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Mathematical Self-Efficacy: Addressing the Declining Interest in Engineering Careers

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Mathematical self-efficacy

Addressing the declining interest in engineering careers

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INTRODUCTION

Students wishing to pursue an engineering degree course are required to be proficient in mathematics. However it is widely thought that mathematics is the "the key academic hurdle" in the supply of engineering graduates [1, 2]. Furthermore "it is now generally accepted that students entering the tertiary level suffer a lack of mathematical skills and no longer find mathematics to be an enjoyable subject … this decline in mathematical skills leads students to avoid overly analytical subjects in later years of degree programmes" [3].

This paper presents the findings of a study investigating whether there is a relationship between students' experiences with school mathematics and their choice of engineering as a career. The study was inspired by the observation that there is a lacuna in the scholarly literature concerning the nature of mathematics' role, if any, as a significant cause of the declining number of students entering professional engineering courses.

The population of interest in this study comprises professional engineers practising in Ireland. Engineers' experiences of school mathematics, factors that contributed to their engagement with school mathematics and the impact of their feelings about mathematics on their choice of engineering careers are investigated.

1 METHODOLOGY

The research methodology employed in the study is a sequential explanatory mixed methods design incorporating a survey followed by interview analysis.

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The sample of 365 engineers who participated in the survey is broadly representative of the professional engineering population in Ireland across industry sector, engineering discipline, gender and geography and the survey sample size is satisfactory for 95% confidence that the findings represent the population of Chartered Engineers[2] in Ireland.

Following analysis of the survey data using Minitab statistical software, interviews were conducted with 20 engineers representing low, mid and high *curriculum mathematics*[3] users [4]. These engineers also comprised a diversity of engineering disciplines; roles; sectors, organisations; urban and rural backgrounds and school mathematics levels. 25% of the interviewees were female and 25% were less than 35 years of age. A manual data analysis process was employed.

2 SURVEY FINDINGS

2.1 Impact of feelings about mathematics on choice of engineering career

Participants were asked to rate the degree their feelings about mathematics impacted their choice of engineering as a career using a 5 point Likert scale.

As shown in Figure 1, 75.9% of engineers say their feelings about mathematics impacted their choice of engineering as a career “quite a lot” or “a very great deal”. 12.3% of engineers say that their feelings about mathematics impacted the choice of engineering “a little”. Only 4.1% of engineers say their feelings about mathematics impacted their choice of engineering “very little” or “not at all”.

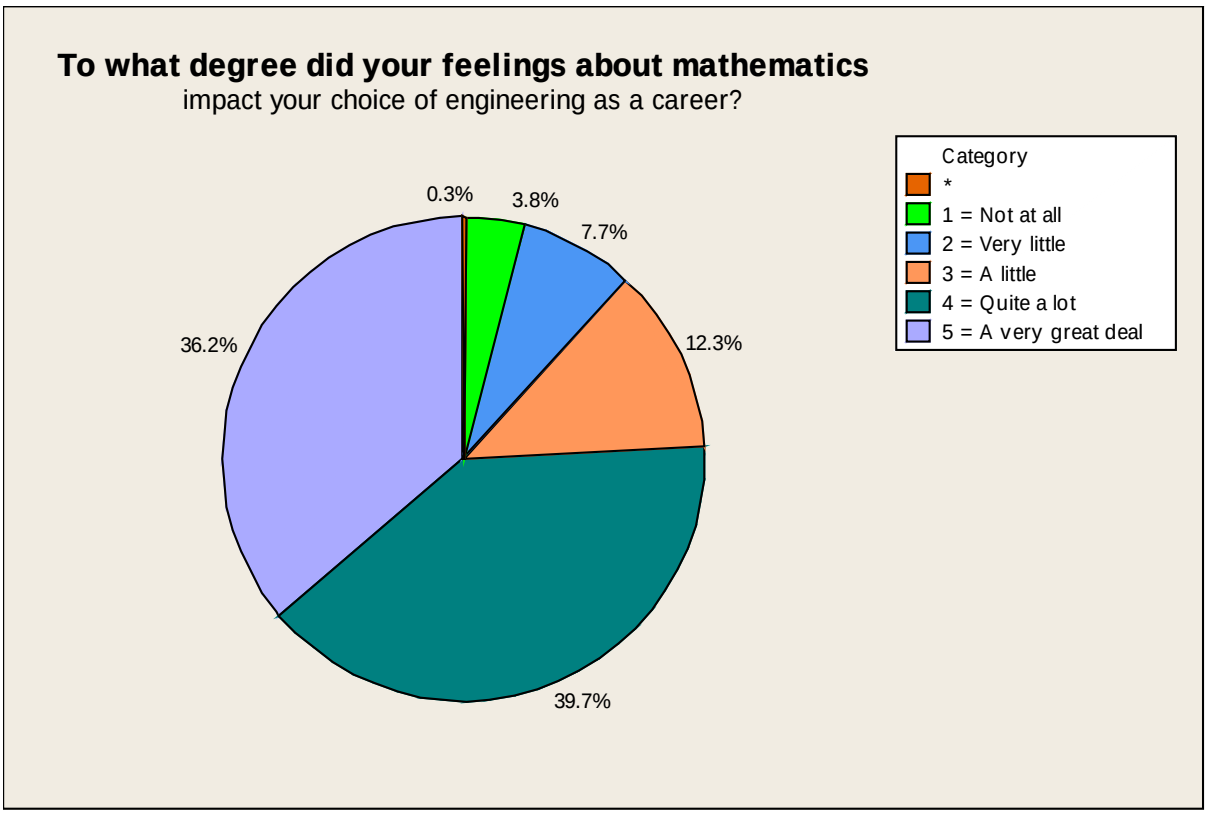

Figure 1. Degree that feelings about mathematics impacted engineers’ career choice

[2] Chartered Engineers are professional engineers registered with Engineers Ireland; they have a minimum of a level 8 academic qualification and four years of relevant professional experience.
[3] Curriculum mathematics: Term devised in this study to represent engineers’ mathematics education at school and university.

2.2 Engagement with school mathematics

In the context of *engaging* with school mathematics participants were asked, in an open question, to identify the events, experiences, aptitudes or other factors within and outside of school that contributed to their interest in and learning of mathematics in primary school, secondary school (years 1 and 2); secondary school (Junior Certificate[4] year) and secondary school (Leaving Certificate[5] years) . The responses show that 80% of the engineers surveyed enjoyed mathematics in school either "quite a lot" or "a very great deal". A further 15.3% of engineers enjoyed school mathematics "a little". Only 4.7% of engineers liked school mathematics either "not at all" or "very little".

The variation of factors within school contributing to mathematics learning with engineers' progression through school is illustrated in Figure 2. The plot illustrates that teacher, compared to other factors, is a major influence on mathematics learning and is of increasing influence as students progress from primary school through to Leaving Certificate. In Leaving Certificate years value variables, including relevance to careers and relevance to science are in second and third place respectively. As in the earlier school years, enjoyment (value) and success (self-efficacy) are strong factors.

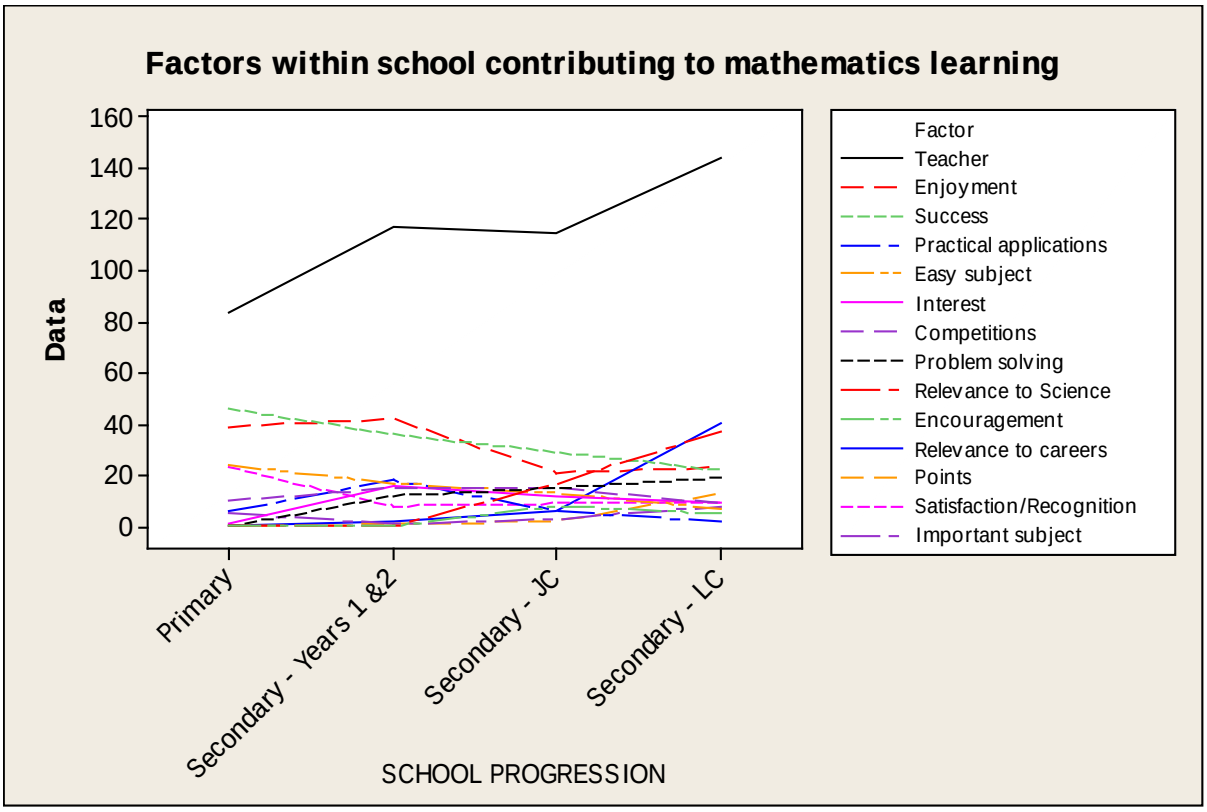

Figure 2. Factors within school contributing to mathematics learning

The variation of factors outside school contributing to mathematics learning with engineers' progression through school is illustrated in Figure 3. The influence of family and parents is a major factor in mathematics learning and is of decreasing influence as students progress from primary school through to Leaving Certificate.

[4] Junior Certificate: Examination taken at year 3 of secondary school in Ireland (age 15).
[5] Leaving Certificate: Examination taken at the completion of secondary school in Ireland (age 18).

After Junior Certificate careers is of increasing influence on mathematics learning. The influence of affective variables including: family (sociocultural influences); careers (task value); interest in engineering (task value); usefulness (task value); ambition (motivational belief); toys and games (task value); and peers (sociocultural influences) are evident at this stage of the engineers' development.

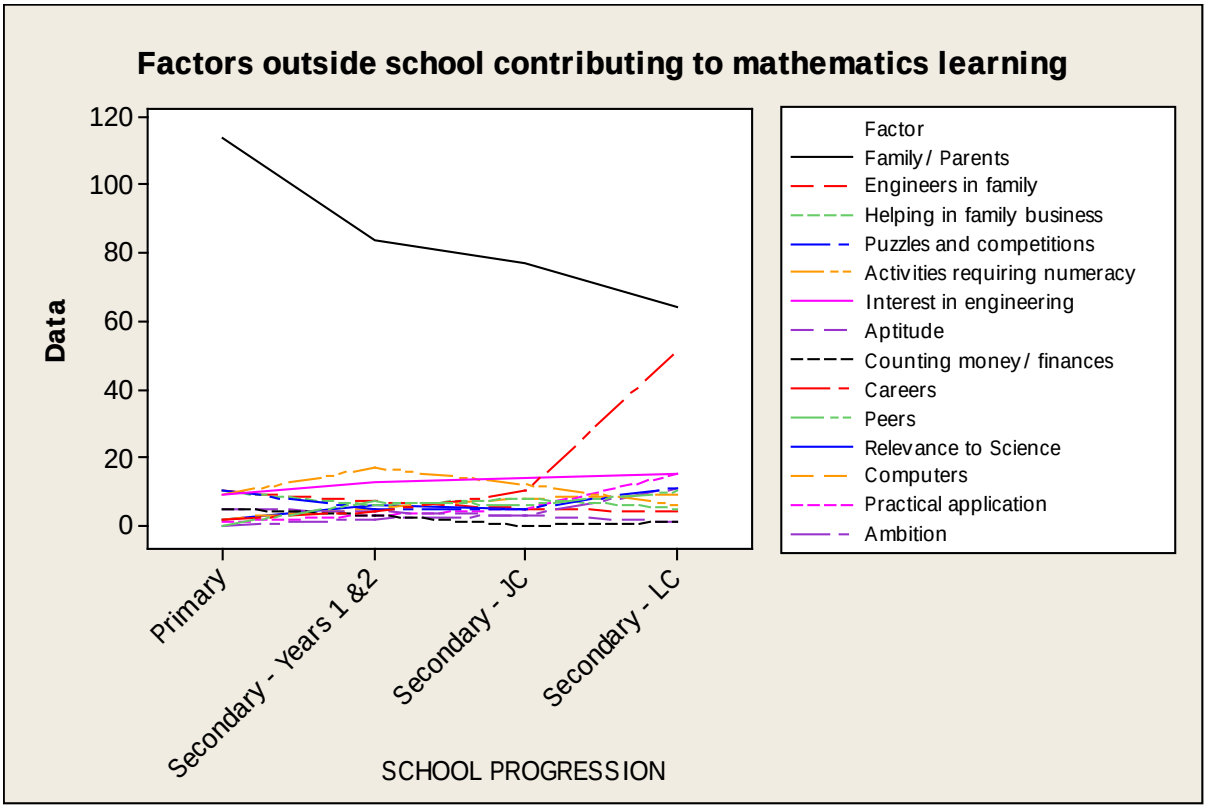

Figure 3. Factors outside school contributing to mathematics learning

2.3 Improving young people's affective engagement with mathematics

Participants were asked, in an open question, how young people's affective engagement (e.g. enjoyment) with mathematics could be improved.

The responses shown in Figure 4 illustrate that teachers are the key to improving young people's affective engagement with mathematics. 92% of the engineers' views about improving young people's affective engagement with mathematics relate to teacher or teaching. Further analysis indicates that teachers should communicate the value of mathematics by teaching content that illustrates the task value of mathematics. Engineers are also of the view that confidence dealing with mathematics develops in school where engineers learn to check their answers and where they are "in the habit of getting 100% in maths and maths-based exams".

The engineers' views are consistent with motivation theory which posits that teachers are a huge influence on students' motivation. In particular teachers' decisions about what activities students engage in are deemed to affect motivation; this is consistent with motivation theory [5]. In this study the engineers' views are that teachers should teach mathematics content that illustrates: the usefulness of mathematics; the relevance of mathematics to modern living; mathematics that is used in various careers; and mathematics that has links with other school subjects. All of the content proposed by the engineers has a high task value.

Many engineers are of the view that because mathematics is a difficult subject, "teaching is the biggest issue facing maths". They say that "teachers must have the skills, enthusiasm and ability necessary to teach the subject" and that "much of the problem sadly lies with" unqualified teachers. Engineers also draw attention to the influence of teachers' own attitudes about mathematics on students; they maintain that teachers' own beliefs about mathematics are responsible for the general "stigma about the difficulty of higher level maths" and engineers are of the view that it is teachers' responsibility to correct this "stigma" and the "fear factor" associated with mathematics. This is consistent with motivation theory whereby it is maintained that efficacious teachers are more likely to plan challenging activities, persist in helping students learn and overcome difficulties, and facilitate motivation and achievement in their students. Such constructivist teaching (theory contending that individuals construct much of what they learn and understand through individual and social activity) changes the focus from controlling and managing student learning to encouraging student learning and development [5, 6]. While the majority of engineers' views relate to affective variables, the engineers also present that "a strong reason for students not enjoying maths is that they don't understand it" and they advocate that mathematics teaching should place "more emphasis on understanding". This view is similar to Vygotsky's theory of social constructivism whereby understanding is accomplished when teachers present appropriate challenges for learners to engage in and make sense of concepts rather than students just passively receiving facts and skills. Vygotsky's zone of proximal development posits that there is a difference between what learners could achieve by themselves and what they could do with assistance from a skilled person [6].

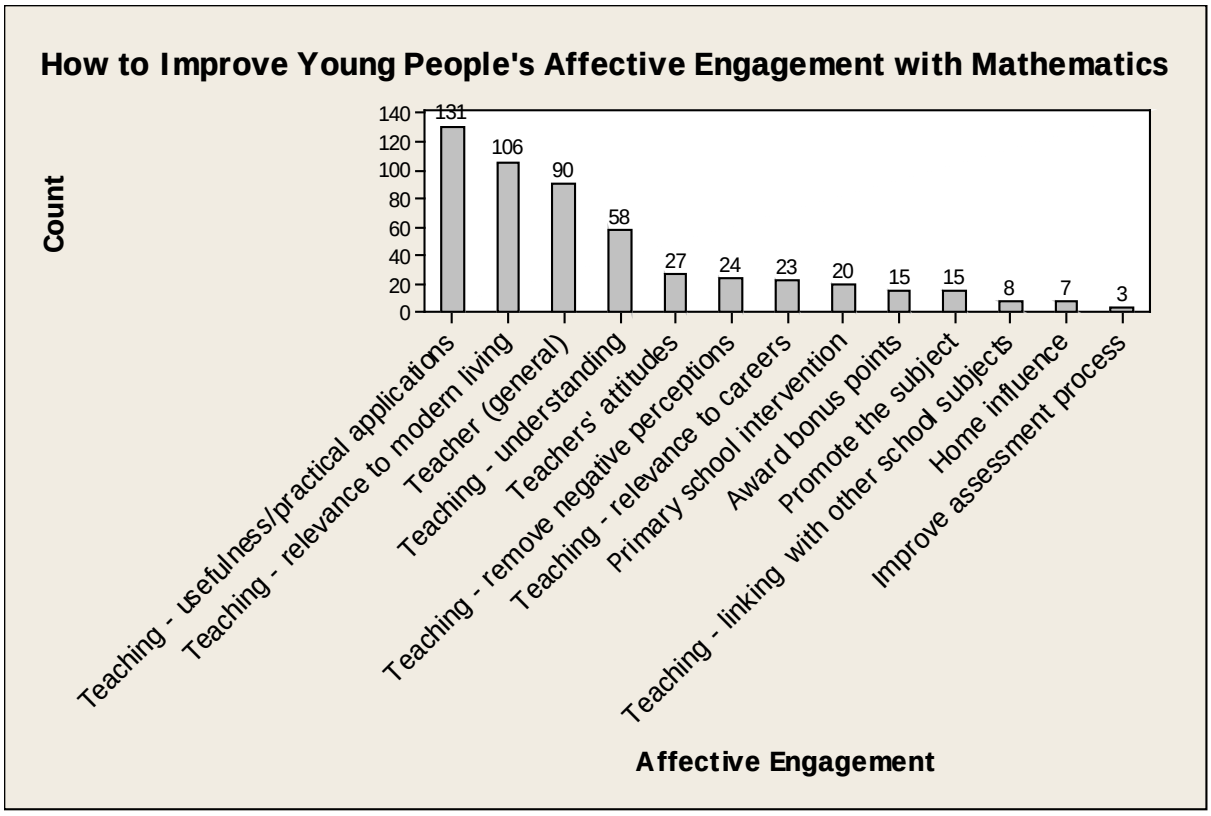

Figure 4. How to improve young people's affective engagement with mathematics

3 INTERVIEW FINDINGS

Following the collection and analysis of survey data in this two-phase sequential explanatory mixed methods research study, semi-structured interviews were employed to further investigate the relationship between students' experiences with school mathematics and their choice of engineering as a career.

The majority of the engineers interviewed say that their feelings about mathematics were the main influence in their decision to choose engineering. Engineers' strong feelings about mathematics in the context of engineering career choice concern their "ability and enjoyment" of school mathematics. Family support with mathematics learning and positive school mathematics experiences all contributed to engineers' good feelings about mathematics and consequently their decision to choose engineering. It is the engineers whose family supported their mathematics learning from a young age whose main reason for choosing engineering was their feelings about mathematics. The engineers, whose main reason for choosing engineering was for reasons other than their feelings about mathematics, didn't get any family encouragement or home support with mathematics. For engineers who had particularly negative school mathematics experiences, their feelings about mathematics did not influence their choice of engineering.

Engineers say that the feeling of success is the main contributor to enjoyment of school mathematics and that confidence in school mathematics stems from recognition of success such as latest test grades, getting top marks or being the best in the class. It is these feelings that influence students to choose engineering as a career. For example, one engineer's career choice was influenced "a very great deal" by "love" of mathematics; he says engineering and mathematics "were hand in hand, I had very much an aptitude for mathematics in school, that's the subject that I found easier, that's the subject that I didn't have to study and to me the engineering followed on from that".

Engineers present that school mathematics focuses on getting the "right answer" whilst other subjects lean towards "subjective analysis". They contrast their ability to get the "right answer" and full marks in mathematics with other subjects whereby "no matter how much work" one puts into the "subjective" subjects one might not get "full marks". Engineers enjoy the "feeling of success" provided by the "right answer". There is a sense that mathematics learning is more personal compared to other subjects. Each student learns mathematics "differently" and "every person takes responsibility" for their own understanding. In agreement with Vygotsky's theory of the zone of proximal development [6], engineers assert that an understanding of each topic is necessary prior to moving on to the next topic. The engineers believe that with rote learning students do not experience mathematics success, instead they "get stuck" and they "fall behind" very quickly. In addition to the knowledge base, engineers maintain that mathematics is an "activity, it is a "process" of problem solving and application and for many students the problem solving nature of mathematics is time consuming.

In agreement with affective theory [5], engineers hold that teachers, task value (why should I do mathematics?), feelings of success and family, peer and societal influences are key motivators to engage in mathematics learning. Engineers also say that teaching is the "number one" factor in mathematics education and good mathematics teachers transform students' mathematics learning and their enjoyment of the subject. The ability to communicate mathematics is the predominant characteristic of good mathematics teachers. While one engineer's mathematics teacher was "excellent" because he "just connected with people through maths" the

"plain ordinary bad" teacher "just could not explain the consequence" of any mathematics topic". Good mathematics teachers are also "positive" about mathematics and they are "enthusiastic to the point" where they "can foster interest and enthusiasm for the subject with a broad profile of students within the classroom". Teachers' own attitudes to mathematics contribute to students' affective engagement with the subject. Engineers believe that there are many "unqualified" mathematics teachers who are neither confident nor positive in their teaching of mathematics and who also fail to communicate the value of mathematics to students.

For some engineers the task value of mathematics (why should I do mathematics?) is evident where from a very young age when they enjoyed "mathematical type game playing" and engaged in authentic mathematical tasks in the home. In school, getting "the correct answer" is the key value of mathematics learning whereby engineers enjoy the recognition associated with success and consequently they were motivated to engage further with mathematics. The costs (perceived negative aspects of engaging in mathematics) include the time required to get "the correct answer" and the fear of getting the "wrong" answer. One engineer says he risked passing his Leaving Certificate exam because mathematics consumed more than half his allocated homework time period. A further cost of school mathematics is the lack of relevance of mathematics teaching to everyday life. Students view higher level Leaving Certificate mathematics in terms of both the value of college entry points and the cost of the effort required to take the higher level option. Engineers are also of the view that society does not value mathematics sufficiently and it is generally accepted by society that only a minority of students take higher level Leaving Certificate mathematics.

Engineers maintain that collaborative learning opportunities assisted their school mathematics learning. Advantages of peer mathematics learning include: the "comfort and positivity" of peers towards numerate subjects; compensation for poor teaching; playing "football together because nobody else would play football" with mathematics "geeks"; turning Leaving Certificate mathematics into this "fun thing"; and motivating students to "get an A in Leaving Certificate mathematics". However engineers also present that there is a stigma associated with being good at mathematics and that being good at school mathematics causes social problems for students who consequently try to hide "the guilty pleasure of enjoying maths".

4 CONCLUSIONS

Both the survey and interview findings illustrate that engineers' confidence in their mathematics ability is the main influence on engineering career choice. For one engineer the key to mathematics learning is "finding that you are able to do it" and the sense of achievement another engineer experienced when he solved a difficult problem spurred him "to do more" mathematics.

The key message for mathematics teachers arising from the study is that the teacher is the "biggest influence" on students' relationships with mathematics. A good mathematics teacher is "positive" about mathematics" and it is the teachers' responsibility to correct the "stigma about the difficulty of higher level maths". According to the engineers interviewed good mathematics teachers transform students' mathematics learning and their enjoyment of the subject. Engineers say the ability to communicate mathematics is the predominant characteristic of good mathematics teachers; the "excellent" teacher "just connected with people through maths".

The study also shows that mathematics is a highly affective subject where motivational beliefs such as affective memories (previous emotional experiences with mathematics), goals, task value (why should I do mathematics?) and expectancy (am I able to do mathematics?) are major influences on students' engagement with mathematics.

It is concluded that enriching students' mathematics experiences holds the key to increasing enrolments in engineering education. "The idea that maths is actually something a lot of people will enjoy" might get children started with mathematics and if they discover that they are "good at it" they might enjoy it more and "stick with it". Students develop mathematical self-efficacy in school when they discover that they are able to do mathematics and they bring this confidence with them to university, work and into society.

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