# Losing Them Young — Puberty, Culture and the Tragedy of Middle School Mathematics

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***Abstract:*** *When advising students in Year 10 on subject choices for Years 11 and 12, and subsequent career pathways into Engineering and Science, school counsellors will refer to results in Mathematics before Science when recommending or endorsing the choice of Physics – still the keystone subject for most Engineering courses – or other Mathematics-rich Science courses. But by Year 10, its game over for many students - before they even realised how important Mathematics was! Mathematics is treated with little special regard in the two crucial post-Primary years. This paper will outline the need for special provisions for Mathematics, both in resources and pedagogy, in the immediate post Primary years, the Middle School, in order to improve the numbers of students in senior school years choosing subjects oriented towards a career in Engineering or Science.*

## Introduction

Any perusal of University Entry Handbooks reveals that Mathematics, Physics and, in fewer cases, Chemistry are prerequisites for tertiary Engineering courses - or at least they are assumed knowledge - and rightly so. If the first year engineering students need to follow a path at secondary school through these subjects, then the subject selection process in schools determines those who may be eligible for Engineering and therefore who will be the raw material for the profession. This paper presents a discussion of some aspects of that process.

## Why Middle School Mathematics?

The usual subject selection process in schools will be to advise students in Year 10 of appropriate subjects to be taken in Year 11, given their broad range of interests, possible career choices and taking into account their academic results thus far. Then, towards the end of Year 11, subjects for Year 12 are chosen, again with reference to the students' interests and academic grades but with additional regard to University entry requirements. For aspirants to University entry into the Sciences and Engineering, Mathematics is often the determinant – particularly for Engineering – but generally it is advised that if a student isn't much good at Mathematics he or she should consider the Arts or a trade. The choice of Physics at Year 11 or 12 – the other "Engineering" subject – is usually recommended only if the students are competent in Mathematics as well.

To backtrack:

- Engineering undergraduates usually require Mathematics and Physics (and/or Chemistry) for admission;
- The choice of Mathematics and Physics at Year 12 depends upon results in Mathematics and Physics in Year 11;
- The choice of Mathematics and Physics in Year 11 depends upon the students' results in Science and more importantly Mathematics in Year 10, as well as some general preferences for their career choices.

So students are making preliminary career choices in Year 10. But in Year 10, the only indication of an inclination to Engineering may be a tentative "I like making things" or "I like seeing how things work". Probably, the student has little idea of the possibilities, let alone career pathways. It is especially the case for students not from "professional" households. This is quite understandable, as school students' experience of the world of work is limited to the experience of their family or family friends and the work they may have undertaken at this age is usually menial and/or some form of retail – supermarkets, video stores or fast food.

The more likely choice at Year 10 will be between "Science" (including Engineering) and everything else! The first question from the counsellor may be "Do you like Science, but the determinant is – "How are you going in Mathematics?"

Even for scientific or technology oriented students, a poor Mathematics performance is usually a fast track towards the non-academic courses, into Vocational Education and Training and an apprenticeship – again all at Year 10!

So Mathematics is the key at Year 10. By then students will have only been studying Mathematics for two and a half years. But that short period of time - Middle School - I contend, determines those who may take Physics and Mathematics for University entry.

If there is concern over the numbers electing to take these subjects in Year 12, and the numbers certainly are declining (SSABSA 2007) , then what happens in Years 8 and 9 in Mathematics – Middle School Mathematics – is worthy of close scrutiny. Since many schools begin streaming Mathematics students in Year 10, in reality it is the Year 9 results that are crucial.

Even if a science-based career is considered, Mathematics is rarely recognised as a necessity in Year 8 and 9. But in those two years the foundations are laid.

**What is in Middle School Mathematics?**

In Year 8 students will probably have their first introduction to: Numbers in a context beyond basic Arithmetic, Algebra, Plane Geometry, Cartesian Geometry, Statistics and Probability. In Year 9, these topics will be extended, with some Euclidian Geometry. It is easy to forget the momentous steps we are asking students to take. Students move from the concrete representation of simple Arithmetic to abstraction, visualisation of perfection and super precision beyond measurement and, worst of all for the pre-adult mind, sequential logic. These topics represent a significant proportion of the extent of human mathematical thought to about 1700 CE, not on a continuum of student learning from Primary School, but as a quantum leap.

**A Cultural Attitude to Mathematics.**

It is no surprise, on this account alone, that "Mathematics" has a particular place in Australian culture. It is in general considered "hard", or "boring", or even "irrelevant" because "my parents have never needed it". It is the common experience of Middle School Mathematics that forms the special attitude towards Mathematics from generation to generation, because it is experienced by virtually all the population, as a compulsory subject, during those Middle Years of schooling. The intergenerational experience of difficulty or failure establishes an ongoing cultural attitude within Australian society, rather than just an immediate reaction to any particular, individual student's immediate lack of success, or failure.

Opportunities for failure in Mathematics abound – with every exercise or problem attempted. It takes only a period of repeated failure or of one element not understood to establish disappointment, defensiveness and finally disengagement. Furthermore, because of the sequential structure of the subject and the interrelatedness of topics, reengagement is unlikely. Remember, we are dealing with children, not adults, in Middle School, but they are being asked to assimilate the thinking of adults. At this juncture, the cultural attitude reinforces the disengagement, which in turn reinforces the cultural attitude in yet another generation.

### Puberty

Over the past decade, evidence has emerged from Neuroscience that the human brain undergoes huge changes through puberty. The three most significant are:

- The network of neural connections is pruned back, creating more efficient pathways;
- The neurons are sheathed with Myelin, which permits faster passage of electrical signals;
- The frontal lobe, responsible for adult thinking, especially logical thinking, judgement and self-control, begins significant development. (This continues to about age 25 in males – very slowly it seems in many cases.) (Blakemore and Frith 2005 p.115)

The implication from the neuroscience is that our Middle School student's brain is really just becoming capable of the kind of thinking we are asking of it, so little wonder the new Mathematical concepts are considered "hard". As puberty is an uneven process in both timing and progression, so the neurological development of each and every student can be expected to be similarly uneven. Thus, difficulties with elements of Mathematics, being based on human development, are an understandable (possibly genetic, possibly environmental) contribution to the generational continuity of latent aversion to mathematics in our culture.

The challenge posed by this uneven development is how to support the slower developers so that they can forge ahead at a later stage. Streaming students in Middle School does not help overcome this developmental inequity, as it advances the early neurological developers while relegating those slower into intellectual puberty to a self-fulfilling decline in expectations ("we're in the bottom Maths – and proud of it"). Furthermore, streaming widens the content gap between the students in the differently graded classes, and within just one school term, transfers upward become more difficult. A study of streaming in Mathematics, in an Australian context, can be found in Zevenberger (2002).

### Puberty Culture

If there is a neurological basis for Middle School Mathematics to be resisted, then other influences can be even stronger. Sexual exploration, the drive for sociability and social acceptance, growing independence from parental control and support (at least as usually perceived) and finally the self-obsessed commercial world of puberty (its music, mobile phones, movies, cyberworld, computer gaming, celebrity and sport) are all issues that demand far more attention and contribute to scholastic atrophy.

### The Tragedy

Despite the heroic efforts of the teachers of Mathematics in the Middle School, the tragedy continues to unfold. It is a tragedy of unrealised potential and restricted aspirations for students and unutilised talent and economic benefit in our society and economy.

Before our students have begun to comprehend the world and their opportunities in it, the die has been cast, by their results in Year 8 and 9, in their Mathematics.

### Does it really matter?

Engineering, to a very large extent, is practised by individuals with adult brains. Why then, if my tragic scenario is true, is entry into Engineering studies determined within our present educational environment by the output of the pubescent brain, at a time when sociological factors of behavioral compliance and family socio-economic status may be the dominant influences, rather than mature intellectual ability and aptitude. "Choose your parents carefully", in other words. Of course there are exceptions.

It is my contention that the teaching of Middle School Mathematics requires adjustment, not with regard to content, but in purpose and pedagogy, to give more students the choice of Engineering and other careers in the Sciences.

## The ladder of logic

Earlier I mentioned sequential logic as essential to an understanding of Mathematics. Sequential logic, precision and persistence, essential attributes of adult thinking, are the brain training elements of Mathematics. "Let no-one ignorant of Geometry enter here" is held by legend to have been carved over the door to Plato's School – not so much for the Geometry as for the discipline of logic required for its mastery. If good adult brains are needed in Engineering, then understanding Mathematics should be the aim of Middle School Mathematics.

In her contribution at the recent "Festival of Ideas" in Adelaide on Thursday 9th July 2009, Rachel Webster, Professor of Astrophysics at University of Melbourne and Chair of the National Committee on Astronomy described a scenario, albeit relating to genius:

"...an individual sees a conundrum, a problem, and they make a leap to the answer and the leap is based in very deep intuition and once they've got there, and they're usually pretty persuasive and pretty strong that it is the right answer, then the ladder of logic is built to that idea – and maybe it takes off....."

Surely it is the construction of that "Ladder of Logic" that characterises Science. In my own experience of the design process in Civil Engineering, any design solution had to be supported by "justification calculations" that satisfied not only the technological requirements of the design but also the legal requirements of duty of care – that too was the "Ladder of Logic".

Any learning in a topic of Mathematics can be divided into two aspects – the mechanics of the solution and the underlying generalised or abstract principles. The first will be referred to as functional Numeracy, as it gets the job done in context; the second is Mathematics. It is the Mathematics that encapsulates the sequential logic. In the mathematics class the processes of logical analysis and sequence, precision and persistence are repeated over and over again with every problem, more than in any other subject. So these ways of thinking are, or at least could be, reinforced in the brain development of the students. That is why the Mathematics, the training in logic, is so important, certainly for Engineering and Science, but also to our society as a whole.

## Literacy and Numeracy (LAN)

But Mathematics is presently being subsumed by the rise of Economic Rationalist based "Numeracy", particularly under the influence of the carrot/stick of the National LAN (Literacy and Numeracy) Testing regime. Commonwealth funding to a school is dependent upon participation. While it is incontestable that the Mathematics taught to Year 10 in Australian schools does provide the tools necessary for competent participation in our society, this functional numeracy is only the minimum to which we should aspire. This is widely recognised:

"In school education, numeracy is a fundamental component of learning, discourse and critique across all areas of the curriculum. It involves the disposition to use, in context, a combination of:

- Underpinning mathematical concepts and skills from across the discipline
- Mathematical thinking and strategies
- General thinking skills; and
- Grounded appreciation of context. (AAMT, 1998, p. 2.)

Of course if Numeracy is to be used across the curriculum, it has to be learnt somewhere first, and this still usually occurs in Mathematics classes.

However, once the LAN testing criteria become significant to a school's income, prestige, enrolments and even survival, functional Numeracy for the sake of the test results (which can be achieved by rote and drill) will become more important than understanding the underlying Mathematics. If functional ability is all that is intended by the promoters of the LAN testing, then this outcome may be acceptable to them. But in the longer view, this approach will have a detrimental effect on students' access to the critical areas of value adding economic activity in Engineering, Science and Technology.

If understanding is to be the path followed both to functional Numeracy and higher Mathematics, some different strategies need to be followed.

**"How do I know what I think until I see what I say." (Forster 1926)**

Firstly, it must be recognised that Mathematics consists of concepts expressed initially in everyday spoken discourse (plain language), then coded into the particular vocabulary of Mathematics and then into a written symbolic code that is the shorthand that we process on the page. This sequence is also the one used when teaching new concepts. Rarely though, is the process reversed and used as a diagnostic tool to verify understanding. If a student can express verbally the concept that is being learnt (in their own words, not as a regurgitation of the teacher's explanation) then we have a window on the neural connections being made during the learning process. When the teacher can appreciate that the student's explanation accords with the concept being taught, then there is evidence of understanding. More importantly, there may be evidence of misunderstanding and so remedial action can be taken then and there, not after disengagement has begun and the topic test has been failed.

This "viva" approach takes time. It has to be done on an individual student basis because the range of misinterpretations of any one concept can be amazingly numerous. But it is a more secure path to understanding for the individuals in a group of variably developed pubescent brains.

**"The mere formulation of a problem is far more often essential than its solution, which may be merely a matter of mathematical or experimental skill." (Einstein 1922)**

Much has been written on the difficulties many students have in deciphering written problems (worded questions) in Mathematics (Zevenbergen 2001). This is usually addressed under Literacy in Mathematics because students often have never learnt to dissect text and group text elements for meaning. Without doubt, the ability to interpret word problems is necessary for functional Numeracy, but it would be made easier and would lead to the next step of Mathematical understanding if the students were able to create the questions for themselves. In creating the question the students have to operate on the elements of a concept and reassemble them in a new form which has meaning - and a "mere" solution. The imaginative leap of creativity is a real test of understanding and establishes the concept as the students' own, not as a teacher-given task requiring only relatively passive response. Problem solving is good, but problem setting and solving better.

Once again, consolidating understanding takes more time. More particularly, it takes more time with each student. The simple time allocation for the twenty eight or so students in each lesson can only be less than two minutes - less when there are whole-of-class issues to attend to. In the time strapped world of the Middle School, an increase in the class time spent on Mathematics in a modular, line-based timetable is unlikely to be possible. However, it is still the time per student per class that needs to be increased, and this could be achieved with a system wide decrease in the size of Mathematics classes. The formulae used generally allocate staff in the ratio of one teacher to twenty five or so students in Middle School Mathematics classes – though they often end up larger for extraneous reasons.

**Intelligent Tutoring Systems**

The incorporation of computer-based teaching and teacher support programs into school Mathematics is perceived to be one solution to too little teacher time being available in the classroom. In at least one case (mathsonline) the program can be used as the basis of a school's Mathematics curriculum. These systems can be useful: additional material conducive to individual or group solutions of simulation or "real life" problems; self paced practice for motivated students; replay lessons for skill modules – at school or at home.

However, they as yet cannot provide the two-way talk that allows the student to formulate the message of the Mathematics in their own words, and therefore thought. With the computer systems it remains as written code and one-way communication. Rewards are restricted to the extrinsic, being based on scores or completion of work tasks. This may be satisfactory for the successful, but teacher/student personal interaction and encouragement provides a better chance of establishing intrinsic rewards for the student and movement towards self motivation.

**Conclusion**

The broadly described world and developmental trials of students in Middle School will be with us into the future. Some actions may help with their attitudes towards Mathematics, the "hard" Sciences, Engineering and Technology.

Firstly, the link between Mathematics and Technology and Science needs to be the focus of information and outreach programs from Industry, Institutions and Universities. Currently many of the outreach programs are of the "Yuk/Wow" entertainment variety which have a place but are superficial with regard to underlying career decision making criteria. This entails addressing the Australian cultural aversion to Mathematics.

Secondly, if the Technology and Mathematics link is school-based for students, then a similar message needs to be promulgated to the rest of the community – especially to parents. Not only do most parents want to help their own children, but re-exposure to at least Middle School Mathematics will, hopefully, help to break down the intergenerational aversion to Mathematics. Structured parent tutoring may be the way forward.

But, finally, it really comes down to professionally educated teacher time with each student in those crucial Middle School years. If we are to finally break intergenerational attitudes, through a generation of students who have an understanding of Mathematics and are not just Numerate, teachers must have the time to do it.

If we can afford to have Physical Education and Home Economics classes of 16 for safety reasons, surely we could stretch to classes of the same size for Middle School Mathematics – for the sake of brain development in our youth, logical thinking and Mathematical understanding in our society, more students taking Mathematics and Physics in Year 12, Science and Engineering at University and a technology rich Economy.

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