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Mathematics in the Middle: Challenging Horizons

Abstract: A core factor in the challenge Australia faces in sustaining a workforce rich with advanced mathematical competency is the perceived lack of intellectual engagement in the middle school mathematics classroom. It could be argued that the middle school years are the cornerstone in the provision of the essential skills of mathematics that empower students to pursue *higher-level mathematics courses. In this paper I discuss the research literature into the first phase of middle schooling within Australia urging us to move toward returning academic rigour to the middle years. To this end, I plan to do a case study to investigate the micro perspective of the middle school mathematics classroom context, with a focus on: the teachers' pedagogical content knowledge; and the students' intellectual engagement. The notion of how teachers and students can be empowered to engage in the constructive processes relevant to broadening their mathematical horizons furnishes the backdrop of this study.*

Introduction

This paper arises in response to the anxiousness being felt within Australia about the provision of the next generation of students with the mathematical competency to successfully progress into mathematics, science, technology or engineering professions (McPhan, Morony, Pegg, Cooksey, Lynch, 2008). The literature identifies the middle years as being critical to providing the core skills required to empower students to pursue their mathematics education at senior and university levels (Carrington, 2002; Prosser, 2006). However, there is a concern about the level of academic rigour in the middle school mathematics classroom, and the resulting impact on students' numerate abilities and mathematical confidence to broaden their mathematical horizons.

The introduction of the national numeracy assessment in 2008 has created an additional accountability requirement for teachers in the middle school mathematics classroom. This, together with Education Queensland's *Numeracy: Lifelong Confidence with Mathematics- Framework for Action 2007-2010* places what teachers do in the classroom as a priority. More than ever, teachers need to become critically aware of how they can implement learning opportunities that are synchronous with the 'Essential Learnings' of the mathematics syllabus and contemporary views on how students learn mathematics. It is becoming more widely accepted that student outcomes in mathematics depend upon the quality of the interactions available in the mathematics classroom. These interactions are steered by the classroom teacher, and the integration of subject matter knowledge, knowledge of students and pedagogical techniques are seen to be pivotal in creating powerful interactions within the middle school classroom. Shulman's (1986) conception of Pedagogical Content Knowledge (PCK) appears to be a credible resource in contemplating the reinvigoration of teaching mathematics in the middle school. It is important to note, however, that for the idea of PCK to be powerful and meaningful in the middle school mathematics context, consideration may first need to be given to how all teachers can become empowered with the impetus to engage effectively in the change process.

In the document *Numeracy: Lifelong Confidence with Mathematics-Framework for Action 2007-2010*, Education Queensland identifies 'teacher knowledge and pedagogy' and 'numeracy leadership as two of the four key priorities, fundamental to improving students' outcomes in mathematics and enhancing numerical confidence. Questions arise though as to how numeracy leadership can be manifested through a synthesis of the micro and macro perspectives of the teachers' role. For example, a macro perspective raises the important issue of how teachers can be empowered to be efficacious change agents to inform curriculum planning. From this, the question may emerge of how the teachers' input into curriculum planning becomes meaningful in terms of the students' numerate abilities. The micro perspective advances the question of how teachers can develop a profound understanding and insight into how students learn mathematics and how this can inform their practice.

As a classroom teacher, with experience in middle and senior years' mathematics education, I have concerns about the availability of high powered intellectual engagement for students in the middle school mathematics classroom. In particular, I wonder how we might rise beyond the rhetoric presented by policy makers about numeracy leadership and student confidence in mathematics so that all teachers are motivated to respond to the urgency within Australia: an urgency to give students the best opportunity to develop a level of mathematical literacy that enables them to participate successfully in their chosen societal context and broaden their mathematical horizon. As a teacher-researcher, I anticipate investigating the opportunities currently available for students and teachers to proactively engage in enriching their intellectual and practical, mathematical knowledge in the middle school context.

Academic Rigour in Middle School Revitalisation

The middle school years have featured on the reform agenda within Australian schools for more than a decade. A focus on middle school education was prompted by the recognition of two key problems: the transition from a student-centred, integrated approach in primary school to a subject-centred, segregated approach in secondary school; and a lack of recognition given to the educational implications of the distinct nature of the young adolescent (Carrington, 2002).

As we move into the second phase of middle school reform the research literature urges us to progress beyond congregating around the pastoral care of adolescent students and organisational structure (Carrington, 2002; Luke, Elkins, Weir, Land, Carrington, Sole, Pendergast, Kapitzke, VanKraagenoord, Moni, McIntosh, Mayer, Bahr, Hunter, Chadbourne, Bean, Alverman, & Stevens, 2003). Indeed, middle schools are urged to address what has been overlooked: supporting the transition between primary and secondary school in an "academic sense" (Perso, 2004, p. 29). This premise underlies Yecke's (2005) report 'Mayhem in the Middle' concerning middle schooling in the United States. This report pertinently summarises the view that:

> Too many educators see middle schools as an environment where little is expected of students either academically or behaviorally, on the assumption that self-discipline and high academic expectations must be placed on hold until the storms of early adolescence have passed. The sad reality is that by the time those storms have dissipated, many students are too far behind to pick up the pace and meet current state academic requirements, much less the challenging expectations of federal laws such as No Child Left Behind.
> (Yecke, 2005, p. 17)

In assessment of the first phase of middle schooling within Australia, Luke et al. (2003, p. 12), suggest that the "second generation of middle schooling…must respond to [the] criticisms of the first generation of middle schooling by fostering academic and intellectual rigour". Furthermore, Carrington (2002) urges us to use the wealth of knowledge gleaned from the first phase of middle schooling to fade the line of distinction between school curriculum and the omnipresent, persuasive multiplicity of youth culture. This idea is summarised by Knobel and Lanksherar (2003, p. 80, cited in Prosser, 2006, p. 9):

> Pedagogy and curriculum cannot be 'hostaged' to every change in cultural tools and uses that appear on the horizon. At the same time, if certain limits to learners' affinities, allegiances, identities and prior experience are transgressed, even 'successful' learners will decline the offer made by formal education.

The climate of fragmented educational reform within Australian middle schools has left schools struggling to meet educational aims. This is evidenced by research showing that "traditionally strong students are at best only being maintained" (Prosser, 2006, p. 9). The latest literature recognises that the middle school agenda needs school-based revitalisation. Specifically, there is an urgent need for "higher order intellectual engagement in literacy and numeracy by members of target groups in order for all to access employment and to pursue improved life pathways through school to post-compulsory study, work and community life" (Luke et al., 2003, p. 7). Certainly, the challenge is to move beyond the "anti-academic mindset" (Yecke, 2005, p. 7) driving the middle school into a focus on empowering and supporting students to acquire fundamental skills and knowledge in mathematics through effective, subject driven pedagogy.

Optimising the Potential of Pedagogy

In response to research evidence (Hayes, Mills, Christie & Lingard, 2006b; Luke et al., 2003), there is a strong shift in the middle school movement to the examination of pedagogy. The 'Productive Pedagogies' project (Hayes et al., 2006b) comprehensively researched the pedagogical techniques of Australian middle school teachers and revealed inconsistencies in pedagogical techniques within schools and across the country. Concerns were also expressed about student involvement, confidence and achievement. The challenge for all educators is to develop intellectually engaging pedagogy and aligning it with a curriculum relevant to student needs (Carrington, 2002; Prosser, 2006).

First, surely effective pedagogy is contingent on the subject expertise of the teacher. The literature undeniably supports Stodolsky's (1998, cited in Chadbourne, 2001, p. 17) opinion that

> the more subject expertise teachers have, the more they can: devise challenging and engaging learning tasks for students…; provide clear and powerful explanations of complex concepts...; and teach for understanding and higher order thinking within their subject.

The Australian Teacher Education Association (Jasman & Martinez, 2002) emphatically advocates the need for teachers to teach within their area of expertise. Jasman and Martinez (2002) discuss research suggesting that teaching outside of their subject areas places excess stress on teachers and limits quality teaching and learning opportunities for their students, especially for "students who are currently disadvantaged by schooling" (p. 9). However, the realities of the Australian middle school have contributed to a deficit in the availability of teachers with robust subject matter expertise (Chadbourne, 2001; Prosser, 2006). For example, some teachers with subject expertise avoid being trapped into teaching teams within the middle school, since organisational structures may prevent them from also teaching in the upper secondary school (Chadbourne, 2001). Jasman and Martinez (2002), suggest that, given the shortage of expert subject teachers, teachers need to be retrained, at the cost of their employer, to improve their competency within specific curriculum areas if they are to teach in the middle school. In the report 'Maths, Why Not?' McPhan, et al. (2008), investigated the question 'Why is it that capable students are not choosing to take higher-level mathematics in the senior years of schooling?' Their findings reveal that: quality mathematical experiences in the middle school underpin the strategic decisions students make about further study in mathematics; and teachers are central to empowering students with quality mathematical experiences. In fact, McPhan et al. (2008), suggest that "school systems need to foster a culture of sustainable professional development within schools that enables mathematics teachers" to: implement pedagogical techniques that converge on students; and focus on "conceptual understanding at all levels and at key stages in learning" (McPhan et al., 2008, p. 118). In order to ensure "quality and equity of education for all Australian children, particularly in subjects such as Science, Mathematics and ICT, which provide high-stake capital in the knowledge economy and current job market" (Jasman & Martinez, 2002, p. 9) middle schools need teachers with subject specific expertise.

The literature suggests that the enduring divide between the teachers’ subject matter and pedagogical knowledge needs to converge if we are to going to move beyond the fragmented approach to practice; so that we can induce the desired high powered intellectual engagement of students in the middle school mathematics classroom (Ball, 2000). What is more, integrating subject matter knowledge and pedagogy may well be the vinculum to teachers constructing the academically rigorous mathematical tasks that empower and engage students to construct their own knowledge. An overarching consensus that has been emerging within the literature is the importance of teachers mobilising the proficiencies of their subject matter knowledge and couching it within the context of the mathematics classroom (Ball, 2000). At this point, it is important to acknowledge a somewhat paradoxical notion that teachers with advanced coursework degrees in mathematics are not inevitably efficacious in the classroom. The research, by Ball (2000) and Wilson and Floden (2003, cited in Ingvarson et al., 2004, p. 19) suggest that a higher level of exposure with traditional teaching techniques in mathematics “may actually imbue teachers with pedagogical images and practices that hinder their teaching”, so much so that they are unable to “unpack mathematical content for students”. Consequently, we need to take heed of the recurring trend within the literature urging teachers to understand mathematics from diverse pedagogical perspectives. These diverse pedagogical perspectives are encapsulated in Shulman’s (1986) conception of Pedagogical Content Knowledge (PCK). Shulman (1987) proposed that:

the key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students.
(p. 15, cited in Veal, 1999, p. 3)

Recent research literature endorses Shulman's (1986) notion of PCK and some suggest that it is the "single factor which seems to have the greatest power to carry forward our understanding of the teacher's role" (Elbaz, 1983, p. 45, cited in An, Kulm & Wu, 2004, p. 146). This idea is supported by Bromme (1994, p. 75 cited in Ticha & Hospesova, 2006, p. 131) who stated: "the fusing of knowledge coming from different origins is the particular feature of the professional knowledge of teachers as compared with the codified knowledge of the disciplines in which they have been educated". Furthermore, "within a given context, teachers' knowledge of content interacts with the knowledge of pedagogy and students' cognition and combines with beliefs to create a unique set of knowledge that drives classroom behaviour" (Fennema & Franke, 1992, p. 162). Ball, Thames and Phelps (2007) created a practical set of domains of "content knowledge for teaching" (p. 42) mathematics, embedding within it Shulman's (1986) initial categories of subject matter knowledge and pedagogical content knowledge. The domains elaborated upon Shulman's (1986) work and concentrated on the act of teaching more so than the PCK dimensions presented by earlier researchers such as Fennema and Franke (1992, cited in Turnuklu & Yesildere, 2007) and Bromme (1994 cited in Ticha & Hospesova 2006).

Another pedagogical perspective offered by Ball (2000, p. 246), is the integration of the essential element of teacher's developing a sense of "trajectory of a topic over time…to develop its intellectual core in students' minds and capacities so that they eventually reach mature and compressed understandings and skills". Shulman (1986, p. 10) touched upon this idea and suggested that teachers require a "familiarity with the topics and issues" within a subject area that span the years. A recent study by Ball, Thames and Phelps (2007, p. 42) also emphasises the importance and possible scope of "horizon knowledge". The authors incite the need for further research into this category of subject matter knowledge and its implications for mathematics education. The notion of horizontal knowledge reinforces the urgent requirement to have specialist mathematics teachers within the middle school, who are acutely aware of how mathematics topics relate to further learning and real life contexts. (Chadbourne, 2001; McPhan, et al., 2008; Prosser, 2006).

An article by Belward, Mullamphy, Read and Sneddon (2007) from the School of Mathematics and Physics at James Cook University discusses the decline over the last "10 to 15 years in the mathematical ability" (p. 842) of students entering university courses requiring mathematics. One of the factors they discuss which contributes to this decline is what they believe is a "lack of consistent mathematics background from secondary school" (p. 843). They surmise that the reform efforts in mathematics education that focus on making the mathematics curriculum more palatable to students through an emphasis on real-life situations detracts from learning the essential knowledge and procedures in mathematics. If we were to use the food triangle as a mathematical metaphor, where should we really place knowledge and procedures in mathematics? It seems that there exists a condition in which knowledge and procedures in the mathematics classroom are jostling for their position within the pyramid. The focus on real-life investigations shouldn't collide with the development of skills and procedures. Instead, the real life investigations should amalgamate with the knowledge and skills in mathematics to give students mathematical power. To this end, an ideal objective may be for teachers to have the PCK to "support and optimise" (Battista, 2001, p. 29) the students' construction of mathematical ideas within real-life and purely mathematical contexts. Perhaps, (returning to the food pyramid metaphor) mathematics teachers need to have the pedagogical ability to get the vegetables (the mathematical procedures and skills) back into the pie (real life problem). The challenge is for students to actively enjoy and employ the vegetables, a nourishing addition and essential to their own pie-making ventures.

Opportunities for Mathematical Power

Mathematical literacy involves a crucial capacity to use mathematical knowledge to creatively respond to a variety of non – routine, real life situations relevant to an individual's life. Romberg (2001, p. 5) refers to the "interplay" between the ideas and procedures of mathematics and its functions as being able to "mathematise". Additionally, an idea seldom discussed is mathematical literacy as encompassing "the functional use of mathematics in a narrow sense as well as preparedness for further study, and the aesthetic and recreational elements of mathematics" (Organization for Economic Cooperation and Development, 2003,

p. 25). What happens in the middle school mathematics classroom is fundamental to the correlates of mathematical literacy that encourage further study in mathematics and related attitudes such as "self-confidence, curiosity, feelings of interest and relevance, …and the desire to do or understand things that contain mathematical components" (OECD, 2003, p. 26). A solid consensus has been emerging within the research literature urging that the starting point for the teacher is the preconceptions that students bring to the mathematics classroom, since "if their initial understanding is not engaged, they may fail to grasp new concepts and information that are taught, or they may learn them for the purpose of the test but revert to their preconceptions outside the classroom" (Romberg, 2001, p. 8). Consequently, an approach where the focus of the classroom practice is on the students' idiosyncratic development, may be a step forward in empowering students to be mathematically literate for their life world.

One of the challenges for the teacher trying to promote mathematical literacy through mathematisation is: "how to create classroom experiences so that a student's understanding grows over time" (Romberg, 2001, p. 8). It may be that teachers need to strengthen their confidence in their mathematical and pedagogical knowledge and skill to depart from the traditional daily classroom routines that Romberg (2001, p. 8) discusses as consisting of three segments "a review, presentation, and study/assistance". Teachers who generate classrooms revolving around these routines tend to "rely on unmodified subject matter knowledge most often directly extracted from the text or curriculum material" (Turnukly & Yesildere, 2007, p. 11) and "tend to make broad pedagogical decisions without assessing students' prior knowledge, ability levels, or learning strategies" (Cochran, 1997, p. 2). The 'Realistic Mathematics Education' (RME) (Freudenthal, 1991, cited in Zulkardi, 2004, p. 2), framework has the potential to unfold the PCK of teachers and enhance practice to support the "constructive processes" (Battista, 2001, p. 29) involved in mathematics. As suggested by Hiebert and Stigler "good intentions to change teaching" are sometimes ineffective and short lived due to teachers returning to familiar, traditional methods; however, it appears that "change is enabled when teachers have a clear target for change" (2004, p. 1). Moreover, perhaps the teacher should have the opportunity to be part of the process in creating the target for change. The target for change advocated through RME is that the mathematics in the classroom must have relevancy in the students' own mind. Lott Adams, (1997, p. 2) advises that this "relevancy, gives children a platform from which they can construct their own mathematical knowledge". The organisation of mathematics education in this way involves a process of "guided reinvention" (Zulkardi, 2004, p. 2). Treffers (1987, cited in Zulkardi, 2004, p. 3) discusses the use of "horizontal and vertical mathematisation" within the RME framework.

Horizontal mathematisation involves students devising mathematical strategies that allow them to conceptualise and solve a real life situation. Open - ended investigations and the effective use of oral and written communication in the classroom are avenues for horizontal mathematisation to occur. These tasks encourage mathematical literacy, since students have opportunities to: describe; identify; formulate and visualise the mathematical problems in their own way; discover relations and regularities; recognise isomorphisms in different problems and transfer real life problems into mathematical problems (Romberg, 2001; Zulkardi, 2004). Vertical mathematisation involves moving within the world of mathematical symbols. Teaching students to independently read and interpret the mathematics is a catalyst in this process. Students need to gain the autonomy to confidently represent a situation using formulas, refine models and ultimately make mathematical generalisations (Zulkardi, 2004).

OECD (2003) acknowledges mathematisation as a fundamental process that educators can use to improve the mathematical literacy of their students. The mathematisation cycle framework (OECD, 2003, p. 38) is described for teachers in the following way:

1. Start with a problem situated in reality;
2. Organise it according to mathematical concepts and identify the relevant mathematics;
3. Gradually trim away the reality through processes such as making assumptions, generalising and formalising, which promote the mathematical features of the situation and transform the real world problem into a mathematical problem that faithfully represents the situation;
4. Solve the mathematical problem; and
5. Make sense of the mathematical solution in terms of the real solution, including identifying the limitations of the solution.

Therefore, mathematisation involves moving between horizontal and vertical mathematics, within a range of situations, from real life to purely mathematical. RME differs from a purely constructivist approach, since the conceptions of the students need to be navigated by the teacher into meaningful mathematical forms (Zulkardi, 2004) that adhere to curriculum and mathematical literacy requirements. Teachers require profound PCK to didactically guide students through the levels of thinking required in mathematising. Returning to the perspective of students being the focus of the classroom practice suggests that students should feel part of the constructive process, since this initiates the mathematical power required to enhance mathematical literacy and the self-efficacy to be mathematically confident (Lott Adams, 1997). It appears that the opportunities for ownership: in mathematisation for students; and in teachers using their pedagogical content knowledge to create targets for change, have the potential to infuse equitable power relations into the middle school culture, that may be a core factor in school based revitalisation for mathematics education.

When considering the various ideas presented by the literature on mathematisation, mathematical literacy and pedagogy, there are several identifiable criteria that appear essential to developing effective teaching and learning strategies within the classroom. They are:

1. Is the starting point relevant to the knowledge and life world (present and future) of the students? That is, are the students the context of the teaching?
2. Does it engage the student? Are barriers minimised? For example, do students possess the necessary mathematical skills and procedures to proceed? Are students mathematically and intellectually engaged and able to learn new skills and procedures that are fundamental to higher level mathematics and mathematical literacy?

3. Is it developing the mathematical power of students so they may confidently exercise their mathematical knowledge and skill beyond the classroom?

The third criterion is the quintessential aim, proving to be the most complex and evidently the most difficult to attain. Perhaps, teachers may consider these criteria as a starting point in a process of 'guided reinvention' when deducing and framing the various components of their own pedagogical content knowledge to develop the resources essential to creating the targets to improve their practice. Acquiring knowledge from the practical experiences in the classroom is an avenue through which teachers may reap benefits from the macro and micro numeracy leadership perspectives. Furthermore, it may be that when teachers feel ownership of the knowledge of how to improve their practice, instead of being passive recipients of externally generated knowledge from "so-called experts, they are on a new professional trajectory" (Hiebert & Stigler, 2004, p. 4).

Contemplating Challenges for Positive Horizons

In contemplating how teachers can develop the resources to integrate their mathematical knowledge and pedagogy, I return to the idea of teachers realising the potential of their numeracy leadership from the macro and micro perspectives. A challenge of the macro perspective is how a culture can be encouraged within the teaching profession that continually "contemplates alternative courses of action" instead of being immersed in a "world of routine practice" (Rudduck, 1987, p. 130, cited in Sellars & Frances, 1995, p. 29) so that teachers can become "change-makers" rather than "semi-professionals and recipients of reform policies" (Collay, 2006, p. 2).

My aim is to do a case study to investigate and give an in-depth description of the context of the middle school mathematics classroom at a single school. The microscopic view of the case study methodology is facilitative of the investigation of a single school context, and may allow for the establishment of parameters that could be applied to further research. As a starting point I propose to investigate the micro perspective of the middle school mathematics classroom in terms of: how teachers integrate their knowledge and pedagogy to support the intellectual engagement of students in the constructive processes of mathematics. By constructive processes I mean how students construct their mathematical knowledge through mathematisation: conceptually; and through the use of the skills and procedures of mathematics. In particular, I endeavour to better understand and describe how the teachers' knowledge for teaching mathematics is forged through the integration of the pedagogical content knowledge domains developed by Ball et al. (2007). Furthermore, the qualitative case study aims to examine and explain how students are afforded opportunities to acquire the essential knowledge, skills and procedures in mathematics. In this sense, my study will look at the active engagement of teachers and students in the middle school classroom context. From this, I anticipate that the notion of how the middle school context facilitates the active engagement of teachers and students will in itself require investigation.

Concluding thoughts

In this paper I have raised urgent issues within Australian mathematics education that really do require consideration. There exists an urgency to empower students to feel mathematically powerful and numerate for their life at school and beyond. The return of academic rigour to the middle school mathematics classroom through high powered intellectual engagement appears to be a salient starting point. Mathematics teachers with profound pedagogical content knowledge are emerging as a critical catalyst in responding to the challenge of equipping Australia with the prime asset of students with higher-level mathematical literacy. However, to be agents for 'numeracy leadership' within Queensland schools, teachers need opportunities to make authentic transitions within the diverse embedded perspectives that exist in the teaching profession. Authentic transitions in this sense relate to teachers understanding and improving the educational processes in their social domain. What I am hoping to better understand is how teachers can improve their practice, by analysing the mathematical challenges presented by the teachers and the students in the middle school mathematics classroom.

This investigation is couched in a view that genuine opportunities for power in knowledge construction for teachers and students underpin the revitalisation process of middle school mathematics; and will concentrate on how teachers and students can be empowered with the confidence to broaden their mathematical horizons. For teachers, this empowerment may lead to a notion that the micro and macro perspectives of numeracy leadership are not mutually exclusive, but rather inherently co-dependent. For students this empowerment (through the development of core skills and procedures in middle school mathematics) may preclude the desire to continue with higher-level mathematics.

It is anticipated that many promising possibilities as well as further challenges will become evident in this study. Clearly, I see value in a school based approach to reinvigorating the middle school mathematics classroom. Furthermore, I propose that opportunities for ownership in equitable power relations within the middle school context may be a factor in broadening the potential of the mathematical horizons of students and teachers.

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