The Influence of Mathematical Beliefs on Low-Achieving Adult Learners

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This paper explores how beliefs about mathematics may influence low-achieving adults' re-engagement with mathematics in the tertiary sector. Adult learners who have problematic mathematical histories often hold negative beliefs about the nature of mathematics and how it is learned. In New Zealand these adults are often required to re-engage in mathematical provision in the tertiary sector to gain qualifications for employment. The beliefs they hold about mathematics may negatively influence their approach to learning mathematics and their affective response to it. This paper explores several ways in which negative beliefs about mathematics may undermine adults' success.

Learners who have problematic mathematical histories often develop beliefs about the topic that negatively influence their cognitive and affective engagement in further provision (Muis, 2004). These learners often leave school without gaining qualifications and continue to hold an abiding dislike of mathematics into adulthood and in many cases experience anxiety when confronted with mathematical tasks. However, many of these adults are required, at some stage in the future, to enroll in entry level vocational programmes to gain qualifications for employment. Here they are required to cope with challenging mathematical concepts and possible negative affective responses that may include anxiety, fear or shame. The beliefs that these adults hold about the nature of mathematics and how it is learned may undermine their re-engagement with the mathematical provision and lead to repeated experiences of failure. This paper explores how research on mathematical beliefs may contribute to our understanding of how adult learners with poor numeracy re-engage with mathematical provision in the tertiary sector, and argues that beliefs should be a key consideration when thinking about adults re-engaging with mathematics. It begins with a brief overview of the literature regarding adult numeracy before examining how mathematical and epistemic beliefs may influence adult engagement in mathematics.

Adult Numeracy

Raising the numeracy skills of New Zealand's adult population is a key strategic priority in the Tertiary Education Commissions 2010-2015 tertiary education strategy (Ministry of Education, 2010). Globalisation, the developing knowledge economy and the increasing role of technology in all spheres of life, continue to increase the level of numeracy skills required of adult populations (Tertiary Education Commission, 2010). Moreover, discussions regarding which skills should be included within the construct 'numeracy', and which of these are necessary to ensure social and economic well-being, are receiving increased attention (Gal, van Groenestijn, Manly, Schmitt, & Tout, 2003). Numeracy is increasingly described as a composite that includes the mathematical skills necessary to understand, critique, and respond to quantitative information *coupled* with the beliefs, attitudes and dispositions necessary to apply these skills where personally advantageous. Two specific areas of research have highlighted the need for the increased focus. The first is the relationship between poor numeracy and negative economic and

In V. Steinle, L. Ball & C. Bardini (Eds.), Mathematics education: Yesterday, today and tomorrow (Proceedings of the 36th annual conference of the Mathematics Education Research Group of Australasia). Melbourne, VIC: MERGA.

social outcomes, and the second is the uneven distribution of numeracy skills amongst the New Zealand adult population.

Studies of adult numeracy indicate that poor numeracy skills have a constraining influence on the educational, economic and social outcomes of adults. In regard to education, United Kingdom and New Zealand research indicates that adults with poor numeracy skills leave compulsory education earlier than those with stronger skills, hold low or no qualifications, and avoid further training opportunities (Carpentieri, Litster, & Frumkin, 2010; Parsons & Bynner, 2005; Satherley & Lawes, 2009). Regarding economic outcomes, adults with low numeracy skills are more likely to experience frequent periods of unemployment and casual work, occupy low paying labour intensive jobs, have fewer opportunities for promotion, and be particularly vulnerable during economic downturns. Regarding social outcomes, adults with poor numeracy skills are more likely to live in substandard and/or overcrowded housing, to have reported poor physical health in the last year, and to suffer depression (Carpentieri et al., 2010; Parsons & Bynner, 2005). Moreover, there is some evidence to suggest that the disadvantage experienced by adults with poor numeracy is intergenerational. For example, Bynner and Parsons (2006) identified that school aged children (six to 16 years) from families with very low numeracy levels were at a substantial disadvantage in relation to their own mathematical development relative to children with parents at higher levels. Given the impact of low numeracy skills on life outcomes, interest lies in determining how many of New Zealand's adults are at risk of attaining such negative outcomes.

In 2006 the Adult Literacy and Life Skills (ALL) Survey measured numeracy skills across five cognitive levels with the highest, Level Five, indicating expert level, and Level One, indicating 'very poor' numeracy skills (Lane & Smyth, 2009). Level Three was established as the minimum level for coping with the demands of everyday life and work in a complex progressive society. The New Zealand results identified 51% of participants as being at Levels One and Two, indicating that half of New Zealand's working age adult population have numeracy skills that the survey describes as 'poor' to 'very poor' (Satherley & Lawes, 2009). A second finding of concern is that New Zealanders' numeracy skills diminish dramatically as educational levels decrease. The survey indicated that of the adults who left school having completed only the lower secondary years, 87% had numeracy skills *below* the minimum benchmark (Lane & Smyth, 2009; Satherley & Lawes, 2009). It is these adults who are entering entry level tertiary programmes and being exposed to mathematical provision in the context of vocational training.

Mathematical Beliefs

While adults with poor numeracy were engaged in mathematics in school they were learning about what mathematics is, how it is learned, and what their relationship to it is (Schoenfeld, 1989, 2011). This learning appears to contribute to the formation of beliefs that constrain the development of conceptual understanding and contribute to negative affective responses to mathematic (Goldin, Rosken & Törner, 2009). Both poor conceptual understanding and negative affective responses have long been identified as barriers when working with adults who have poor numeracy (Coben, 2003). Hence the growing evidence that both domains are impacted by the mathematical beliefs an individual holds is of vital importance to adult educators. Despite the paucity of direct research on the mathematical beliefs of adults with poor numeracy, an abundance of research has accumulated from studies of school aged children, college students, pre-service and in-service teachers that is able to inform the topic. These studies suggest that the beliefs a low achieving adult learner holds about mathematics may be a key barrier preventing positive re-engagement and the development of conceptual understanding. The following section explores how beliefs may influence adult learners with poor numeracy.

Defining and Identifying Learner Beliefs

Researchers have struggled to develop a theoretical definition of beliefs. However, some key agreements about the nature and structure of beliefs have been established. Goldin's (2002) attempt at a unifying definition highlights some of the key concepts under investigation.

> Beliefs are defined to be multiply-encoded cognitive/affective configurations, to which the holder attributes some kind of truth value (e.g., empirical truth, validity, or applicability) (p.59).

This definition indicates the cognitive nature of beliefs while giving equal consideration to affective aspects. The subjective nature of beliefs is also described in that beliefs are something to which the 'holder' attributes truth value.

Despite the debate regarding the nature of beliefs, three aspects regarding the psychological structure of beliefs are widely accepted. First, beliefs are theorised to be held not in isolation but rather to exist as part of a belief system organised around a key idea or object (Green, 1971; Philipp, 2007). Most researchers agree that beliefs are best categorised by the specific idea or object to which they belong. Hence, beliefs about mathematics, beliefs about self, and beliefs about the social context of mathematical learning are persistent categorisations used across the domain. Second, the stability of an individual belief can be thought of in regard to its centrality within the system. Peripheral beliefs are considered less stable and possibly more easily changed. Third, the relationships between beliefs within a system may be held in a 'quasi-logical structure' in which primary beliefs serve as foundational to derivative beliefs (Goldin et al., 2009; Green, 1971; Philipp, 2007). Hence, mathematical beliefs held by adult learners are likely to be consistent, creating powerful self-supporting systems that culminate around particular views of mathematics.

A common cluster of beliefs about mathematics has been identified consistently across a range of ages and contexts. The most common beliefs include: mathematics is a collection of rules, facts, and procedures that must be memorised and followed; mathematics problems are able to be solved quickly or not at all; the only goal of mathematics is to get the correct answer; there is one right way to solve mathematical problems; the size and quantity of the numbers are responsible for the difficulty of the problem; mathematics requires a good memory; mathematical success is a product of ability rather than effort; mathematics is only created by gifted individuals (Muis, 2004). These beliefs are not unique to school students, but also appear to persist into adulthood as seen in research with pre-service teachers (Swars, Smith, Smith & Hart, 2008), university students completing remedial courses (Briley, Thompson & Iran-Nejad, 2009) and teachers (Philipp, 2007).

There is evidence to suggest that such beliefs 'constrain' the development of mathematical understanding by influencing the decisions learners make when engaging in mathematical activities (Schoenfeld, 2011). Essentially, such beliefs have relationships with behaviours contrary to those recommended by research-based reforms that emphasise conceptual understanding rather than procedural fluency (Boaler, 2008). Instead these beliefs tend to align with more instrumental or non-constructivist views of mathematics.

A second area informing this discussion is that of epistemic beliefs and their relationship with mathematical beliefs. Many researchers suggest that specific mathematical beliefs are linked to general epistemic beliefs; that is, one's beliefs about the nature of knowledge and knowing (Schommer-Aikins, Duell & Hutter, 2005). Schommer's multidimensional framework models epistemic beliefs across four separate dimensions: (1) the certainty of knowledge, ranging from knowledge is unchangeable to knowledge is evolving; (2) the structure of knowledge, ranging from knowledge is isolated and unconnected, to knowledge is organised as interrelated concepts; (3) the speed of knowledge acquisition, ranging from learning occurs quickly or not at all, to learning is gradual; (4) one's control of knowledge acquisition, ranging from the belief in an inherited fixed ability to the belief that the ability to learn can change over time (Schommer-Aikin, Duell & Barker, 2003).

The epistemic beliefs held by learners have relationships with their mathematical achievement. For example, the greater the extent to which learners believe that knowledge is characterised as isolated facts, the greater difficulty they have comprehending mathematical tasks (Schommer, Crouse & Rhodes, 1992). The belief that knowledge is simple and unambiguous is linked to poor comprehension of texts and poor academic achievement (Schraw, Dunkle & Bendixen, 1995). Students who believe that learning happens quickly or not at all tend to place less value on problem-solving than alternatively minded peers, apply less effort, and have less confidence engaging in problem-solving activities (Schommer-Aikin et al., 2005). Finally, Muis (2004) identified a range of studies that found that many students believe that only uniquely gifted people are able to create mathematics and hence believe that knowledge is produced and justified by sources of authority rather than through reason or personal discovery. Learners holding such beliefs tended to accept information passively, relying on teachers and text books rather than logic or reasoning.

The literature is consistent with the view that learner beliefs about mathematics influence their subsequent achievement. However, determining how beliefs relate to behaviours is difficult. Schommer-Aikins et al. (2005) note that the challenge of this inquiry is that the influence of beliefs is mostly indirect. An additional complexity is that the influence of beliefs is intertwined with cognition, affective responses and behaviours (Goldin, Epstein, Schorr & Warner, 2011). The following section explores three emergent findings that go some way in describing how negative beliefs may influence the behaviours of adults with negative mathematical histories. These include the influence of beliefs on learners: self-selected learning goals and subsequent standards; use of learning strategies; and affective responses. Finally, the case is made that adult learners with poor numeracy may be most vulnerable to the influence of negative beliefs.

The Influence of Beliefs on Learner Behaviour

Researchers investigating the role of self-regulated learning are increasingly incorporating beliefs into existing models (Muis & Franco, 2009). A key aspect of all self-regulation models is the role that goal setting plays as an initiator of individual action. Schunk (2001) defines self-regulated learning as "the learning that results from students' self-generated thoughts and behaviours that are systematically oriented toward the attainment of their learning goals" (p.125). Therefore, a learner's initial goals are *pivotal* to subsequent engagement in any learning task. Learners select learning goals, and subsequent standards, that are consistent with their beliefs (Muis & Franco, 2009). Once the goals are established, and standards are set that define the success of the goal, learners select what they believe are appropriate learning strategies and the success of such strategies are evaluated against the initial goals (Hofer & Sinatra, 2010).

In the case of an adult learner who holds maladaptive beliefs about mathematics, this is problematic. For example, learners who view mathematics as a rule-based topic in which single solutions are learned and applied quickly may set as a learning goal the memorisation all rules, formulas and relevant procedures. The corresponding standard for learning may be that the appropriate procedures can be recalled in response to specific problems. For such learners, non-routine thinking, collaborating, discussing multiple solution strategies, positing and justifying solutions, and seeking conceptual understanding are likely to be perceived as extraneous to their goals (Schoenfeld, 2011). In contrast, learners who hold that mathematics is interrelated and is derived from logic and reasoning are likely to set goals consistent with this belief and employ elaboration strategies, collaborate and actively seek connections between concepts (Meyer & Parsons, 1996). Adults re-engaging in mathematical provision in the tertiary sector will set goals for themselves based on their beliefs about what constitutes success in mathematics. In many cases this will be a surface level memorisation of rules and procedures.

Secondly, the learning strategies learners use to achieve their learning goals are impacted by their mathematical beliefs. A growing body of research links learners' beliefs to their use of either deep-processing learning strategies or, in contrast, less productive surface-level approaches that focus primarily on memorisation. Learners holding more negative beliefs appear to favour rehearsal strategies designed to memorise facts and generally fail to use organising or elaboration strategies at all (Briley et al, 2009; Paulsen & Feldman, 2007). They are also less likely to collaborate and less likely to monitor their own progress and make changes where necessary (Muis & Franco, 2009).

These findings raise critical issues regarding mathematical provision in the tertiary sector. They suggest that even in the case of motivated learners eager to re-engage with mathematics, their own beliefs about what constitutes success and how to achieve this may undermine their efforts. Motivated learners may focus on memorising content and perceive themselves as succeeding. Unfortunately, this strategy is linked to poor mathematical achievement (Boaler, 2008). The subsequent experience of failure, when one has believed one is succeeding, is likely to lead to frustration and possibly consolidate negative beliefs about one's ability to learn mathematics.

Beliefs and Affect

The affective domain has long been recognised as a critical aspect of mathematics education and has generally been investigated across four areas: beliefs, values, attitudes and emotions (Grootenboer, Lomas, & Ingram, 2008). Mathematics anxiety has also been commonly investigated as an emotional response, and has found to be particularly damaging to adults who have experienced difficulties with mathematics (Coben, 2003). In fact, the impact of mathematics anxiety is so severe on learners that its effects have been compared to a mathematical learning disability (Ashcraft, Krause, & Hopko, 2007). However, some have called for research that can better inform *why* individuals experience negative affective responses to mathematics rather than simply measure the impact (Bibby, 2002). Goldin et al, (2011) suggest that beliefs and or belief systems provide the cognitive and social conditions in which negative emotional and attitudinal aspects of affect, such as mathematics anxiety, thrive. Learner beliefs may explain why some adult learners experience negative affective responses and consequently disengage from provision.

Affect has been described as one of several internal representational systems that encode and communicate information (Goldin, 2002; Goldin et al., 2009). Goldin argues that feelings encode information, and that feelings of fear encode, and thus communicate, a threat to either the physical self or social self. In a similar tradition, Scheff (1994) proposes that while fear may signal a threat to the physical being, 'shame' signals a threat to one's social being. Therefore, negative affective responses to mathematics such as fear, anxiety or shame can be viewed as an internal communication of danger to the individual. How then do maladaptive mathematical beliefs contribute to mathematical environments being interpreted as dangerous?

Maladaptive beliefs about mathematics may create conditions in which individuals perceive themselves as suffering social damage if they fail to perform in the particular ways their beliefs about mathematics define (Turner et al., 2002). For example, Blackwell, Trzesniewski and Dweck (2007) found that learners who believe that mathematical ability is innate and fixed tend to conclude that mathematics proficiency is a measure of intellect. The mathematics classroom is viewed as one in which correct answers are supposed to be reached by drawing on one's internalisation of knowledge. Therefore, most mathematical classrooms provide the conditions for frequent judgments to be made about one's intellect. This potential for negative judgment by others, presents a risk to one's social being and therefore engenders negative emotional responses.

The concept of 'shame' has been employed to describe this reaction to other peoples' criticisms (Bibby, 2002). Bibby identified that the risk of suffering social damage generated a range of strategies designed to minimise potential harm. These included absconding or shutting off, disguising one's lack of knowledge in the hope of avoiding attention, creating distractions and even using verbal self-denigration. These behaviours suggest a substantial reduction of behavioural agency in mathematical learning environments, the exact opposite of numerate behaviour. Thus, because of beliefs about mathematics, adult learners behave in ways that constrain their engagement and therefore, constrain their learning. It is reasonable to conclude that the negative influence of beliefs on engagement may be particularly acute in adult learners returning to study after having experienced failure with mathematics in the school system.

Mathematical Identities

Research with adults with low numeracy suggests that the most serious effects of those described above have already occurred (Coben, 2000, 2003). Mendick (2005) suggests that school experiences and popular culture tend to contribute to an environment in which failure or success in mathematics is dichotomised as an either/or relationship. For many adults the sense of failure with mathematics often consolidates as a mathematical self-identity in which they position themselves as a 'non-math person'. Adults who hold such identities tend to view mathematics as 'what they cannot do' (Coben, 2000; Wedege, 2002). In fact, many adults perceive the mathematics they know, not as mathematics but simply as common sense (Coben, 2000). Thus they are never able to see themselves as being mathematically successful.

The development of a mathematical self-identity as a 'non-math person' suggests the individual has accepted the perceived stigma that accompanies difficulties with mathematics, that is, the implication that one is 'not intellectually gifted'. Consequently, adults will avoid situations where this perceived inadequacy is exposed to others, and thus experience discomfort when compelled to re-engage with mathematics as part of a tertiary training programme. In fact, the thought of being exposed again, both privately and publicly, creates the perfect conditions to generate negative affective responses and associated behaviours.

Conclusion

Research about mathematical beliefs suggests serious implications for adults attempting to re-engage with education after experiencing failure in the school sector. A repetition of the difficulties experienced in school may entrench patterns of failure and end a learner's engagement with formal education permanently. T herefore, understanding better how beliefs influence engagement and discovering solutions is imperative. Further research may help the tertiary sector to unlock the talents and resources of thousands of otherwise educationally marginalised adults.

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