

ADDRESSING MATHEMATICS AND STATISTICS ANXIETY

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Abstract: Mathematics above all other subjects strikes real fear and anxiety in some students, these students are taken well out of their 'comfort zone' when confronted with mathematical content in their courses. For these students, fear can become a huge barrier to overcome and can become a distraction from their studies in general. In this paper I will give some very personal reflections on this and discuss which students are particularly at risk from maths anxiety and the strategies that one can use to help these students in very practical ways to develop their confidence and skills.

Keywords: Fear, anxiety, barriers, diversity, mature students, practical help

1. Introduction

Being asked to present this paper has given me a tremendous opportunity to reflect on some of my personal experiences over many years of working with students for whom mathematics has been a real struggle and a cause of great anxiety; it is very much for these students that I want to present the following paper.

In this paper, I want to put my personal teaching experiences into a more grounded discussion of the psychological and social aspects of maths anxiety, drawing together some common themes, which I am sure will resonate strongly amongst all teachers/lecturers faced with the student who just becomes paralysed with worry/stress as soon as an equation comes up in a course. I don't think many of the ideas presented in this paper are radically new, but, I hope that I can convey some of the philosophy of my approach to helping this group of students.

I will suggest some very practical ideas that may be helpful in starting to break down some of the barriers to enable students to both use maths practically and even enjoy it! Rather than running away/avoiding maths content at any cost.

Many of the practical ideas presented in this paper have stemmed directly from an HE-STEM funded 'Practice Transfer Adopter' project which I ran at University of Exeter, College of Engineering, Mathematics and Physical Sciences during 2012,(Strawbridge, S., 2012). This project followed on from an initial project run by Stephen Hibberd at the University of Nottingham (Hibberd, S., 2010) which had looked principally at supporting engineering students coming from non-conventional backgrounds. I could see many similarities between my students and those at Nottingham and this was the motivation to develop and push this project at Exeter.

The project centered on understanding and helping remove barriers that students from non-traditional (i.e. non-A level backgrounds) encounter with the mathematical content of their courses. The cohorts I worked with on the project came from our Medical Imaging and Engineering programmes at Exeter.

The support offered to students taking part in this project consisted of long term and regular one-to-one sessions (weekly), with a specially trained and supported postgraduate tutor. These sessions took place in a variety of locations very often over a coffee (i.e. somewhere the student felt comfortable), the pace and style of delivery was very much dictated by the student. I want to share a little about the project and more importantly discuss the on-going legacy/impact arising from it. I hope that readers will find this paper thought provoking and practically useful.

In thinking about what to include in this paper I was very struck by the following observation by Jacquelyn Gill, which not always, but often applies to the students I see:

“Math anxiety doesn’t arise because someone is incapable of understanding math, but because they think they can’t; in other words, the best cure for math anxiety is to be proactive about acquiring math skills” (Gill, 2011)

It is getting past the ‘I can’t’ barrier that is in my view the most difficult aspect to overcome because the reason/s students feel this can be highly complex and also very individual. What is clear, is, it is essential to be very proactive in developing skills quickly, so that students can start to gain the confidence they CAN do it. Thus, avoiding giving students the opportunity to dodge confronting their problems. It is without doubt the case that the longer these problems are left the greater the level of anxiety the student will feel, when finally there is no choice and this often leads to unnecessary failure.

2. First steps

It is very easy when teaching a large cohort to just not see the students who are having problems, until the first assessment, unless you can make sure that they feel that they can come and seek help from the start. Consequently, my focus has been on making maths help accessible in a very friendly, personal way, by providing one to one or very small group learning in non-stressful environments, enabling students to work alongside trained, empathetic postgraduate tutors. To get this approach right, you have to understand something about the extent and nature of the problem you are encountering and as part of that understand the students who you intend to help.

2.1 Identifying the problem

What is the problem?

“In all STEM subjects’ mathematical skills are vital tools, and mathematical fluency to a greater and lesser extent is unavoidable for all students undertaking a science based discipline.” (Ashcraft, 2002)

The students I principally work with are on the Medical Imaging programme at Exeter. Many of the students joining this programme, are very motivated by the healthcare and clinical aspects of the programme, they all want to be radiographers. However, in their course it is essential that they must have an understanding of the scientific (physical) principles that will underpin their future clinical practice. So the “unavoidable” in Ashcroft’s comment is particularly pertinent to my teaching experience. For these students, it is the concern about the mathematical content that can cloud their ability to fully access an understanding the physics I need to teach them. The same was true of the engineering students I worked with on my HE-STEM project, they all wanted to be engineers but, their problems and related stress with maths had the potential to get in the way. This observation is certainly not unusual, in a large study undertaken by McMullan, Jones & Lea (2012) which involved 229 UK nursing students the strong correlation between student failure in tests based around drug dose calculations and anxiety levels was highlighted, being able to perform such calculations is a vital skill, illustrating, ‘unavoidable’ nature of maths in the nursing profession.

Over the years, it has been very apparent to me that although the majority of students cope well with a more traditional delivery and thrive on it (i.e. it works well), there is always a significant minority who do not thrive in this environment. It is not because they are lazy or ‘stupid’, this is a group for whom, maths strikes a sense of dread and fear and this can, if not addressed will stand in the way of them getting the most from their degree. This is why it is so important these issues are addressed quickly.

The reason why large group/lecture style teaching doesn't work for these students is because they quickly become lost, confused and intimidated in such an environment. They have a large degree of uncertainty in what they need to know, how and when to apply the maths they encounter, not seeing where the maths fits in to the larger picture etc... this detracts from their need to understand physical principles. As a consequence the mathematical content of the lecture dominates the student's perception of the entire lecture, at the expense of all other content. It is easy to see from this perspective, how quickly things can slip and how quickly a student can become overwhelmed and disengaged. Not coping leads to avoidance and inevitable failure. It is like a self-fulfilling prophecy unless the cycle can be broken.

Liew & Lench (2014) have investigated this type of avoidance behaviour in individuals and the concomitant impact this has on their performance in standard tests, exploring this from a behavioural perspective, it is a study well worth reading. The key point is: it is really important you can see students not just as recipients of one's teaching, but, as individuals, all having different personality traits, especially when trying to understand and respond to their needs.

So, my problem was, how does one approach teaching and support for this group of students? How do you create the necessary anxiety free space to allow students to develop their confidence, so they are able to fully access the required level mathematics to succeed in their chosen degree?

2.2 Understand your students and student groups

Diversity: Medical Imaging at Exeter, in common with other health related degree courses, has a very diverse student intake, consequently, entry qualifications can vary dramatically. The only requirement for mathematics is to have a minimum of a C at GCSE or the equivalent.

All students coming in from the A level route are required to have at least one science A level, but, there is no requirement for mathematics at A level. A number of school leavers who join us come from the BTEC route, these students, in my experience, generally come into the programme with a lower level of mathematical understanding than those coming from the traditional A level route, even if they haven't taken maths at A level, those with a science A level will have generally encountered maths beyond GCSE level and seen its application to a greater extent than those coming from the BTEC route.

We also have a large intake of mature students (~1/3 of the cohort). Our mature students generally come in *via* Access courses, I have found that these courses can be very variable in quality and coverage, resulting in this group's performance being unpredictable, however, this is the group who consistently display the largest level of anxiety within the cohort with respect to mathematics.

Within the cohort most years, we typically have ~ 1/3 of our students who come in with a good (A/B) at A level in mathematics or higher. Having to teach physics with its concomitant mathematical basis to such a wide ranging cohort is very challenging and, I am sure in the lecture situation those with limited mathematical knowledge do struggle. It is this group of students I will discuss and explain how implementing some much more targeted/personal help really can help, setting them up to succeed in future years.

A great deal of research over many years has made it very evident that the causes of maths anxiety are much more complex than just simply just a lack of knowledge, and that only providing additional resources to cover this lack of knowledge is not enough. A large element of the problem has very much more to do with the psychological state and social expectations of the student. In the past maths anxiety has been treated as in a very stereotyped way (Steele, 1997), I wonder if have things really changed? Parsons & Croft (2009) investigated this

Thinking about what causes these students problems? It is often their own perceptions, the 'maths is hard' or 'you have got to have mathematical mind' mind-set that is a problem. This has to be confronted. This can be largely rectified by enabling students to experience of some success with

maths, I don't feel that level is important at the start, just being able to feel in control and secure in their knowledge and getting things something right for a change!

The myths about maths as a subject will always abound, but what these myths in reality do for the student is effectively psychologically mask an underlying feeling of uncertainty and insecurity. In my view it is these feelings of uncertainty that are guaranteed to induce anxiety. You are not likely to have much self-confidence in these circumstances.

There are several real reasons for these perceptions; firstly, not understanding, this is common to lots of students, but this is often combined with a feeling that they should be able to understand, it can be very demoralising when you just don't seem to be able too. Secondly, by not understanding/getting it, the first time around, students often start to fall behind, this can be the fatal trap, leading to avoidance and a feeling that one does not want to be humiliated by exposing your ignorance as the rest of the class moves on. To overcome this, you need to help the student develop a more positive proactive response, when faced by this type of situation. The old adage of 'eating the elephant' by taking small (certain) steps and building on the sense of achievement as each step is achieved is very helpful and can reduce this helpless feeling and start to alter perceptions. Giving students a sense of security and success is vital. My grandmothers saying that '*nothing succeeds like success*' is really worth keeping in mind.

Poor teaching, often long before getting to university can colour a student's view of mathematics for life. I have very many personal experiences of students who have been avoiding maths for years because of this. Mature students still go back to school days to describe their perceptions of maths. This long term problem has been recognised by many others (Noyes et al., 2011).

This group of students generally see maths as dull, unimaginative and repetitious, requiring a huge memory and effort to remember all those strings of unrelated rules, consequently, they are not engaged from the start, and this combined with often extreme anxiety is at the root of the reason they are not picking up things, despite attending what you perceive as the excellent, coherent lecture you have given to the class!. The solution to this is very much down to you as a teacher. You have to get past these student pre-conceptions when you introduce them to the new ideas, if you don't you will continue the cycle.

I always ground the mathematics I teach in story/narrative terms, before I approach a problem formally (mathematically/numerically). I encourage students to verbalise what they are doing, annotate physics equations etc... This approach allows students to understand what it is they are meant to be doing, this markedly reduces anxiety and helps cultivate understanding in ALL the students in the class. This is especially the case when you are introducing new concepts, such as those encountered in calculus for example. I strongly believe that verbalizing works because it brings the mathematical concepts up to a conscious level, allowing the student to learn about their own thinking and logic, really seeing how they are approaching a problem, that's a very useful skill. Those students who are anxious are very often happy doing this, consequently, this is one of the techniques I encourage tutors to adopt. I realise this is not an entirely unique approach, Nancy Bell and Kimberly Tuley (1997) developed a maths visualisation program (widely used by teachers in the US) aimed mainly at school children, that has been highly successful. Interestingly, as part of another project I ran, I have also used this approach with 2nd year mathematics students getting them to talk me through proofs, demonstrating it works at all levels. For the students who are very maths phobic/anxious taking the formalism of mathematics and putting it in words at first really helps.

There is a complex and very clear link between confidence and achievement in mathematics, the link between the 'in belief you can to do' and ability has been evident in the psychology literature over decades (Fishbein & Azjen, 1975). We all recognise, when we meet with students across all subjects, that self-belief is an essential part of helping the student to do well, very clear correlations between self-confidence and exam performance have been demonstrated over and over again. A study undertaken by Parsons *et al.*, (2009) which used a questionnaire to investigate a range of factors associated with maths performance including confidence which clearly demonstrated this correlation.

“...by ignoring the powerful role that anxiety plays in mathematical situations, we are overlooking an important piece of the equation in terms of understanding how people learn and perform in mathematics” (Maloney, & Beilock, 2012)

Finally, there is one difficult aspect that should not be ignored when thinking about mathematics anxiety, which is the role gender plays. In general society, maths has been consistently stereotyped as a masculine subject (Ashcraft & Ridley, 2005) I had dismissed this gender stereotyping as not being important before I started to teach, I have since changed my view considerably. The use of gender based thinking does occasionally rear up as an excuse made by a few female students as a reason why they can't do maths. This is what I would call the *'little princess syndrome'*, where social perceptions of maths being 'too masculine' for a female to fully grasp and the notion that it is not feminine to be seen as good at it! Is really felt by these students. It is worrying that these are still attitudes that are strongly in play. This theme was picked up by Springer, (1994). In my view, this argument can be used by students as a foil, in order to avoid having to do the required maths, in effect as a mask for their own insecurities. In this case it is very much more a case of social identity rather than cognitive ability being predominant. I make sure that all my teaching promotes maths/physics as genderless. In my experience, I have just as many men as women seeking help. However, it is important to be aware of these undercurrents, because they do impact on anxiety levels and also the willingness to seek appropriate help.

The key point to take away is that the students see themselves as an individuals and their mathematical ability as part of a cohort, is inextricably linked in the minds of some students with their worth as an individual, therefore they see themselves not as having to work on and gain skills in mathematics in order to overcome problems with maths (which is how we as educators often see them), but as a failure as a person because they can't do it, i.e. it is a very personal thing.

Having said all this, I believe it is equally important it make sure that students realise that hard work and determination are needed to succeed and anxiety can be overcome or at least lessened once they start to conquer maths problems. For the lecturer, by framing everything you teach in positive light, and thinking about your students' perceptions rather than your own, you will raise the levels of engagement across the class and provide a safe environment for those who are struggling. In this, you must recognise that there will be, in every large and diverse intake, a few students who this general approach will not be enough.

2.3 Getting the learning environment right

I view learning as a social activity in a university setting, although students often see themselves as isolated individuals, struggling on their by themselves, in reality this rarely the case. Therefore, developing an atmosphere where peer support is the norm, where a “we're all in it together” ethos in encouraged is really beneficial. You need to foster the development of non-judgemental learning groups within the cohort. This must also be combined with access to similarly non-judgemental and sympathetic tutoring if needed. These two planks are the key towards creating a safe environment to develop self-confidence and skills. A relatively recent paper by Taylor & Fraser (2013), investigated the relationship between the learning environment and students' mathematics anxiety, this paper also looked at differences between the sexes in perceptions of learning environment and anxiety. Although this paper focused was more on school classroom environments, many of the same themes I have discussed above were highlighted.

3. Practicalities

3.1 How to encourage students to take up help

The personalised approach if it can be achieved is by far the best way of getting students to engage with support. During the project and subsequently, I have made the conscious decision that targeting students directly, i.e. spotting students who might present with problems and then making additional

maths a compulsory element within a module was not an approach I wanted to take as in my view this can be fraught with problems. Yes, you can target students, but, my objective was to develop engagement and reduce the anxiety, by making attendance for example at additional classes a module requirement it has the potential of inducing and reinforcing even more negative feelings (REF to paper on this). The students identified are likely to feel they have been deemed to be no good at maths! This is not a good starting point.

So what's the solution? You want students to come to you, this requires good communication, students must therefore be told very clearly what's on offer and know they can come to you privately to ask for help. You can do this during lectures, use posters or engage individual students in personal tutorials. If they recognise that help is going to be in a safe and non-judgemental environment and they are not going to be made to feel stupid, they are much more likely to come to you. As I remarked earlier, it is a very personal to that student. So, it is really important that students understand that they are not alone and that they will be in a safe environment, once they do this they will seek and accept help

3.2 Selection and training of postgraduate tutors

To make this work you need to have tutors who can teach, support and develop new learning strategies for individual students. To do this successfully they need two qualities, firstly, empathy, an openness/approachability and secondly and vitally a really deep appreciation and understanding of mathematics, so that they are always on firm ground when they are teaching, (trying to foster understanding in something where your knowledge is shaky is disastrous), It is essential tutors have the knowledge, but also, the enthusiasm for the subject and positive approach at ALL levels to get the best out of the students they work with.

When recruiting postgraduates, the most important thing to look for is someone who is friendly and open, someone who is able to take mathematics back to basics. They have got to be confident and reassuring.

It is important to develop tutors as teachers, not just provide them with a heap of material to cover with students. I wanted them to be able to provide some much more bespoke help. This can only be achieved by giving tutors the freedom to develop their own teaching style, which is dictated by the student, rather than a uniform delivery of the same content and teaching across all students. Tutors need to be able to recognise common problems, for example, lack of calculator skills, where often stopping and giving a calculator driving lesson or two is much more appropriate and often this is all that is needed to get the student making real progress. Recognising that maybe a side step must be taken before the student is able/confident enough to move on is part of good teaching. Also, it is essential to be aware that progress can be slow at first, especially when the student is very anxious, a stressed student will not be helped much if they are feel pressured. Being able to make steps and goals smaller and more realistic is a skill that needs to be developed and supported by good tutor training.

You need to get your tutors to think about where they are going to teach, i.e. somewhere that is not a classroom, the physical environment really matters, it's fine to sit in the coffee shop etc.... Just being in an informal environment often helps the tutor get to the bottom of the problem/s.

I am also very fortunate at Exeter in having some excellent support from our student engagement and skills advisor, who has been able to provide some additional training sessions to help develop the these skills in our postgraduate tutors, using teaching/student scenarios' and opportunities to discuss teaching methodologies and experiences together, tutors gain a much wider appreciation of the problem and develop an empathy for those who really find maths a struggle.

3.3 Working with the University and College

You must have institutional support and interest at senior management level to really embed any project, because after the initial funding is gone your project/s have to be sustainable and that requires resources. With respect to my project and subsequent work, it does look an expensive way to deal with students and the question, *why not put them all together in a classroom and just give them some more maths lessons?* Is sometimes asked, I always point out attrition is far more expensive than providing a relatively small sum, to train and pay a tutor/coach.

I work in a College of Engineering, Mathematics and Physical Sciences, where the need to provide for support to a wider group of students is well recognised and provision support is at all levels is regarded as important, from the very basic to the much more complex concepts encountered in pure maths. I make sure that the needs of students who are highly anxious about maths who need this one to one support are appreciated by senior management. I want to ensure that a personalised tutoring/support system is in place where it is needed. I am currently working with our medical school to develop maths support. None of this would be possible without being able to recruit postgraduates who can take on this role and you need other academics cooperation as these postgraduates have been drawn from all disciplines in the College.

4. Legacy and the future

The project has had a great legacy, I have maintained this model of support because it really works. It has become embedded in how we do things at Exeter, I am currently working with the Medical School, our PGCE programme and university student engagement and skills advisor to get a similar support mechanism underway at our other campus.

The most positive legacy is the effects on the students, seeing students who really struggled and were very anxious and stressed in the first year, develop and end up working at high level by the end of their degree. I put most of this down to gaining the self-confidence they have the knowledge that they can do it!

A number of tutors that have worked on the project are now teachers, at school and university level, they have all found working with students who have real mathematics anxieties a challenge, but also very rewarding and hopefully they will take the ethos with them into their own teaching practice

On a personal level, I have over many years developed an understanding, and real appreciation of just how hard it can be for some students to overcome their real fear of maths. Getting some funding was instrumental in putting some of these ideas into practice and demonstrates the need to make sure funding streams are kept open for this type of project. However, I know I still have a huge amount to learn and I am keen to continue to take part in the pedagogical dialogue around mathematics anxiety.

5. Conclusions

Just recently I have had a mature student in my office, (who when he started was full of self-doubt and anxiety about what was to him new maths) he wanted to show me a book he had just bought, it was Bostock and Chandler's Core Maths for A level, he was full of enthusiasm, he told me he would never have even opened a book like this before starting at university and now he was learning maths because he wants to and it was all down to Darryl his postgraduate tutor, who had shown him he can! That's the reason I spend time encouraging this approach across the university.

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