That First Step: Engaging with Mathematics and Developing Numeracy

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Many resources have been created with the aim of helping children and adults overcome difficulties with mathematics and to develop or improve their numeracy. However, these are only used once the individual has *decided* to act – to do something to improve their mathematics and numeracy. Unfortunately, someone who knows that they need to improve their mathematics or strengthen their numeracy is not always accessing these resources. In this theoretical paper, I explore reasons why individuals may not engage with resources designed to help them develop their mathematical understandings and numeracy and identify the need to address how to get individuals to take that first step.

It is not a new finding that some individuals do not want to engage with mathematics or choose to develop their numeracy. Avoidance of mathematics is a behaviour of both children and adults. For example, Kemp and Hogan (2000) reported children may take actions to enable them to avoid mathematics. However, this avoidance can contribute to a feeling of failure in regard to the successful completion of mathematical activities (Chinn, 2012), which leads to more avoidance, when the opposite should happen. Negative views towards mathematics can also impact engagement with mathematics (Grootenboer & Marshman, 2016). Avoidance and negative attitudes towards mathematics also will impact the development of numeracy.

Many resources are available for individuals to access to address their mathematical skills and knowledge and to contribute to the development of numeracy. These resources are developed for many members of the community – children (e.g., http://splash.abc.net.au), young adults (e.g., www.khanacademy.org/math?t=classes), and adults (e.g., www.utas.edu.au/mathematics-pathways) – but these may not be accessed by those who would benefit from them (Mac an Bhaird, Fitzmaurice, Fhloinn, & O'Sullivan, 2013). With the opportunity for these resources to address mathematical skills and knowledge and to develop numeracy, often by transforming thinking and behaviours (for example, Boaler, 2013a, 2013b; Callingham, Beswick, & Ferme, 2015), the question of how to get individuals to take the step to access these resources needs to be considered.

Numeracy and Mathematics

Numeracy has been described in a variety of ways since the word was coined by Crowther (1959) to be used as a mathematical equivalent of literacy. He referred to numeracy as "an indispensable tool to the understanding and mastery of all phenomena" (p. 271), stating that it had two aspects, "an understanding of the scientific approach to the study of phenomena… (and) … the need… to think quantitatively" (p. 270). Cockcroft (1982) argued that the word numeracy had changed since Crowther (1959) described it, as "the association with science is no longer present and the level of mathematical understanding to which the words refer is much lower" (p. 11). Cockcroft (1982) proposed that numeracy should attribute two traits to the individual – "an 'at-homeness' with numbers and an ability to make use of mathematical skills which enables an individual to

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cope with the practical demands of his everyday life" (p. 11)

Cockcroft's (1982) description provided a stronger emphasis on the link between mathematics and numeracy. The description of numeracy has changed over time to incorporate an aspect of disposition regarding mathematics, such as "personal confidence, comfort and willingness to 'have-a-go' through the use of mathematical or quantitative means" (Australian Association of Mathematics Teachers [AAMT], 1997, p. 14). In their review of how numeracy has been conceptualised, Geiger, Goos, and Forgasz (2015) examined the use of the word *numeracy* (and its doppelgänger, mathematical literacy) and found that it had many aspects and components attributed to it. These included mathematical skills and processes, competencies, communication, interpretation, capacities, understandings, engagement, contribution, and connection, and are evident both in the classroom and in everyday lives.

Ernest (2002) took a different perspective and considered how an individual may be empowered mathematically. He proposed three domains, within the classroom (mathematical empowerment), through status gained via achievement (social empowerment), or through personal identity and their ability to create and use of mathematical understandings. Although not presented as an expanding model, Ernest's (2002) three domains of empowerment differ in terms of the context within which the individual engages with mathematics and the sphere of individual power that results from their engagement. This context can reflect the aspect of mathematical experiences and activities in the real world and everyday life that is considered by many to be critical in the description of numeracy (Geiger et al., 2015). Common amongst the three contexts is confidence and disposition to engage with mathematics, an element considered by the AAMT (1997) as a component of numeracy.

The question is: How can an individual be encouraged to engage with mathematics and develop numeracy – to take that first step? Three reasons are explored below. The first reason concerns how individuals perceive mathematics, as this can impact their engagement with mathematics and the development of their numeracy. Frameworks from Ernest (1989) and Grigutsch, Raatz, and Törner (1998) are used to investigate how individuals' perceptions of mathematics may link to actions in regard to mathematics. The second reason concerns whether mathematics is seen as existing beyond the classroom and as useful in everyday lives (Grootenboer & Marshman, 2016). If mathematics is seen as not useful, then engagement with mathematics and the development of numeracy may not be seen as worthwhile (Di Martino & Zan, 2011). The final reason focuses on individuals' perceptions of whether they are maths-able (Boaler, 2013a). Perceptions of oneself as maths-able depend on experiences and community expectations (Parker, Marsh, Ciarrochi, Marshall, & Abduljabbar, 2014), If individuals do not consider themselves as maths-able, they would be less likely to work on their mathematics skills and knowledge or on developing their numeracy.

The Impact of Perceptions of Mathematics

Ernest (1989) and Grigutsch et al. (1998) had similar approaches to describing how individuals may perceive mathematics. Ernest (1989) discussed three philosophies of mathematics: instrumentalist, Platonist, and problem-solving. He described instrumentalist as viewing mathematics as a "set of unrelated but utilitarian rules and facts" (p. 99), Platonist as "a static but unified body of certain knowledge" (p. 100), and problem-solving as "a dynamic, continually expanding field of human creation, a cultural product" (p. 100). Grigutsch et al. (1998) described four aspects: schema, formalism, process, and application, with schema and formalism belonging to a static view of mathematics and process belonging to a dynamic view of mathematics. Benz (2012) described these four aspects as focusing on calculations (scheme), formal characteristics such as terminology (formalism), problem solving through understanding and discovery (process), and practical use (application). Grigutsch et al. (1998) proposed that application was more likely from a dynamic view of mathematics (that is, comprising the aspect of process).

Viewing mathematics as instrumentalist (Ernest, 1989) or static (Grigutsch et al., 1998) would involve seeing mathematics as an external set of rules that need to be recalled or accessed and used in a precise way to generate an answer or solution. Individuals who hold this view of mathematics would focus on recalling rules and using these rules (Ernest, 1989). Seeing mathematics from a Platonist perspective would involve developing conceptual understandings of the knowledge created by others to underpin and connect the procedures used (Ernest, 1989). Finally, seeing mathematics as problem-solving (Ernest, 1989) or dynamic (Grigutsch et al., 1998) would involve considering mathematics to be more creative and evolving, enabling individuals to try different solutions and potentially be less fearful of making a mistake.

Ernest (1989) highlighted the impact that the educator may have, suggesting that the perceptions that educators have will likely influence how they teach mathematics. He proposed that educators who have an instrumentalist view of mathematics may focus on instructing students to learn rules and generate answers, educators with a Platonist view would explain the external mathematical ideas to their students to enable them to make connections between mathematical ideas, and educators with a problem-solving view of mathematics would create activities that enable their students to actively construct their mathematical understandings and encourage them to engage in problem-solving and problem posing. Anders and Rossbach (2015) stated that the educator's beliefs and actions can impact their students' mathematical learning. When considered in terms of learning and teaching mathematics, Attard (2015a) found that educators who utilise and promote problem solving and collaboration are more likely to engage children with mathematics.

Benz's (2012) findings support these connections between teachers' perceptions of mathematics and how they might teach mathematics, with educators who professed a process view having a higher level of agreement towards constructivist approaches to learning and teaching mathematics than educators who agreed with the static aspects of formalization and scheme. Furthermore, Benz (2012) found that educators with a static approach were more likely to focus on the importance of a correct result. This focus may lead to children disconnecting from mathematical activities (Boaler, 2015), which would impact their numeracy. Attard (2013) indicated that greater student engagement resulted when teachers encouraged students' active participation or social interaction during the lesson and incorporated connections to the students' lives (both current and future) in the lesson. In addition, she found that children who were learning mathematics through discussions and cooperative learning stated they enjoyed the activities. All of these actions are aspects of constructivism, and it is the educator with a process view (Grigutsch et al., 1998), which incorporates problem solving and discovery [similar to Ernest's (1989) problem-solving perspective], who is more likely to agree with a constructivist approach to learning and teaching mathematics (Benz, 2012).

Much like those of adults and educators, children's perceptions of mathematics can also vary. McDonough and Sullivan (2014) stated that it is important to find out children's perceptions of mathematics as they may impact the activities in which they will engage. These researchers suggested specific perceptions that coincided with Ernest's (1989) instrumentalist view might link to children determining the teacher is the source of understanding rather than discussions with their peers. In their research, Di Martino and Zan (2011) found that children perceived that mathematics involved the remembering of rules, was uncreative, focused on answers, and was not applicable to life. Again, many of these aspects relate to Ernest's (1989) instrumentalist view. These perceptions of mathematics, as shown with the last of Di Martino and Zan's (2011) findings, can determine whether children and adults see the applicability of mathematics beyond the classroom.

Seeing Mathematics as Useful Beyond the Classroom

Individuals may dislike the need to do mathematics and to be numerate. Grootenboer and Marshman (2016) stated that children do not always see mathematics as being useful outside of the classroom. Even in the classroom, children sometimes state they that they hate mathematics (Bates, Latham, & Kim, 2013) or that do not want to do mathematics and are happier when there isn't a mathematics lesson (Attard, 2013). Some adults also hate mathematics (Grootenboer & Marshman, 2016) and would prefer not to have to do mathematics in their work, such as pre-school teachers (Bates, Latham, & Kim, 2013). It is likely that these people are able to do mathematics in their everyday lives; however, they just do not recognise that what they do is mathematics (Kimball & Smith, 2013) or they fear engaging in classroom mathematics (Grootenboer & Marshman, 2016).

To be numerate requires mathematics to be seen as of use and useful (Geiger et al., 2015), as numeracy is "the application of mathematics to solve real-life problems" (Grootenboer & Marshman, 2016, p. 45). Unfortunately, the mathematics learned and taught at school may not be seen as being of use or usable outside of school (Kemp & Hogan, 2000) and may be a source of "frustration and powerlessness" (Grootenboer & Marshman, 2016, p. 22). Research has shown that mathematics is used in many everyday instances (Northcote & Marshall, 2016), and this everyday use demonstrates the real-world connection of numeracy (AAMT, 1997). It may be the case that children do not identify when and where mathematics is used in everyday life or recognise that they can use mathematics outside of school (Di Martino & Zan, 2011). Being able to see mathematics inside the classroom as useful and having mathematics outside of the classroom made visible may enable children to develop a disposition that leads to more engagement with mathematics and thus the development of their numeracy (Barnes, 2008). It may be necessary, as Barnes (2008) states, to take actions to enable children to recognise mathematics as useful in their everyday lives and to value becoming numerate.

Individuals' Perceptions of Who can do Mathematics

Self, gender, and societal expectations may impact individuals' beliefs about whether they can do mathematics. Galdi, Cadinu, and Tomasetto (2014) found that young children start building gender stereotypes, with children as young as six years of age developing implicit gender stereotypes. Their findings indicated that, although explicit gender stereotypes were not evident for six-year-old girls and boys, six-year-old girls had implicit gender stereotypes, identifying boys as more able at mathematics than girls. Research suggests that these beliefs continue as females become older, with mathematics seen as a masculine and not feminine ability (Solomon, 2012).

An individual's perception of who can do mathematics can be constructed from their environment (Parker et al., 2014). In a school situation, this can include the mathematics textbooks used by educators when teaching mathematics. In their analysis of images contained in a mathematics textbook for students in high school, Norén and Björklund Boistrup (2016) found that images were more likely to promote a passive or consumer orientation for females and an active, producer, or fixer orientation for males. These orientations, they proposed, could be linked to how mathematics might be used by each gender and could feed through to choices later in life.

Individual and societal beliefs and images of who can do mathematics can also impact perceptions about who is capable of engaging with mathematics. Boaler (2013a) referred to the harm that beliefs about who was maths-capable could have on individuals, specifically, beliefs that "mathematics is for select racial groups and men… (and)… the teaching practices that go with it, have provided the perfect conditions for the creation of a math underclass" (para. 4). These perceptions of who can do mathematics may relate to confidence, which is critical as "confidence mediates their capacity to engage in mathematical learning experiences… (and)… will also be influenced by the nature and perceived success of their involvement in mathematical activities in the classroom" (Grootenboer & Marshman, 2016, p. 24).

These beliefs can also contribute to mathematical self-efficacy. Parker et al. (2014) described mathematical self-efficacy as an individual's beliefs about their competence and capabilities in mathematics. They found that mathematical self-efficacy was positively related to achievement in mathematics some two years later. An antithesis to mathematics self-efficacy is mathematics anxiety. Metje, Frank, and Croft (2007) described how the cycle of failure in mathematics and negative attitudes regarding mathematics may connect to avoiding mathematical activities and contribute to mathematics anxiety. In addition, this cycle of failure makes it difficult to help individuals to overcome mathematics anxiety, particularly as mathematics anxiety will reduce confidence for engaging with mathematics. They propose that remembrance of past failures and mathematics anxiety could result in individuals not taking actions to address mathematical skills and numeracy.

Encouraging that First Step

The three reasons why individuals may not improve their mathematical skills and knowledge or develop their numeracy do not impact a specific population or group. Approaches that target these reasons relate to providing different experiences with mathematics that can impact perceptions of mathematics, show that mathematics is useful beyond the classroom, and change who might be seen as maths-able.

Targeting how individuals see mathematics and how empowered they feel may encourage them to take steps to improve their mathematical understandings and numeracy. If the individual views mathematics as instrumentalist (Ernest, 1989) or schema and formalism aspects within the static view (Grigutsch et al., 1998), they may be disempowered mathematically and then disengage from mathematics (Di Martino & Zan, 2011). This is extended by Ernest (2002), who stated that the disempowerment of the individual who views mathematics as an external set of rules occurs as the rules were external and sanctioned by others. However, if the individual views mathematics as process and application (Grigutsch et al., 1998) or as problem-solving (Ernest 1989), it would enable the individual to have choice in what they do when engaging with mathematics and to see mathematics as a creative or dynamic pursuit (Grootenboer & Marshman, 2016). The opportunity to create solutions, rather than follow set rules or procedures that need to be remembered precisely (with or without understanding) may generate engagement (De Martino & Zan, 2011) – promoting individuals to take that first step. However, this would be tempered by self-efficacy and confidence (Bates, Latham, & Kim, 2010). Thoughtful consideration of these opportunities would be needed, as

> Belief change does not occur simply through the presentation of new, desirable beliefs. … belief change usually requires revisiting and reviewing episodes which gave rise to the held beliefs, and then creating new encounters where new and desirable beliefs can be experienced in positive and successful ways (Grootenboer & Marshman, 2016, p. 17).

Targeting the identification of mathematics in everyday life or seeing mathematics completed in a mathematics lesson as applicable in their lives may impact individuals taking that step to develop their numeracy (Grootenboer & Marshman, 2016). Being able to identify that mathematics is everywhere (Barnes, 2008) – in daily household activities (Anders & Rossbach, 2015) and in work (Northcote & Marshall, 2016) – could be powerful in encouraging the individual to take that first step as their recollections of success could move beyond scores in mathematics assessments to a wider range of experiences where they have seen themselves as successful.

Targeting perceptions of who is maths-able may support individuals in identifying themselves as successful in mathematical experiences or as numerate. The provision of images in the educational environment (Norén & Björklund Boistrup, 2016) and other environments that show all individuals involved with mathematics and demonstrating numeracy may encourage individuals to also see themselves engaging with mathematics or being numerate. An explicit use of positive gender priming, where females are shown successfully and actively engaging in mathematics, may also help individuals to see themselves as maths-able. Galdi et al. (2914) demonstrated the impact of providing positive gender priming for six-year-old girls. When presented with an activity that showed girls achieving in mathematics, the results in a mathematics assessment improved.

Boaler (2014) believed that if individuals are "encouraged to believe they can be successful in mathematics... we will have many more confident and capable mathematics learners" (para. 11). This is reflected in the impact of the individual's mathematical self-efficacy – It needs to reflect a belief that the individual can successfully complete a mathematical task (Parker et al., 2014). The educator can have an impact on engagement with mathematics and the development of numeracy, as discussed by Metje et al. (2007). An example of this is described by Boaler (2013b), who discussed how making mistakes in mathematics should be used by educators as a positive learning opportunity, rather than as a future reminder of previous failures (Metje et al., 2007). Creating an environment where mistakes are no longer regarded as a negative (Boaler, 2013a) could unleash the power of learning from mistakes and help ameliorate mathematics anxiety.

Although approaches were connected to specific reasons why an individual may not act to improve their mathematics or develop their numeracy, approaches may address several reasons. For example, providing positive priming can reflect gender and connections to the real world (Norén & Björklund Boistrup, 2016), using problem-solving in the classroom can incorporate context from everyday lives (Geiger et al. 2015), authentic work examples used to demonstrate the relevance of numeracy (Northcote & Marshall, 2016) can extend beyond mathematical empowerment to epistemological empowerment (Ernest 2002), and examples of everyday use of mathematics may provide remembrances of successful and non-anxious engagement with mathematics (Metje et al., 2007).

I will now return to the question of how to get individuals to take the step to access resources. As Di Martino and Zan (2011) proposed, we need to identify the reasons that each individual has for not engaging with mathematics and their numeracy, and then address the reasons with targeted interventions. However, how will individuals needing to improve their mathematics and numeracy engage with these two processes, that is, take that first step?

Conclusion

Individuals of different ages may recognise the need to address their mathematical knowledge or numeracy, but they do not take that step to access resources that would assist them. Targeting perceptions of mathematics, the usefulness of mathematics beyond the classroom, and who might be seen as maths-able may transform individuals' beliefs about mathematics and who can do mathematics (Boaler, 2013a, 2013b) and their views of numeracy (Grootenboer & Marshman, 2016). As Di Martino and Zan (2011) indicated, we need to focus on the individual. Research is needed to, first, find ways to identify the specific reasons why an individual who needs to improve their mathematics or develop their numeracy does not engage with resources designed to help them and, second, create targeted interventions that address those specific reasons. The overarching third area of research is how to get these individuals needing to improve their mathematics and numeracy involved in these processes – the tangible action of wanting to do it – where the individual takes that first step.

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