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MATHEMATICS CLASSROOMS - WHY ARE SOME FIREWORKS AND OTHERS JUST SPARKLERS?

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The name of this paper and the presentation which accompanies it is “Mathematics classrooms – why are some fireworks and others just sparklers? Why is it that some classrooms are vibrant places of lively debate, reasoning and mathematical inquiry and others are places of anxiety and disengagement? The following article will address research that underpins some of the affective elements that need to be considered in order to tackle the content of mathematics in a way that makes students feel engaged in the mathematics learning process.

Introduction

Can I ask you to please recall a time when you really loved something -- a movie, an album, a song or a book -- and you recommended it wholeheartedly to someone you also really liked, and you anticipated that reaction, you waited for it, and it came back, and the person hated it? So, by way of introduction, that is the exact same state in which I spent every working day of the last six years. I teach high school math. I sell a product to a market that doesn't want it, but is forced by law to buy it. I mean, it's just a losing proposition. Meyer, D. (2010) <https://www.youtube.com/watch?v=qocAoN4jNwc>

Above, is an extract from a “TED Talks” clip by an American mathematics educator, Dan Meyer, Dan is expressing a feeling and often a frustration, that is well-known to many people who teach mathematics. That feeling, that much of the general population does not seem to see the importance, or the relevance, let alone the elegance, of mathematics.

I would like to start by making a statement and then posing a question. The STEM (Science, Technology, Engineering and Mathematics) subjects are vital to Australia and the world. In 2013 The Chief Scientist highlighted the five most significant societal challenges as being: living in a changing environment; promoting population health and wellbeing; managing our food and water assets; securing Australia's place in a changing world; and lifting productivity and economic growth. He stated that the way to address these challenges was through high quality STEM enterprises which called for building the quality of the disciplines that are the foundation of STEM. I actually do not know of anyone who disagrees with STEM being a priority, not even those journalists renowned for opposing anything and everything, can find the will, to be dissenting voices. So why is it then that STEM subjects, and in particular Mathematics, has trouble in attracting participation?

This paper will look at just some of the myriad factors which may lead to engagement or disengagement in mathematics from our students, focusing particularly on some elements of the affective domain; the domain, which it can be argued, is the domain where teachers have the greatest opportunity to make choices.

Beliefs and Attitudes, Part of the Affective Domain

If you have been around students it is not hard to argue that the affective domain, someone's beliefs and attitudes, plays a vital role in the learning of mathematics. Research is rich in studies showing that

the affective domain has a great deal of impact on teaching practices and student learning (Attard, Ingram, Forgasz, Leder & Grootenboer, 2016). It tells us that teachers who entertain positive attitudes and beliefs about the teaching of mathematics tend to: embrace innovations (Gresham, 2008); use a variety of instructional strategies (Swackhamer, Koellner, Basile & Kimbrough, 2009); be highly motivated (Bandura, 1993); encounter less stress (Tschannen-Moran, Woolfolk-Hoy & Hoy, 1998) and; have higher expectations and goals for their students (Zambo & Zambo, 2008).

If teachers with positive attitudes and beliefs are, as the research indicates, more likely, to be highly motivated, take on a variety of instructional strategies and embrace innovations; there should be a flow-on effect to the students. It does not seem unreasonable to think that these positive attitudes and beliefs will be transmitted to the students and in turn make them feel more positively disposed towards mathematics. This assumption is supported by research such as that completed by Calder and Campbell (2015) who found that reluctant students could be encouraged to become involved in mathematics through the use of engaging pedagogy. This then opens the question about what pedagogies might engage students, something which has been the topic of much research (Marshman & Brown, 2014) and much teacher debate. I will pursue this later in this paper.

Beliefs

According to Tschannen-Moran and Woolfolk-Hoy (2007) there has been an accumulation of compelling evidence to support the link between teachers' beliefs about their ability to enhance student motivation, and student achievement. Beliefs are usually defined as being understandings, premises or propositions that are held true (Goldin, Rosken, & Torner, 2009), and beliefs, unlike knowledge, maybe held with various degrees of conviction (Philipp, 2007). Although much has been written about the inconsistency between teachers' beliefs and teacher practice (Beswick, 2006), teacher beliefs should not be discounted as being unauthentic but rather as representations of intended practice (Liljadhur, 2009). What this means is that a person might espouse a firm belief without necessarily enacting it, but this in no way negates or dilutes the perceived 'truth' of that belief. For instance, I can firmly believe that an inquiry-based mathematics class is highly beneficial to students but might not feel comfortable, for a whole host of reasons, about presently running my class this way.

Beliefs and action develop together and influence each other, and so can be logically argued to be related (Grootenboer, 2008). Furinghetti and Moselli (2009) wrote that "...beliefs are behind reasons for teachers' decisions and in this role, relies the importance of beliefs in relation to practice" (p. 61). Raymond (1997) proposed a model (Figure 1) to represent the relationship between teachers' mathematical beliefs and their teaching practice.

It can be seen through this model that the relationship is quite complex and I would suggest that this model only hints at the relationship's gestalt. It is clear that beliefs are complex and are subject to many mitigating and strengthening influences, for instance the many ways that the dynamic of the immediate classroom situation can influence the decisions that are made. Any experienced teacher will tell you that no two classes of students are the same, and what works brilliantly well with one group can prove an abject failure with another. For example, using manipulative materials with one cohort may promote deep, positive, reflective learning, whilst with another it provides the opportunity to play without purpose.

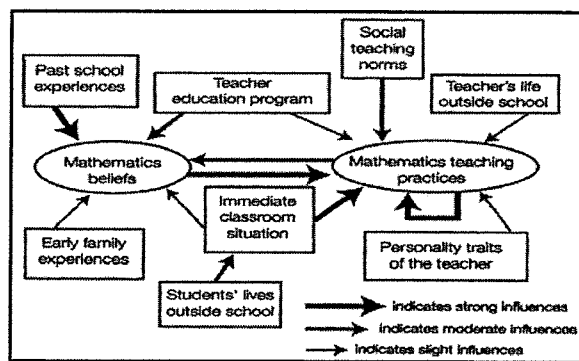


Figure 1. Raymond's (1997) revised model of the relationships between mathematical beliefs and practice

The model also illustrates the influences on teachers of their past school experiences and the teacher education programs with which they were involved. For instance, Goulding et al. (2002) wrote that beliefs are inextricably tied to subject matter knowledge as they determine how a teacher may approach mathematics teaching. For instance, if due to their own school and teacher training experiences, a teacher has a strong belief in the rote learning of routines, then this will probably have an impact on their teaching. This impact on teaching will then have a direct influence on students' beliefs. That is, the student are likely to develop a sympathetically strong view that rote learning of routines is important and therefore, this becomes their paradigm as to what mathematics is and what you require to be a mathematician.

If a teacher decides to adopt new beliefs about the teaching of mathematics they need to be offered credible, well-researched pedagogical practices that are powerful and effective. Practices which enable them to blend or shed previously held beliefs and that further enhance their students' capacity to engage in productive classroom mathematical practice.

Attitudes

Attitude is an ambiguous concept (Hannula, 2002) and there is a diversity of definitions and constructs regarding attitudes. These constructs are often seen to conceptualise attitudes as having emotional elements that places them nearer the affective than the cognitive end of the spectrum; as having an impact on intention and hence behaviour (Ajzen & Fishbein, 1980); and as being dependent upon experience (McLeod, 1992) and beliefs (Ajzen & Fishbein, 1980). Cognition and emotion are seen as being two complementary aspects of mind and the interaction between the two is so entwined and intense that neither can be separated from each other (Hannula, 2002). That is, we ignore the affective at the peril of the cognitive. In search of the definition of the mathematics attitudes, Di Martino and Zan (2010) proposed a three dimensional model for attitude (Figure 2) that shows interconnections between emotional dispositions towards mathematics, vision of mathematics and perceived competence in mathematics.

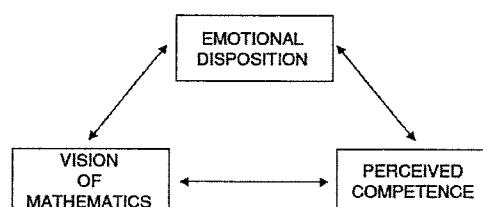


Figure 2. The TMA model for attitude (Di Martino and Zan, 2010)

Di Martino and Zan (2010) described mathematical activity as the interaction between cognitive and emotional aspects, and recognised that teachers are aware that mathematics is a subject which triggers

strong negative emotions amongst students, which can eventually lead to disengagement and block thinking processes.

Attitudes are learned and they predispose a person to some degree of consistency and can be judged to be either positive or negative (Hannula, 2002). They are linked to beliefs, as each person has a corresponding attitude to each belief. This attitude shows itself in the performance of a behaviour or task and the manner in which it was performed. The positive relationship which exists between attitudes and achievement is widely documented (Wilkins, 2008). It is no secret to teachers that a student's positive attitude can go a long way to increasing their level of performance.

The Effect of Teachers' Beliefs and Attitudes

There have been a number of studies completed on teacher confidence and attitude (Bobis & Cusworth, 1994) which paint a fairly unsettling picture. Research indicates that many school teachers, particularly primary school teachers, are fearful, anxious, pessimistic and resentful of the subject of mathematics and hold beliefs and attitudes about mathematics which can be narrow and debilitating (Szydlik, Szydlik & Benson, 2003). These beliefs have been found to be firm, tenacious and resistant to change (Swaris, Hart, Smith, Smith & Tolar, 2007). Goldin et al. (2009) asserted that beliefs are unlikely to be replaced unless they are challenged and proven to be unsatisfactory. These tenacious and unchallenged beliefs often prevent teachers from teaching mathematics in ways that empower students (Schuck & Grootenboer, 2004) and can affect the level of cognitive complexity in instruction (Charalambous, 2010). Aguirre (2009) argued that the beliefs that teachers hold, ultimately make the difference between failure and success in classroom reform. If, as Ajzen and Fishbein (1980) report, beliefs and attitudes influence behaviour, and as Wilkins (2008) asserted, knowledge, beliefs and attitudes all influence instructional practice, then negative attitudes and beliefs about mathematics will probably manifest in actions contrary to increased mathematical learning taking place. This could be demonstrated through decreased instruction time, over-reliance upon text books, lack of subject content knowledge, an inability to provide conceptual explanations, a reluctance to adopt alternative pedagogies or to allow for a spirit of inquiry and argumentation to take place.

If we want to challenge the unproductive and debilitating attitudes that teachers might have, then we need to better inform them of alternative visions of mathematics (Di Martino & Zan, 2010). It is pointless to deconstruct someone's set of negative attitudes without providing them with demonstrations of practices which allows them to replace the negative attitudes with a more positive disposition towards effective teaching and learning.

Beliefs and Attitudes About Gender

There is a long history of writing concerning gender inequity issues in mathematics (e.g. Fennema & Sherman, 1977) which in recent times has morphed into concerns regarding the lack of female participation in STEM subjects (Office of the Chief Scientist, 2013) and further commentary on the poor participation rate of females in Year 12 mathematics subjects across Australia (Barrington & Evans, 2014). The sad fact of the matter is that females are underrepresented and their lack of participation is injurious to the welfare of society. This is despite the evidence that psychological research suggests there are no gender differences in children's cognitive abilities and therefore no difference, on average, in the potential for females and males to achieve in mathematics (Spelke, 2005). Despite these findings, gender-stereotyped views are still prevalent (Forgasz, Leder, & Tan, 2013).

We have to ask ourselves, why it is that females are less likely to be attracted to mathematics than males. Is part of the reason that mathematics is associated as being a masculine pursuit (Mendick, 2006)? Who are the role models that females can aspire to emulate? It is true that across both genders not many students (or teachers for that matter) would be able to recognise a picture of Andrew Wiles or Terrence Tao, but it is far sadder that many people are absolutely unaware of the contribution to mathematics and therefore the world that women have made (for example; Hypatia of Alexandria, Maria Gaetana Agnesi, Marie-Sophie Germain, Amalie Emmy Noether (considered by Einstein to be most important woman in the history of mathematics), the 2014 Field's Medal winner Maryam Mirzakhani, Australia's own Cheryl Praeger).

Just consider, there are significantly less females (25%) engaged in Year 12 intermediate of advanced mathematics than males (34%), and yet 70% of all teachers in Australia are female (Figure 3 is as high as 81% across primary schools) (ACER, 2016). Therefore, in a profession that employs predominantly females, we are drawing from a pool of mathematics students which is under-represented. If we want our teachers, both primary and secondary, to be the best possible candidates then this is not a situation that should be allowed to continue.

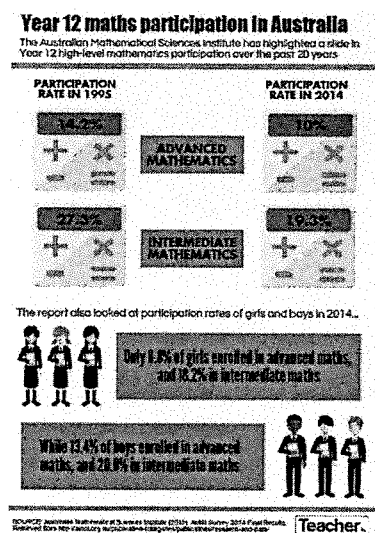


Figure 3. Infographic: Declining maths participation (ACER, 2016)

Pedagogy and Engagement

If we are trying to engage students in mathematics learning, then we must take specific actions to do so. As much emphasis needs to be placed on the social aspects of the classroom, the mathematical interactions between the students, as on the mathematics itself (Leach, Hunter & Hunter, 2014). There is a need to encourage the communicative processes for mathematics students through judicious modelling and scaffolding of argumentation; processes such as explaining, justifying, and responses to challenges (Marshman & Brown, 2014).

Research conducted in Australia has shown that mathematics teachers are dependent on a variety of commercially produced materials, particularly the student workbook (Watt, 2004). International research by Johansson (2006) suggested that up to 90% of mathematics lessons employ a textbook to form content, sequencing and instructional activities and ideas for lessons. Other international studies have shown that textbooks influence what teachers teach by delineating what topics are covered and how these topics are presented (Stein, Remillard, & Smith, 2007), how they teach mathematics, and what homework or activities they assign to their students (Alajmi, 2009). The research by Jamieson-Proctor and Byrne (2008) further confirmed that contemporary schooling has a heavy dependence on textbooks in spite of the fact that there is a lack of conclusive evidence to support the efficacy of them (Shield & Dole, 2013). Such unquestioned reliance on textbooks could be quite problematic as it could lead to what Haberman (2010) calls the “pedagogy of poverty” (p. 45) where teachers are overly didactic, dole out information and assign problems. It should however be noted that Hill, Ball and Schilling (2008) offered a countervailing argument to the objection to using text books:

Teachers are flooded with messages *not* to use their textbooks, starting with scholarly work (Ben-Perez, 1990) and continuing on to the materials thrust upon them in professional development and ending with district curriculum documents that piece together units from disparate resources. This may have been appropriate in an era when most textbooks were similar in their mathematical drabness; however, the quality of available materials has sharply improved, yet this ethos persists. And we argue that solid mathematical tasks and representations that come from a drab textbook are preferable to teacher-created math lessons in the hands of teachers with little mathematical knowledge

for teaching. Without the ballast of mathematical knowledge, teachers' implementation of supplementary materials is chancy at best. (Ball & Schilling, 2008, p. 499)

However much Hill, Ball and Schilling's (2008) statement may seem to be at odds with prevailing opinion and research, it is a position which would resonate with many teachers. Surely then it is not necessarily a question of *if* we use a textbook, but rather *how* we use a textbook? Do we use the textbook as a default curriculum or is it just one tool of many to provide a rich and varied teaching and learning environment? This is a question each of us must answer, both as individuals, and as part of a teaching community.

A Concluding Comment

Few teachers would truly believe that the study of mathematics is a purely cerebral one. In fact throughout the ages deep-thinkers both within the field of mathematics and outside of it have rhapsodised over the affective elements of this subject. If our classrooms are going to be places that are about fireworks rather than just sparklers then we as teachers need to understand that a mathematics lesson is more than just the important content that is being presented. The mathematics classroom is a place where participants, both students and teachers bring their whole being, it is a place where their attitudes, beliefs and understandings are exposed and tested. It is a place where current paradigms of what constitutes a mathematics classroom and mathematics learning, needs to be examined. It may be that in the classroom we can feel restrained by the syllabus we are required to work within, but in the space of being able to set the agenda regarding affect, we seem to have more affordances than constraints. Once we analyse our capacity to influence affect, then perhaps students will be better disposed to engage with mathematics. The difference between engagement and disengagement may be as simple (or as complex) as the teacher understanding that, "If you always do what you've always done, you'll always get what you've always got" - Henry Ford.

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