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Mathematical learning with a purpose

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Abstract
Creating real-world, relevant and purposeful learning experiences in mathematics for children correlates strongly with the three forms of engagement: cognitive, operative and affective. Affective engagement is the most problematic as it is unachievable without purposeful mathematical learning experiences, however, the three forms of engagement are interrelated. Each must be considered when planning for purposeful mathematics, as they are all vital to assist moving beyond the common attitude towards mathematics as boring or irrelevant. Enabling students to engage cognitively, operatively and affectively with mathematics, enhances their ability to have a more positive and successful experience. The aim of this article is to demonstrate how real, relevant and purposeful mathematical experiences can look in a classroom context, taking the three forms of engagement into account.

Keywords
mathematics; purposeful learning; engagement; cognitive; operative; affective; students; classroom; authentic

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Creating real-world, relevant and purposeful learning experiences in mathematics for children correlates strongly with the three forms of engagement: cognitive, operative and affective. Affective engagement is the most problematic as it is unachievable without purposeful mathematical learning experiences, however, the three forms of engagement are interrelated. Each must be considered when planning for purposeful mathematics, as they are all vital to assist moving beyond the common attitude towards mathematics as boring or irrelevant. Enabling students to engage cognitively, operatively and affectively with mathematics, enhances their ability to have a more positive and successful experience. The aim of this article is to demonstrate how real, relevant and purposeful mathematical experiences can look in a classroom context, taking the three forms of engagement into account.

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Purposeful mathematics in the classroom

A vital component of a quality mathematics classroom is the provision of purposeful learning experiences. These involve children experiencing real-world, relevant or meaningful mathematics (Sparrow, 2008b) and moving learners beyond the common attitude towards mathematics as being boring or irrelevant (Sparrow, 2008a). Although there is becoming more awareness in the field of mathematics pedagogy necessary to construct mathematical understanding, it still remains a challenge to deliver purposeful mathematics tasks in many classrooms (Sparrow, 2008a).

It is important to make students aware of the central role of mathematics in life beyond the school classroom (Sparrow 2008b). However, many teachers themselves do not recognise the extent to which mathematics is fundamental (Garii & Okumu, 2008). This, in turn, can impact negatively on the effectiveness of their teaching practice, as they may lack the aptitude to connect classroom mathematics with real-world mathematics (Garri & Okumu, 2008).

Purposeful mathematics can be defined as incorporating elements of the real world (Sparrow, 2008a). There are two ways to view purposeful mathematics: as real-world mathematical experiences or as exploring/solving a mathematical problem (Brough & Calder, 2014; Sparrow, 2008b). This reflects both the work and the passion of mathematicians, which are greatly contrasted with the typical textbook or worksheet mathematical experiences students often encounter in the classroom (Sparrow, 2008b). While students can apply mathematics to solve problems within the

context of using a textbook, textbook problems often lack relevance to the interests of students; thereby mathematics is no longer meaningful and their personal valuing of mathematics is diminished (Sparrow, 2008a). Tailoring learning experiences to develop a student's mathematical knowledge, understanding, skills and abilities from situations that pertain to their interests, reflects an important characteristic of meaningful mathematics (Sparrow, 2008a), that of transferrable, real-world connections.

Linking purposeful mathematics with an engagement framework

When delivering mathematical activities that provide purposeful learning experiences, the main target is engaging students cognitively, operatively and affectively, as identified in Attard's (2012a) engagement framework. Cognitive engagement refers to students having a deep understanding of concepts and their applications; operative engagement – also known as the hands-on level – represents the active participation of a learner; and affective engagement is the value placed on mathematics by the student within their own life, where mathematics is considered significant beyond the classroom (Attard, 2012a). The provision of purposeful mathematical learning experiences is important in achieving student engagement on these three interrelated and multifaceted levels (Attard, 2012b). In particular, purposeful mathematics that involves real-world, relevant and meaningful experiences that reflect student interests and incorporate choice can develop a students' affective engagement – a form of engagement that can be difficult to achieve (Attard, 2012a; Rukavina et al., 2012). When students enjoy mathematics and see the connection between the mathematics learned at school and the mathematics they use outside of school (Attard, 2012b) they are more likely to acquire a positive attitude towards mathematics (Sparrow & Hurst, 2010). This is crucial to overall mathematics achievement, as it increases students' willingness and motivation to learn (Mata, Monteiro & Peixoto, 2012; Pinxten et al., 2014).

How might purposeful mathematics look in the classroom?

The mathematical diet of students should not be one of monotony, but instead incorporate a range of different activities and a variety of positive learning experiences (Burton, 2010; Sparrow & Hurst, 2010). That being said, it is not an easy task to bring relevance into the classroom, as the challenge is in the ability to provide real-life examples for mathematics which shift beyond the typical teachings of cutting up pizza (fractions) and carpeting a room (measurement) (Sparrow, 2008a). A good place to begin is developing mathematics from situations that pertain to the students' interest, whilst they are learning and applying mathematical knowledge, skills and understandings that are relevant to them at the time, thus fostering a mathematical experience that is meaningful to students (Sparrow, 2008a). There are a number of ways for this to be done to achieve purposeful learning and engagement on all three of Attard's levels (cognitive, operative, affective). These can be applied using both Information and Communication Technologies (ICT) or traditional methods.

A cycle of student-centred investigations

Green and Graham (1994) developed a Pose, Collect, Analyse, Interpret (PCAI) cycle, where students are able to *pose* the questions themselves, *collect* the data, *analyse* the results and then *interpret* the results. This type of student-centred, investigative approach facilitates meaningful and purposeful mathematics, as the students have devised the task and acquired sense of ownership over the problem they are solving as well as the mathematics they have used (Brough & Calder, 2014; Sparrow, 2008a). Affective engagement is reinforced, as students are able to connect mathematics used in the classroom with the real world, as can be seen in Sparrow's (2008a) example of the PCAI cycle for potato chips. The students were asked to brainstorm a range of questions they had about potato chips and were then able to sift through to identify the best question to investigate. They worked in small groups to collect data through tallies, surveys and other various methods and then represented this data in a pictorial or graphical form. This allowed the students to examine the results in relation to the question and draw conclusions or find solutions, which may also lead to further questions (Sparrow, 2008a).

Connecting purposeful activities and meaningful contexts

Connecting purposeful activities and meaningful contexts can be seen in Haylock's (1991) 'planning chart', which is a visual grid that displays different types of purposeful activities and meaningful contexts, within which these activities can be applied. This chart can be a developing framework that enables a teacher to plan *purposeful* activities within *meaningful* contexts, and the combination of the two can facilitate all three of Attard's levels of engagement. For example, by employing a purposeful activity such as designing and constructing or solving a real-world problem within a meaningful context such as school organisation or fundraising, students can use and apply mathematical skills, knowledge and understandings in an authentic context (Nicol & Crespo, 2005). Connecting purposeful activities and meaningful contexts are also evident in Lyon and Bragg's (2011) school kitchen garden project. In this project students were able to engage cognitively when designing cost-effective garden beds to fit within the kitchen garden, prior to starting the kitchen garden program (Lyon & Bragg, 2011). Involving the students in the construction enabled them to problem solve by: making various mathematical computations, exercising estimation skills, using a multitude of mathematical terminology and having enriching mathematical discussions (Lyon & Bragg, 2011). This not only potentially leads into the integration of mathematics with science, where analysis can be made of effectiveness of fertilisers and measurement of plant growth but it can springboard into other real and relevant activities, such as creating rain gauges or exploring ratios for pesticides, compost or worm farms (Clarkson, 2010; Lyon & Bragg, 2011). In these tasks the students were actively involved in the learning process (making and doing), thus engaging them operatively (Attard, 2012a). The tasks incorporated in Lyon and Bragg (2011) mirrored real-life situations, making the learning both meaningful and purposeful for the students, this is a significant factor required to enable students to experience affective engagement (Attard, 2012b).

Game-based engagement

Games can be introduced to students for many reasons, such as enjoyment, as a way to practice skills or for a reward. Mathematical games have also been shown to build a positive attitude toward mathematics, along with creating a positive learning environment (Bragg, 2007). Some mathematical games can be utilised as a pedagogical tool to engage students operatively, cognitively and affectively. This can only occur if the game meets specific criteria of rich mathematical games, where the game has: particular cognitive objectives, rules, potential to engage, an opponent to challenge, elements of strategy or skill and a distinct finishing point (Bragg, 2012). For example, fraction mats (NSW DEC, 2015) is a game in which two students compete with each other by taking turns at rolling a die and colouring the equivalent fraction on the game board. They must record the fractions they roll and the first person to colour the entire game board wins (NSW DEC, 2015). The student must add the fractions to ensure they have the total sum of the original game board (NSW DEC, 2015). The cognitive objectives of this game are for students to think about the equivalence and addition of fractions. This pursuit requires students to be thinking at a high level (engaging cognitively), because they must use strategy (Bragg, 2012) to determine which equivalent fraction to colour in order to colour the entire game board the quickest. Bragg (2012) suggests that playing games demands involvement, thus fraction mats engage students operatively. Not only are the students engaged operatively and cognitively but they are also engaged affectively because they are enjoying the learning as it is of relevance or interest to them, being in a game form, consequently encouraging them to be more effusively involved in the mathematics (Attard, 2012b).

Cross-KLA integration

Mathematics is an integral part of everyday life and can be applied to a range of contexts that go further than the mathematics classroom, this includes connecting with other Key Learning Areas (KLAs) such as: English, Science, Art, Geography and History (Board of Studies, NSW (BOS NSW), 2012). The integration of mathematics with various disciplines can produce a meaningful and authentic teaching and learning environment, in which students are able to connect more deeply with learning material, as they have opportunity to link prior knowledge with new learning (Wilder, Lang & Monegan, 2015). This consequently allows them to see the relationship between the disciplines and their lives (Wilder, Lang & Monegan, 2015). Essentially, this supports the retention of information in students' long-term memory, exudes relevance and enables transfer of knowledge, hence developing multiple and stronger connections to learning (Wilder, Lang & Monegan, 2015). For example, integrating English with Mathematics can be done through literature, reflection journals, concept mapping, narrative problems and barrier games. Of these, an engaging way to combine English with mathematics through the utilisation of a resource such as children's literature to enhance the learning of mathematics concepts can be seen in Clarke (2007), where *Sir Cumference and the Great Knight of Angleland* (Neuschwander, 2001) is a book that provides an authentic context to explore geometry and mathematical language in a way that is highly engaging. Thatcher (2001) acknowledged the potential of such literature to act as a springboard for mathematical investigations and a catalyst for developing a cognitively engaging

environment for students (Thatcher 2001). The activities that follow the story should enable students to actively participate in explorations of the mathematical concepts, just as Clarke (2007) has done, thus engaging the students operatively. In this way students are developing an appreciation for mathematics, as it has been contextualised in an authentic, relevant, stimulating and well-connected way, thus providing students with affective engagement (Attard, 2012a; Clarke, 2007).

Conclusion

Purposeful learning experiences within meaningful contexts are a means to encourage students' cognitive, operative and affective engagement (Attard, 2012a). These ideas can be adapted for any stage and present opportunities for differentiation to meet the various needs of learners. They also paint mathematics in a positive light because the learning occurring is of high quality, enjoyable, real and relevant to the lives of students (Brough & Calder, 2014; Sparrow, 2008a, 2008b).

Cognitive, operative and affective engagement should be considered when planning purposeful mathematics, as they are crucial to avoiding the development of students' attitudes toward mathematics as boring and irrelevant (Attard, 2012a; Sparrow, 2008a). Although it is challenging to deliver purposeful and meaningful learning experiences in authentic contexts (Sparrow, 2008a) it is vital for teachers to facilitate a successful experience by promoting students' willingness to learn and gearing them toward developing a positive attitude toward mathematics (Mata, Monteiro & Peixoto, 2012; Pinxten et al., 2014).

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