes in current approaches to the recruitment and retention of engineering students and practising engineers reflecting on evidence from our previous and ongoing studies e.g. Teleprism (www.teleprism.com), Maths Anxiety (http://mathsisok.com/) and TransMaths (www.transmaths.org) etc. These aims will be achieved by engaging with industrial partners and relevant stake-holders to fulfil the following objectives:

- To discuss findings on reported aspirations regarding engineering to help increase future participation in engineering.

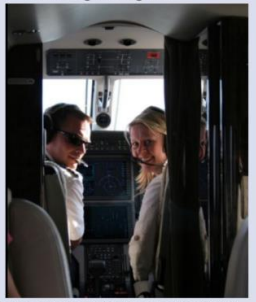


- To provide the basis for improving culture and inclusivity in engineering by sharing and debating gender-related findings.
- To invite reflection on those aspects of stakeholders' practice which require reviewing and development in the light of the research findings.
- To co-develop a new research agenda.
- To inform the research and development/ evaluation work of the professional engineering institutions (PEIs).

Benefits to the University and External Partners

This project builds on seven projects undertaken at the University of Manchester and will therefore provide the opportunity to disseminate our engineering-related findings to new audiences. The interest in this project demonstrates that this is an area of concern and has value outside academia which may lead to future collaborations with our external partners:

- **Jaguar Land Rover**
- **Women's Engineering Society**
- **IBM UK Ltd.**
- **AEON Engineering Ltd.**



Sharing our research will help our external partners to understand the drivers that affect career and lifestyle choices and will also provide them with valuable insights. Further, by working with the University of Manchester on an evidence-based policy will help to inform and influence educational experience to improve awareness and perceptions towards engineering as a career, better matching the nation's skills needs with the aspiration of the future labour market.

Methodology

Our approach to the project will be based on:

- Organising two half-day workshops
- Taking the research into schools with the support of the Research Councils UK School-University Partnership Initiative (SUPI).
- Developing a research-informed comic for pupils and parents.
- Establishing and maintaining a web presence via dedicated web pages.

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Expected Outputs

Engineering Industry Forum and Engineering Education Forum
These two half-day CPD-style sessions/workshops will enable long-term engagement with engineering businesses, professional engineers, the PEIs, academics and other groups and individuals who have significant insights into engineering education. Moreover the exchange of ideas from these disparate groups will facilitate the sustainability of the impact of the current work, help to shape our future agenda and support us in the development of a research proposal.

Research-Informed Comic
To raise awareness of engineering opportunities among young people and provide a resource for industry and teachers to talk to students about engineering (freely available from our dedicated webpages).

Presentation of findings
- in schools (via SUPI network)
- at the Engineering Professors' Council Recruitment and Admissions Forum

Publication of three research papers
Submissions to peer-reviewed practitioner and research journals.

Creation of dedicated web pages
To ensure access to our research.

Expected Outcomes and Impact

Policy Change: Policy@Manchester will support the project by providing advice and guidance on developing a stake-holder engagement plan. They will also help us to engage with the Education Select Committee and the All Party Parliamentary Engineering Group.

Practice Change: The research findings will be presented to industry, the professional engineering institutions, teachers and pupils in order to provide insights into engineering education.

Quadcopter Challenge 2017, reproduced with kind permission of Raytheon UK

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