MATHEMATICS ANXIETY AND ENGINEERING

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BRITISH ACADEMY SYSTEMATIC REVIEW OF RESEARCH INTO THE ISSUE OF MATHS ANXIETY

Unsettling Understandings of Maths Anxiety: A critical synthesis to inform policy and practice

This Special Research Project is part of the British Academy's initiative to deepen awareness and demonstrate the importance of quantitative skills

BRITISH ACADEMY
for the humanities and social sciences

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' as such 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).

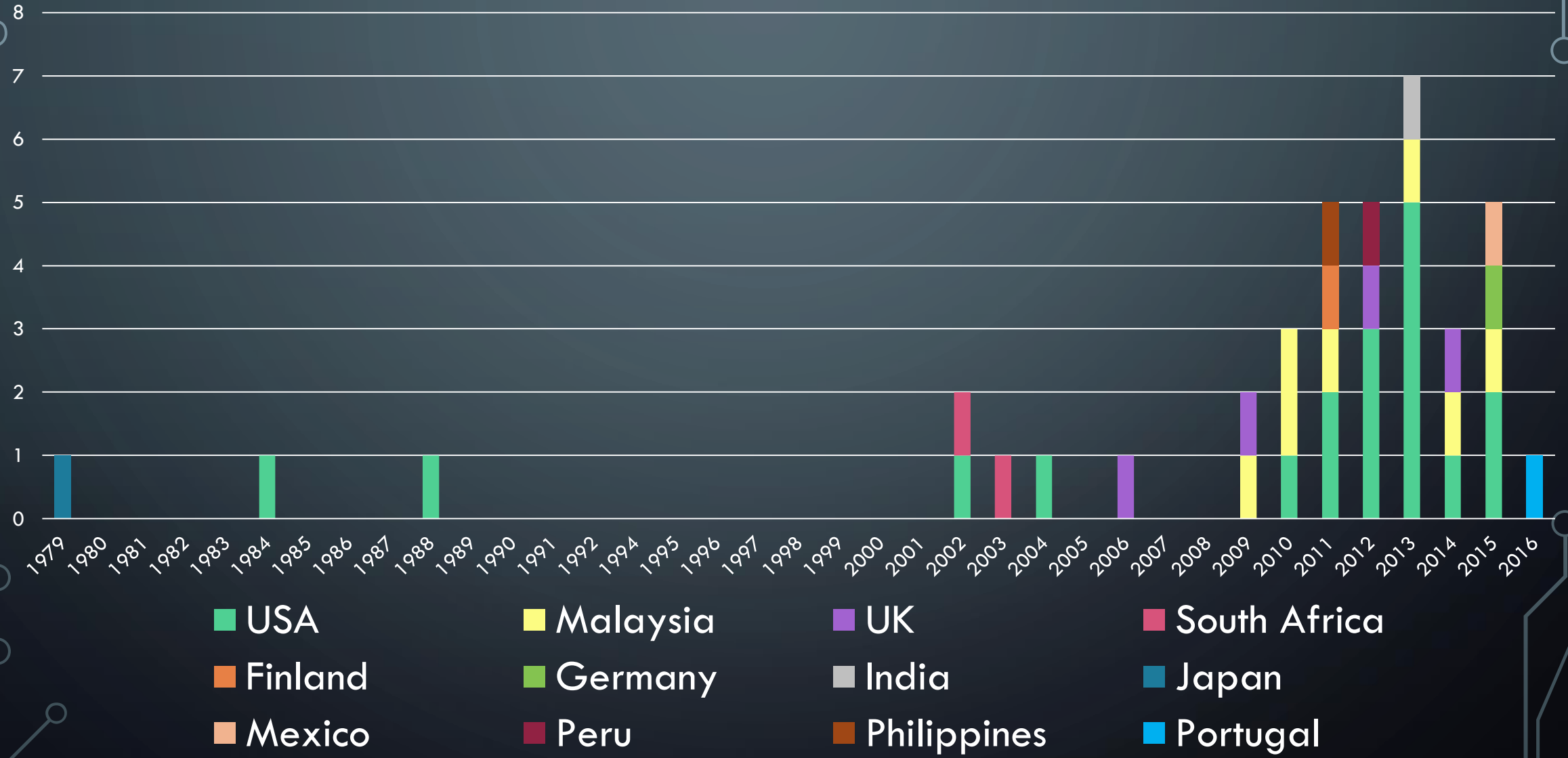
EXAMINING THE ENGINEERING-RELATED PAPERS THE SCREENING PROCESS:

798 papers in total
157 STEM-related papers

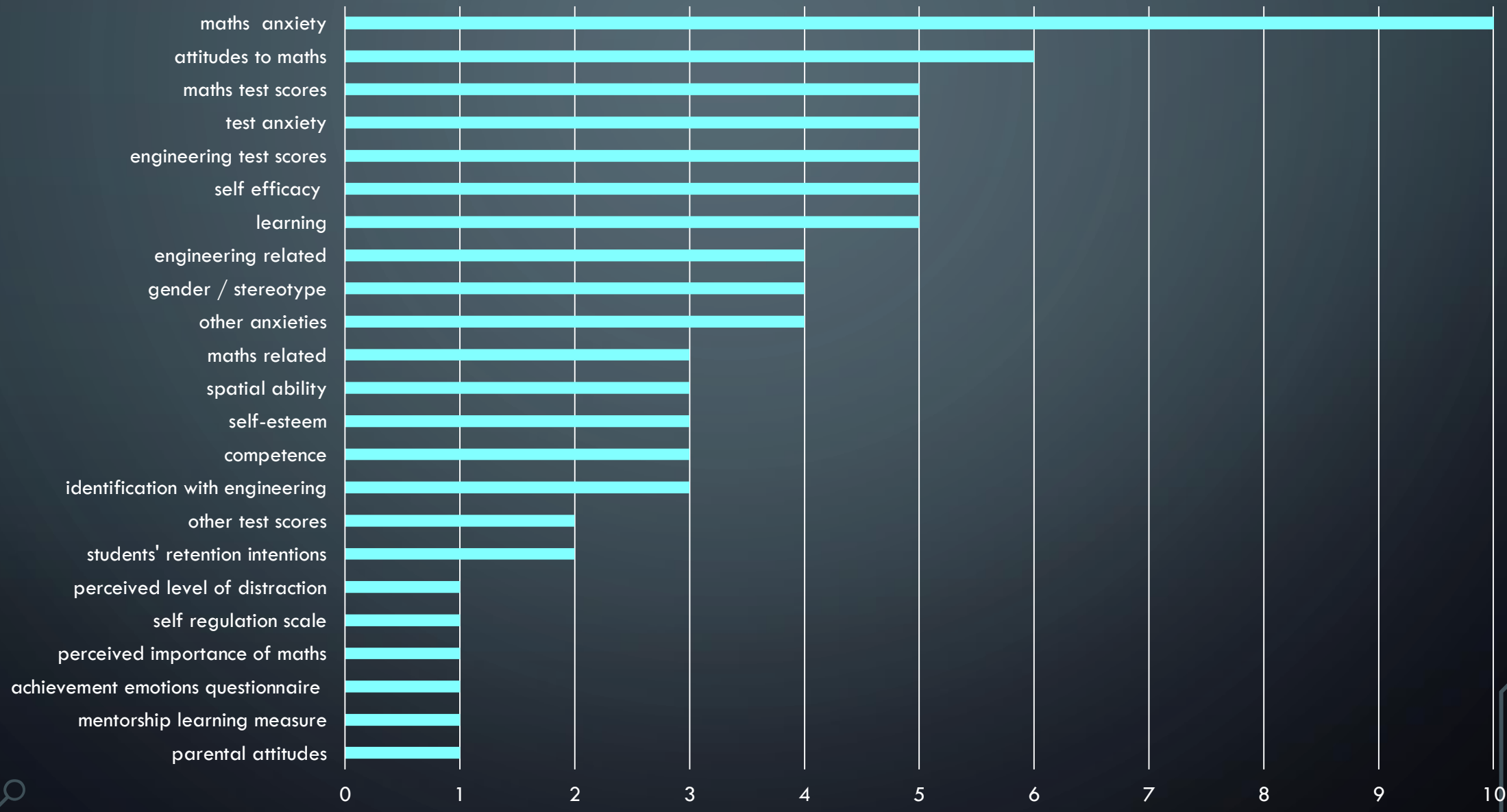
ENGINEERING
39 papers

papers from Proquest, SCOPUS, Web of Science, PsychInfo, PubMed, JSTOR

Graph of maths anxiety-related engineering papers published each year by country



Constructs/measures used in the engineering-related papers



THEMES IDENTIFIED IN THE ENGINEERING-RELATED PAPERS

Engineering students and mathematics: • Attitudes to maths • Maths test scores • Motivation	**Engineering students and maths anxiety:** • Level of maths anxiety • Level of maths anxiety related to • Level of maths anxiety can be reduced by… • Other anxiety issues
ICT, pedagogy and financial support: • Attitudes to ICT • ICT in teaching and learning • Pedagogy • Financial Support	**Gender and stereotype threat:** • Similarities and differences between male and female engineering students: • Stereotype threat • Retention • Female-oriented interventions

ENGINEERING STUDENTS & MATHEMATICS

Attitudes towards maths

May be improved by:

A positive classroom environment, especially in the early stages of learning process.
(Nordin et al., 2015)

Attitudes towards maths can have a negative effect on:

- undergraduates' learning of maths
- their potential engagement with numerically focussed activities
- their achievement

(Tariq & Durrani, 2012)

Maths test scores

May be improved by:

Logical-mathematical intelligence (Gonzalez-Nucamendi et al., 2015)

The lowering of maths test anxiety via music (Namwamba, 2013)

May be made worse by:

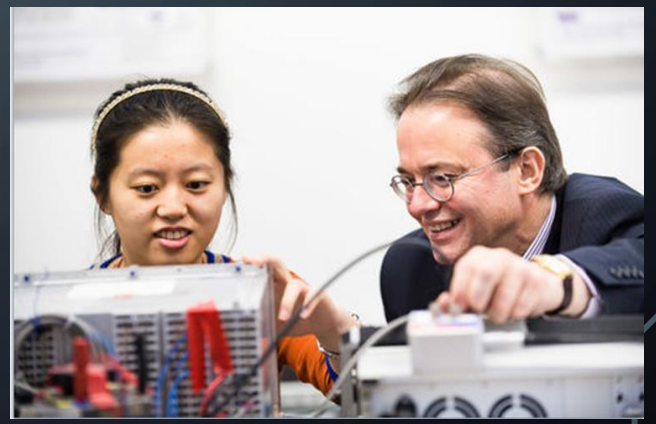
High test anxiety
(Hayes & Embretson, 2013)

Lower score expectations (although they obtained a better score than they expected) (Karjanto, 2013)

Motivation

Learners with high intrinsic motivation are very likely to pass their courses. (Gonzalez-Nucamendi, 2015)

Perceived costs and identity development play important roles in academic choices.
(Perez et al., 2014)



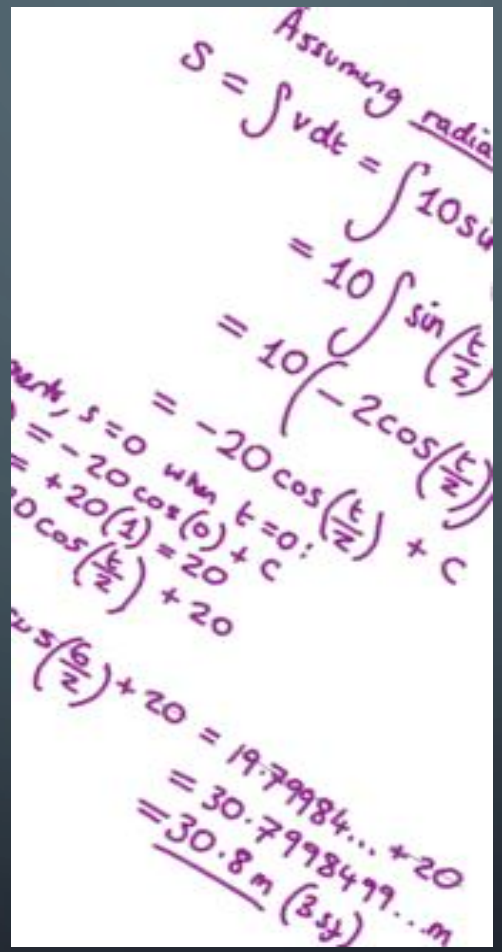
ENGINEERING STUDENTS & MATHS ANXIETY

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., 2010a)

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

ENGINEERING STUDENTS & MATHS ANXIETY

Level of maths anxiety can be reduced by:

Music
(Namwamba, 2013)

Students engaging in critical thinking
(Villavicencio, 2011)

Lecturers/tutors emphasizing and alleviating mathematics anxiety
(Kargar, Tarmizi & Bayat, 2010)

Other anxiety issues:

There is a risk in isolating mathematics from its use in engineering.
(Alves et al., 2016)

Campus environment was found to be a contributing factor to social anxiety potentially affecting all students.
(Vitasari et al., 2010)

A course that contains a high level of applied maths content improves interest, level of anxiety and maths skills.
(O'Brien, 2011)

ENGINEERING STUDENTS - ICT, PEDAGOGY & FINANCIAL SUPPORT

Attitudes to ICT

There were neutral attitudes towards education robots and reluctance to learn with them. (Reich-Stiebert & Eyssel, 2015)

Student involvement in designing/developing games improved their perception of the concepts of graphics. Learning became a passion rather than a burden. (Dawn, 2013)

ICT in teaching and learning

New computer software enabled students to obtain higher scores than those using traditional/collaborative learning only. (Khalid et al., 2014)

Online instruction enabled high school students to master challenging new STEM and technology literacy skills. (Piliouras et al., 2013)

Incorporating computer-assisted instruction assists students to adjust to the pace and depth of the work involved in maths. (Weatherby, 2002)

Developing systematic methods for improving computer assisted learning materials supported the students. (Sakamoto et al., 1979)

Pedagogy

Maths diagnostic tests, individualized learning programmes and face-to-face study support can combine significantly to increase undergraduate pass rates. (Pate & Little, 2006)

Active learning and action research provided a basis for structuring a new support course. The strategies were then integrated into the curriculum of other first year engineering courses. (Steyn & Steyn, 2002)

Financial support

Recruitment of Hispanic 1st-generation economically disadvantaged students tripled with scholarship funds and academic success initiatives. (Martinez et al., 2010)

GENDER & STEREOTYPE THREAT

Similarities between male and female students:

Women are equally as capable at performing well in maths. (Ball, 2015)

Students attribute their own performance as reflective of the academic competence of their race and/or gender group. (Beasley & Fischer, 2012)

Differences between male and female students:

Engineering identification is a stronger indicator of women's (rather than men's) likely persistence in their programmes. (Jones et al., 2013)

Women who implicitly associated maths with male were less likely to identify with maths, especially if they were strongly identified with being female. (Nosek & Smyth, 2011)

Stereotype threat:

Women were negatively affected by the negative stereotype i.e. they were not as capable as men in maths. (Ball, 2015)

Women who have higher self-confidence in their cognitive abilities and/or lower trait anxiety, are more likely to perform better in a testing situation in which a negative gender stereotype exists. (Hausmann, 2014)

Some women who face stereotype threat on a daily basis, via engagement in counter-stereotypic domains, are able to thrive in spite of negative performance expectancies. (Crisp, Bache & Maitner, 2009)

Retention

Engineering identification was found most helpful in predicting men and women's likely persistence in their programmes.(Jones et al., 2013)

Lack of graduating majors in STEM fields is not due solely to a lack of initial interest, but rather occurs through attrition during the course of college. (Beasley & Fischer, 2012)

FEMALE-ORIENTED INTERVENTIONS

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It is important to identify factors and interventions that might increase engineering identification, especially for women. (Jones et al., 2013)

FEMALE-ORIENTED INTERVENTIONS

Eleven month engineering training programme specifically for women

(Wittig, Sasse & Giacomi (1984)

23 to 55-year-old women (mean = 33.2 years).

Assessment revealed changes in aptitude for engineering with significant improvement in skills.

Similar programmes may be successful for other women, though not necessarily for other under-represented groups.

Fennema-Sherman Mathematics Anxiety Scale indicated that these women have lower levels of mathematics anxiety than those in other academic majors.

4-day / 3-night residential summer mathematics camp
(Laird & Ward, 2004)

11 to 13-year-old girls.

The camp aimed to:

- develop critical thinking skills
- reduce maths and science anxiety
- expand mathematics and science career expectations and options
- provide an introduction to the profession of engineering
- provide positive career role models.

The girls completed maths and science courses with higher scores than the national average.

Intimation that the girls' maths anxiety was reduced through participation.

A year-long after-school mentoring experience by women engineering students "Girls Helping Girls"
(Holmes, 2012)

10 to 12-year-old girls.

Participants were confident in science and mathematics.

Participants were interested in working on engineering activities after school.

Strong association between the quality of the mentoring relationship and the girls' confidence in mathematics.

Girls' worries and concerns about maths were reduced.

THOUGHTS AND CONCLUSIONS

The engineering-related literature focuses on:

- the relationship between maths and maths anxiety in engineering
- gender and stereotype threat
- teaching-related aspects within this area.

Significant negative impact of maths anxiety is reported on students' mathematics scores and ultimately on their overall engineering performance. The factors contributing to maths anxiety include:

- difficulty
- lack of understanding and interest
- threat of failure in maths.
- Isolating mathematics from its use in engineering.

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Ways of reducing or alleviating maths anxiety include:

- courses designed to improve skills
- courses designed to increase interest (e.g. by including context)
- students engaging in critical thinking.

WHERE NEXT?

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

MANCHESTER 1824

The University of Manchester

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

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Background

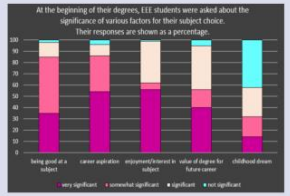
Currently, only 9% of practising professional engineers in the UK are women (WES, 2016) as compared with 21% across all Science Technology, Engineering and Mathematics (STEM) subjects (WISE, 2016). This is the lowest percentage of women engineers of the 28 European countries, over half of which have 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 (ESRC and other) studies. 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.

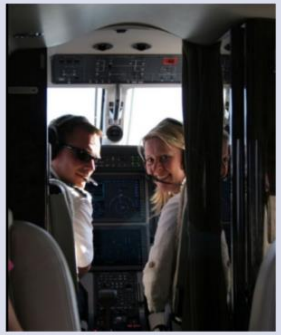


• To provide the basis for improving culture and inclusivity in engineering by sharing and debating gender-related findings.
• To invite reflection on those aspects of stakeholders' practice which require reviewing and development in the light of the research findings.
• To co-develop a new research 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.

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