A Course in the Fundamentals of Mathematics and their Applications to Sonic and Visual Composition

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Unless people make a real and positive connection to mathematics during their schooling, they are unlikely to ever want to think with it once they have finished their studies. Most of the educators attending this conference deal with students who know that they need mathematics in their studies and perhaps later, in their professional lives. It's a necessary "chore" subject and this necessity provides some motivation (often the fear of failure!) for trying to come to grips with it.

Oh to be so lucky! Many, probably most, of the music and visual art students coming to University today suffer from severe mathophobia. Imagine their surprise, shock, horror and even anger then, when having enrolled in a degree in the creative arts, believing they had put <u>that</u> devil to rest for good, they are faced with the reality of needing to use mathematics in their technical development and even in their creative thinking!

Somewhere along the line they had "lost the thread" and now can't remember anything but the most basic of mathematical principles. Even in their first year, fresh out of the Secondary system, many of them have only dim recollections of the principles of logarithms, let alone how to actually use them. In their daily lives, they don't function even just computationally with anything but the basics of arithmetic and proportion. "Trigonometry and circular functions?" forget it! "Quadratic equations?", erratic whats? "Calculus" brings cries of woe, "imaginary numbers" elicits cowering like an dog too often beaten.

What is common to all these responses is FEAR. And when fear is experienced over a long time, as it is with many of these students, elaborate defence mechanisms are built up and used to protect the self esteem. Most students that I see are afraid of mathematics, afraid to speculate and reach into themselves for mathematical ideas when they are perfectly happy to do this type of speculation, in visual art and music. The distinct impression I have is that the natural interest and curiosity for mathematising has been "weeded out" of them at an early age.

Further difficulties arise because students taking a particular course are in different stages of mastering the basic material and they also tend to be secretive about what they know and what they don't. For instance many students don't correctly add fractions -typically they might argue

$$\frac{a}{b} + \frac{c}{d} = \frac{a+c}{b+d} \quad \text{(This is much simpler than } \frac{ad+cb}{bd}\text{)}$$

Many students feel guilty that they are shaky even on such things as addition of fractions and are therefore slow to admit it, even to themselves! What is even more inhibiting for them is that the addition of fractions is a very boring topic for those in the class who already know 'how to do it'. There is nothing more unsympathetic to acquiring a good understanding than to feel responsible for holding the rest of the class in suspended animation whilst a basic principle which everyone else thinks is easy (and don't mind telling you so, after all they've got nothing else to do whilst the class is so suspended) is "revised".

Now whilst it might be tempting to call into question the general intelligence of these "problem" students, by all other accounts these people <u>are</u> intelligent - even keenly so, and to make the problem of their making is surely to miss the point. All this negative energy is so unproductive! Isn't it better that we stopped "blaming the victim" and set about seriously trying to understand the problems these students have and how they arise, by working through teaching methods which could be tested and evaluated in the student's and teacher's daily lives?

Any student needing Bridging Mathematics represents a failure of earlier mathematics teaching to adequately communicate the ideas involved. Problems arising from a failure of understanding are curable. I know that in general teachers do not lack for dedication, resources, or intelligence: what we lack is direction based on sound practical principles. However, if there is no adequate theory of teaching - generalisations based on tried practices, not pseudo-psychology - , if prospective maths teachers themselves spend most of their time trying to understand the mathematics they're going to teach rather than on learning how to be mathematicians and how to communicate mathematical ideas well, there will continue to be a growing need for Bridging Mathematics teachers.

The Bridging Mathematics community should have as one of its goals to find ways to eliminate itself. This means finding better solutions to teaching mathematics, and then developing teaching theories (ie workable generalisations) of how to teach mathematics better so that they can be shared by all mathematics teachers.

I am not a mathematician, nor is teaching mathematics my profession but I do know that every day there are many students in schools and universities who sit and quietly scream throughout mathematics classes. Although I don't feel sufficiently equipped to offer a grand theory for why the current critical situation is the way it is, I have some hunches and I would like to explore some of them with you and then briefly describe how they have influenced the design of a new subject which we began teaching this year at ACAT[1] called *Design Structures*.

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[1] The Australian Centre for the Arts and Technology (ACAT) was established in late 1989 and provides a

1. Mathematics is taught very heirachically, narrowly, serially - with very many layers, one built upon the last, whereas a broad approach (mathematics is a broad subject area) is surely better. For most students their mathematical sophistication reaches a certain height above which it's conceptual base can support no more growth and so it halts, falters or fails. This suggests to me that, especially in the early years, mathematics should be taught very broadly and with less of an emphasis on compute-ability and more of an emphasis on acquiring an understanding of general principles and the interconnectedness of ideas. This would allow quicker students to work through the same material in greater depth, with more computation and excursions into related topics. As a result of this heirachical approach generalised and relatively easily understood topics, like topology for instance, are ignored until they can be dealt with algebraically - which for most students is never!

2. Students commonly lose touch with the intuitive and "real-world" nature of mathematics. Most teachers are trained at universities with few if any research mathematicians and most research mathematicians are not involved in teacher training. Young children frequently come up with ingenious ways to solve mathematical questions, but teachers who are often uncomfortable with anything off the beaten tract, will discourage non-conventional approaches. (After all we need to be constantly reminding ourselves that it is not always easy to understand what a child is thinking or trying to say.) So, by the time a student reaches university they are inhibited from thinking for themselves and from admitting out loud what they are thinking. Instead they try and figure out what routines they are supposed to learn for the all to frequent and all to important TEST.

3. There is too much emphasis on being quick, on finding the answer rather than understanding the concept, at the expense of being thoughtful. This approach emphasizes questions with some hidden trick rather than problems where a systematic and persistent approach is best. Whilst speed is helpful it is only one quality and is probably not very important. Speed is too easily used as a form of intimidation: it emphasizes precociousness and group competitiveness rather than experiencing, thinking and then understanding.

4. It is hard to get a sense of the breadth and depth of mathematical thinking possible from an ordinary experience of mathematics in school. It seems to me that most of the top group of students, those who master the subject matter, are those who find some other channel for learning mathematics outside the classroom. (puzzles, chess, go, electronics, chemistry, music etc in the home, from books, from an unusual teacher etc.) We should thus concentrate on improving the general quality of mathematical exploration within the classroom and to teach with it in an undiluted way that begins from a student's real life experiences. This begins by encouraging students to reflect on their experiences rather than the all-to-often "put-down" or "morality message".

In *Design Structures*, a broad range of mathematical topics is covered in a relatively short space of time. (All the major topic areas in less than 100 hours in a single year.) We are attempting to contexturalise mathematical thinking in the arts both as a way of encouraging reasoning with aesthetic principles and as practical tools for making art (in our case, with computers).

The course is very new and we are experimenting with ways of understanding mathematical ideas and of understanding different students perceptual strengths and weaknesses. Sometimes this involves understanding when to use different representational types: symbols, maps, models when appropriate. We have found that there is a danger in abstracting algebraically too early because the student can learn a set of rules and manipulate the rules to form "well-formed" reasoning without obtaining an intuitive grasp of the underlying principles.

We emphasise mathematics as the historical and cultural activity that it is, rather than as an "objective" context-free-grammar. The utilitarian uses of mathematics are important, but fundamentally, when it come to understanding of mathematical concepts, they are secondary. Mathematics is surely the first and most all-pervasive interdisciplinary subject. It has a beauty and a power and a conceptioning found if few other domains of human endevour. For mathematicians, it is a play, a dance which sharpens the perceptions and in doing so produces patterns everywhere around.

In the course of their studies, few students have much experience of doing mathematics, most don't "graduate" from computation. We live in an age where machines can do this computation much more quickly and reliable than humans. Someone calculated that the first macintosh computer (1984)

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unique environment for artistic use of computers. Activity at the Centre includes the creating, study, research, and publishing of music and dynamic visual art which is specifically made with new technology. It is a national focus for the education of multi-disciplinary artists interested in using new technologies as expressive tools. The author is the founding head of the Centre.

could do all the calculations the Newton had done in his lifetime in 11 seconds - and much more accurately! Why then do we continue to teach mathematics as if it is primarily an exercise in computation?

It is my experience that what we might call the "aesthetic approach" to teaching mathematical principles, draws students to mathematics of a certain depth, complexity and generality, that would not be possible if the approach was computational, and it is this depth and beauty of patterning which makes the mathematics manifest - sometimes in unexpected ways - in other human endevours such as the sciences and the arts.

Even though our *Design Structures* course is still very new we are already seeing (and hearing!) the positive effects. It would be remiss of me if I were not to mention another important ingredient in our approach: we are passionately and overtly enthusiastic about our subject matter. This makes it very difficult for a student to remain neutral, to "switch off", but draws them into the experience of mathematising, to manipulating ideas mathematically before they realise that that they can't.

I conclude that when mathematics is taught more as an art than what we today so often narrowly and monothesistically define as science, it provides not only a more accurate image of what doing mathematics is, but is more useful to the student in the long-run in all their endevours. The challenge for all of us is to find a way to reawaken the enthusiasm (dare I say passion?) for "doing" mathematics ourselves. This enthusiasm is infectious, it creates the "why?" and will result in our students wanting to find the "how", wanting to <u>do</u> mathematics.