Setting the Scene

The Mathematical Attitudes, Beliefs and Ability of Students

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There is growing evidence of the importance of students' attitudes and beliefs about mathematics for their achievement in and successful applications of the subject [1]. Research studies have shown that students in higher education who are not maths majors often have negative images, beliefs and attitudes towards mathematics [2]. There is great variation across all students, especially with engineering students, who can be mathematically very strong through to some who are quite weak. It is often but not invariably the case that mathematical achievement is correlated with positive attitudes to the subject. Typically, it is confidence in one's own mathematical ability that is correlated with achievement rather than liking or pleasure in the subject.

Where such correlations do occur it is observed that the achievement-attitude link forms self reinforcing cycles [3].

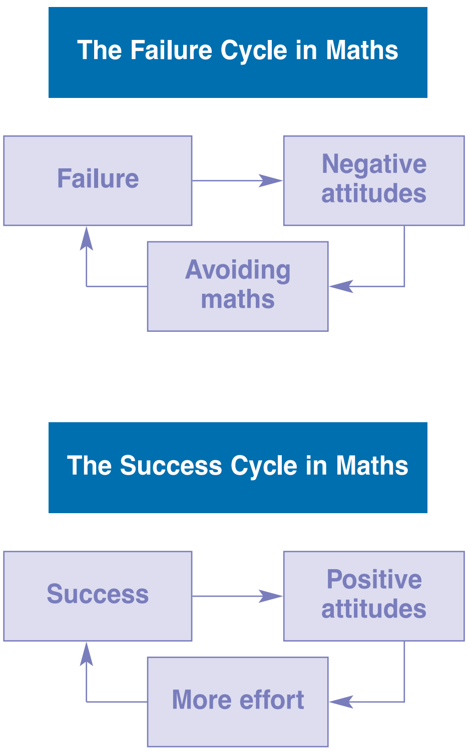

Figure 1: Failure and Success Cycles in Maths

Low achievement or repeated failure in maths often leads to negative attitudes and lowered confidence, resulting in reduced effort or even maths avoidance, leading to further failure. This is a vicious cycle. Engineering students are likely to have strong overarching goals concerning success in studies and may refuse to allow any developing negative attitudes to maths to impede their learning efforts. However in such circumstances their beliefs about maths will tend to be that it is simply a toolkit, a 'necessary evil' required for their overall success. Nevertheless a minority of students caught in such a cycle may be discouraged enough to give up their studies.

Positive achievement and success in maths often lead to enhanced attitudes and raised confidence, resulting in increased effort and persistence, and further success. Many engineering students will have a history of success and achievement in mathematics behind them as this is normally an entry requirement for engineering courses. But there is no simple pattern to the beliefs about maths of engineering students, for in addition to what they bring with them on entry, their learning experiences on their university course will do much to shape their beliefs about mathematics.

Mathematics for engineering students at university has in the past typically been made up of service courses provided by the mathematics faculty. A 1988 survey of 60 engineering departments in the US found that most were happy with the courses provided by maths departments. However, the mathematicians did not seem to have a favourable attitude to the engineers, who in turn opted only to take the minimum number of courses necessary [4]. Many mathematics staff dislike service teaching. Courses often have overloaded syllabuses, are far from mathematicians' research interests and are made up of large lectures with many apparently disinterested students [5]. A key question is "should the way to teach mathematics to engineers be different than for pure maths students?" [6].

Two sets of contrasts can been drawn: 1) between mathematics taught for its own sake or as a service subject, and 2) between maths taught as a separate subject and integrated into other studies [7]. Traditionally mathematics for engineers is taught separately as a service subject. While not all students react in the same way to this experience, a number of studies report that engineers subsequently view maths as a toolkit, the application of which needs to be learned almost 'by heart', and they also have difficulty in using maths in relatively low-level problem solving and non-routine engineering applications [8].

Thus a common belief about mathematics that emerges from such experiences is that it is an isolated set of abstract ideas, with seemingly little relevance to applied problems, and comprises a set of tools whose applications need to be mastered individually for every context or type of problem. In other words, this knowledge seems to lack ease of transfer to new problems and general applicability. This is not healthy for future engineers. Such students also share the perception that it is a 'cut and dried' set of rules and procedures which provide a single or best way to formulate and solve mathematical problems.

However, teaching mathematics separately as a service subject does not have this impact on all engineering students. A minority with a strong grasp of mathematical concepts and principles clearly benefited from this approach and subsequently viewed maths as a powerful and well integrated discipline with broad and general applications. Such students see mathematics as separate from applications, but recognise the multiplicity of possible solutions to engineering problems [9].

There are a number of experimental practices in Denmark, UK and USA, for example, in which mathematics is taught integrated into engineering and other applied studies. It is argued by proponents of such an approach that the development of a feeling for mathematics and mathematical common sense in such applications is much more important than mathematical rigour. These capabilities aid the integration of mathematical knowledge and skills into engineering and lay to rest the commonly expressed doubts about the value of certain mathematical topics studied in isolation [5].

Integrated approaches are typically based on modelling exercises which can be described as simulations and case studies. Although such courses initially cause bewilderment and confusion among traditionally taught students, because of their open-ended tasks and lack of specific directions, by the end of the course most students have superior confidence and some creativity in applying mathematical knowledge [10]. When asked the differences between such approaches lower level students often focussed on two features: the validity and acceptance of multiple solutions methods and the lack of need to remember by heart a single 'correct way'. These students also reported growing confidence in their mathematical skills in a supportive and non-threatening environment in which seeking to find the unique correct way was not the main goal. Mathematics was "a challenge and not a problem" [11].

Thus there is some evidence that an integrated or modelling approach to mathematics for engineering students leads to improved attitudes and more helpful beliefs about mathematics. By improving application skills and fostering teamwork and communication skills (these are often integral to integrated courses) such approaches may address the often heard concerns of employers that graduates have a relative lack of presentational and communication skills, a lack of pragmatism, business and engineering skills and inexperience in some contexts [12].

Such findings and recommendations must be viewed with caution. Clearly engineering students' attitudes and beliefs about mathematics are important. Not only can they sustain them through their studies and have an impact on their willingness to engage in further studies post-graduation to continually upskill themselves during their professional careers. But also they can impact on their ability to successfully apply their knowledge to engineering tasks and problems.

However there is no guaranteed method of course delivery that can guarantee to deliver these outcomes. A well designed and taught service course in mathematics may be more effective than an integrated course of mathematics for engineers if the latter does not reinforce, draw out and make explicit the key concepts and methods in practical engineering applications. Furthermore it is unlikely that all mathematical needs can be addressed this way, for there will always be a need for the mastery of a repertoire of skills and methods. Nevertheless, such integrated modelling based courses appear to be a fruitful avenue for further development and experimentation.

References

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