

Designing Data Collection Instruments to Research Engagement in Mathematics

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Engagement is a multifaceted concept that has attracted recent attention by researchers both in Australia and internationally (Attard, 2012; Chan, Baker, Slee, & Williamson, 2015). For many years mathematics education has been seen as boring and dull, and students have disengaged from a relatively early age in learning and participating in mathematics (Grootenboer & Marshman, 2016). Therefore, there seems to be an imperative for research and action into this issue, as low levels of engagement among school students can put them at risk of decreased participation and, ultimately, low levels of academic achievement (Fredrick et al, 2004). It is evident that there are three types of engagement consistent across the literature; emotional, behavioural, and cognitive. However, it appears that there are no existing data collection instruments that specifically focus on capturing student engagement in mathematics. Thus, some tools have been designed that derive specifically from the theoretical framework on engagement with the aim of being theoretically robust, conceptually relevant, and practically manageable.

The concept of engagement in mathematics has become a growing concern for researchers in Australia and internationally in recent years (Attard, 2012; Chan, Baker, Slee, & Williamson, 2015). Improving engagement is believed to be the means of ameliorating low levels of academic achievement and high levels of student boredom (Fredricks, et al, 2004). There is an imperative for research in this field as low levels of engagement can result in low achievement and participation. Consequently, this has the potential to affect our country's perennial shortage of mathematically literate citizens (Attard, 2011). There are also historical, economic, and practical reasons for the budding research interest in school engagement (Fredricks, Blumenfeld, & Paris, 2004). Many students now view mathematics as dull and inaccessible, and so disengage (Grootenboer & Marshman, 2017). Observations such as these are especially alarming as the new and rapidly changing international economy requires workers with mathematical knowledge in order to synthesise and evaluate new information, problem solve, and think critically (Fredricks, Blumenfeld, & Paris, 2004). Even though school is mandatory, students need to be engaged in their education if they are to succeed at school and thrive thereafter. For example, most higher education courses require specific levels of mathematics upon entry. Students who are disengaged from mathematics throughout their schooling, not only face a limited choice of courses available to them but additionally they limit their capacity to grasp the mathematical perspective present in everyday life experiences (Sullivan, Mousley, & Zevenbergen, 2005). McPhan, Moroney, Pegg, Cooksey, and Lynch (2008) claim that central to increasing participation rates in mathematics are teaching strategies in the early years that engage students in investigative learning. Students who are engaged in mathematics in the early years are more likely to learn, find a sense of satisfaction from the experience, and therefore progress to higher-level mathematics courses (Marks, 2000).

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Engagement in Learning Mathematics

Attard (2011; 2012), a key Australian researcher into student engagement in mathematics, suggests that effective mathematical engagement occurs when a student is enjoying the subject, can easily see the relevance that their work has to their own lives and future, and can make meaningful mathematical connections between the classroom and outside the school environment. Also highlighted, is the significance of choice and creativity in the mathematical learning context, and the suggestion that, if students are engaged in activities that encourage creativity and that provide opportunities to make decisions about their learning, their engagement will increase. Attard (2012) also incorporates the notion of “fun” in her studies, stating that “most of the ‘good’ [fun] lessons discussed by the students were those that include physical activity, active learning situations involving concrete materials, and/or games” (p. 11). Additionally, Fägerstam and Blom (2013) state; “The pupils in this study all described positive experiences regarding the outdoor lesson... all of them spontaneously uttered remarks such as ‘it was fun’” (p. 68). Similarly, Brunsell, Fleming, Opitz, Ford, and Ebrary (2014) found that “joyful” learning was significantly connected to better learning. Fägerstam and Samuelson (2014) also report that outdoor learning provided students with a more enjoyable approach to education. It is likely that an individual’s sense of enjoyment or feeling like an activity is fun can have direct, positive impacts on their school learning experiences.

Motivation concepts are suggested to have significant relevance, and are often synonymous, where the conceptualisation of engagement is discussed. Students’ motivation to complete tasks dramatically increases when games are included in mathematics (Attard, 2011; 2012). Additionally, when students can make links between the mathematics they are learning and “real” life their engagement significantly increases (Ajmal, 2013; Attard 2012). Thus, is it critical that students are able to make links between what they are learning, their knowledge, and both inside and outside classroom experiences (Opitz & Ford, 2014).

The literature frequently suggests that outdoor learning is an effective pedagogical approach to increase student engagement and it is often suggested that students perform significantly better in outdoor activities (Fägerstam & Samuelson, 2014; Haji, Abdullah, Maizora, & Yumiati, 2017; Young & Marroquin, 2008). Attard’s (2012) research suggests “the incorporation of tasks that mirrored life-like situation appears to have been a strong factor in engaging students in mathematics tasks, as were the tasks that required the students to take the mathematics out of the classroom and into the school playground” (p. 11). Waite (2011) reports on the benefits of outdoor learning stating, “Another very important aspect of our findings was the levels of involvement of children in planning and use of outdoors. This seemed to ensure a greater sense of ownership, more engagement and higher levels of usage...Enjoyment and engagement of the whole child was common across all the case studies” (p. 78). Young and Marroquin (2008) also report on the effectiveness of lessons taken outside on the playground, “Reluctant students were more apt to engage in the activities and volunteer to explain their thinking or justify their answers” (p. 282). As observed, the word ‘engage’ and its derived forms are not uncommonly used in literature discussing outdoor learning.

Previous Studies into Engagement in Mathematics

Reflected in the research literature, the multifaceted nature of engagement has been commonly defined around three dimensions; emotional, cognitive, and behavioural

(Fredricks, Blumenfeld, & Paris, 2004), and this is discussed in the next section. For example, Skilling (2014), using Fredricks, Blumenfeld, and Paris' (2004) framework, investigated engagement in a mathematical educational setting. She found that students who were emotionally engaged tended to demonstrate interest and enjoyment, and cognitively engaged students demonstrated effective planning, and they managed and regulated their learning. Also, students who are behaviourally engaged actively participated, persisted, and asked questions.

Also, in an Australian context, Attard (2011; 2012) comes from an educational background rather than a psychology background and has devoted a significant measure of research to the different domains of engagement. Using the work of Fredricks et al (2004) she has developed literature on the practicalities of the theories of engagement.

Theoretical Framework

Given the literature on engagement and the previous studies outlined above, the work of Fredricks, Blumenfeld, and Paris (2004) is seen as seminal and provides a sound and robust theoretical framework for investigating engagement in mathematics education. This will now be outlined and discussed

Types of Engagement

Fredricks, Blumenfeld, and Paris (2004) suggest that emotional engagement “encompasses positive and negative reactions to teachers, classmates, academics, and school” (p. 60). They explain that there is a direct correlation between how students react to these school experiences and their willingness to do work. However, Attard (2011; 2012) does not define this particular domain of engagement as other researchers have and instead labels it as belonging within the affective domain. She centralised her analyses not around the internal state (emotions) of students' engagement, but rather around students' experiences with school and their associated affective responses. Grootenboer and Marshman (2017) also attempted to comprehensively characterise the affective domain through the interrelated dimensions of beliefs, values, attitudes, and emotions. Often seen to be related, emotional engagement and motivation can be seen as synonymous but in reality they are very distinct concepts. Motivation encompasses internal (emotional), private and unobservable aspects while engagement is the manifestation of these qualities that are observable on the outer (Skilling, 2014). However, research in the field of motivation is often critical if the deeper influencing factors of students' engagement in mathematics are to be understood holistically (Skilling 2014).

Behavioural engagement refers to an individual's active participation and involvement in academic and social activities (Attard, 2011; 2012). Finn, Pannozzo, and Voelkl (1995) emphasise that inherent to the construct of behavioural engagement is the concept of participation, which is a crucial component in achieving positive academic outcomes. Behavioural engagement is most commonly conceptualised in three interrelated ways. The first entails how an individual adheres to classroom norms and follows the rules (Finn et al., 1995). The second aspect of behavioural engagement is concerned with students' actions such as their “efforts, persistence, concentration, attention, asking questions, and contributing to class discussions” (Fredricks, Blumenfeld, & Paris, 2004). Often the term “effort” is seen to be problematic as it is included in definitions of both behavioural and cognitive engagement and distinctions are not always made clear (Fredricks, Blumenfeld,

& Paris, 2004). The third dimension involves an individual's participation in school activities such as sports or leadership roles (Finn 1989; Finn, Panno, & Voelkl, 1995).

Attard (2011; 2012) defines cognitive engagement as an individual's investment, acknowledgment of the value of learning, and willingness to go above and beyond the minimum requirements. Cognitive engagement relates to the desire for hard work, persistence in problem solving, and endurance in the face of failure (Attard 2011; 2012; Connell & Wellborn, 1991). Fredricks, Blumenfeld, and Paris (2004) explore cognitive engagement from two different perspectives where one encompasses the psychological investment in learning (Newmann, Wehlage, & Wisconsin, 1995) while the other targets cognition and emphasises strategic learning (Zimmerman, 1990). The literature concerned with cognitive engagement as a psychological investment defines it as an individual's direct efforts towards learning and mastering the knowledge, skills and crafts associated with academic work (Fredricks et al, 2004). Again, the word effort is indistinctly used across definitions of engagement as it parallels those found in research on behavioural engagement. Psychological definitions of cognitive engagement also strongly resemble definitions found in the motivation literature. Students who are intrinsically motivated demonstrate persistence in the face of hardship and experience a sense of satisfaction when given challenging tasks (Brophy, 1987). The alternative definition of cognitive engagement emphasises students demonstrating highly strategic learning qualities. Often described as being self-regulated, strategic students complete tasks by using metacognitive strategies to arrange and assess their cognition (Zimmerman, 1990). They are efficient in suppressing distractions, as well as maintaining and regulating their efforts to sustain their cognitive engagement (Fredricks, Blumenfeld, & Paris, 2004). They explain that both definitions of cognitive engagement are valuable and that neither alone can adequately deal with the qualitative aspects of engagement.

The conceptualisations of emotional/affective engagement, behavioural engagement, and cognitive engagement incorporate a wide variety of constructs. It is critical to acknowledge that these engagement factors are not isolated processes occurring within the individual, but rather they are dynamically interrelated and a shift in one can dramatically influence the others.

Developing Research Tools and Approaches

As observed, the word 'engage' and its derived forms are not widely used in literature discussing mathematics learning, albeit that it is seen as important in practice. Yet it is seldom seen that a distinctive definition of engagement is integrated and the word is often cryptically used. The majority of the literature seems unsuccessful in making conceptual links between the different types of engagement and the effectiveness of outdoor learning and therefore there are no available instruments that would be suitable for such a study.

It appears that there are no existing instruments that specifically focus on capturing student engagement in mathematics learning. Therefore, some tools have been developed that derive specifically from the theoretical work of Fredricks, Blumenfeld, and Paris, (2004) that was outlined and discussed above. The aim was to have data collection tools/approaches that were theoretically robust, conceptually relevant, and practically manageable. The three data collection tools/approaches relate specifically to the three dimensions of the theoretical framework as is outlined in Table 1 below.

Table 1
Data collection

Dimension of Engagement	Data Collection
Emotional engagement	A survey that the students will complete at the conclusion of each lesson.
Behavioural engagement	Observations of students participating in the lessons using an observation framework.
Cognitive engagement	Student work samples will be collected in each lesson

The data collection tools/approach are designed to be used together around the observation of a particular mathematics lesson. Specifically, the data re behavioural engagement is collected by observing the students behaviour in the lesson; the data re emotional engagement is collected through a student survey immediately at the end of the lesson; and, the data re cognitive engagement is collected by analysing student work samples that were generated in the lesson.

Emotional Engagement

To identify levels of emotional engagement, the survey (see Figure 1 below) was designed based on the work of Fredricks, Blumenfeld and Paris (2004), but also drawing on the findings of Skilling (2014) and Attard (2011; 2012). Fredricks, Blumenfeld, and Paris, (2004) defined emotional engagement as showing interest in a task, and they defined “interest” as displaying “enjoyment of the activity” (p. 63). Similarly, Skilling (2014) suggests that students who are emotionally engaged “demonstrate interest and enjoyment” in mathematical tasks (p. 589). To this end, the first two items in the survey focussed on enjoyment and interest. Furthermore, although not the sole focus of mathematics education, Attard (2011) identified that the element of “fun” can play a significant role in student engagement, and she suggests that “the element of fun was identified as an element of “good” mathematics lesson” (p. 371). Therefore, the third item asks students about the fun in the lesson. Finally, the last item encompassed these features of engagement by asking it the student ‘would like to do that lesson again’.

As would be evident, the survey would be given to the students after the observed lesson and is designed to be quickly and easily completed by primary school students.

Emotional engagement Survey					
	Strongly agree	Agree	Uncertain	Disagree	Strongly Disagree
I enjoyed that lesson					
I thought the lesson was interesting					
I had a lot of fun during that lesson					
I would like to do that lesson again					
Do you have any other comments about the lesson?					

Figure 1: Emotional Engagement Survey.

Behavioural Engagement

To understand and establish levels of behavioural engagement, the behavioural engagement observation checklist (see Figure 2 below) was designed, again building on the work of Fredricks, Blumenfeld and Paris (2004) and also using Skilling (2014). Fredricks suggests that behavioural engagement “includes behaviours such as effort, persistence, concentration, attention, asking questions, and contributing to class discussion” (p. 62). Similarly, Skilling suggests that students who are behaviourally engaged “actively participate, persist, and ask questions” (p. 589). These features and defining qualities were used to develop the instrument as can be seen in the left column. The intervals in which the data will be observed and recorded on the behavioural engagement observation checklist will be dependent on the nature of the lesson but will most likely be every 3 to 5 minutes, or in accordance with the phases of the lesson.

A key feature of the observation checklist was that it had to be able to be completed ‘in the moment’. This necessitated that the data collected was simple and manageable. Clearly this means that the data collected will not necessarily have as much detail as would be desired but was seen as feasible and adequate given that the data will be collected through observations of mathematics classes.

Behavioural Engagement Observation Checklist - Example											Key
Are the students...	5 min	10 mins	15 mins	20 mins	25 mins	30 mins	35 mins	40 mins	45 mins	Notes	A = All
(INSERT SPECIFIC LESSON PHASES HERE)											M = Most
actively participating?											H = Half
asking questions?											S = Some
contributing to class discussion?											N = None
persisting with tasks?											
displaying strong levels of concentration?											
Additional Notes:											

Figure 2: Behavioural Engagement Observation Checklist.

Cognitive Engagement

Third, Attard (2011), and Connell and Wellborn (1991), suggest that students who are cognitively engaged show a desire for hard work, persistence in problem solving, and endurance in the face of failure. The literature concerned with cognitive engagement define it as an individual's direct effects towards learning and mastering the knowledge, skills and crafts associated with academic work (Fredricks et al., 2004)

While the actual nature of the student work samples will be largely dependent on the specific topic of the lesson and the activities involved, in general the following features will be looked for: evidence of mathematical conceptual development /learning vis-à-vis the focus of the lesson; evidence of higher-order thinking related to the topic of the lesson; and, evidence of persistence and sustained effort in the activities of the lesson; These are less definitive than the processes and tools for the first two dimensions of engagement, but this is inevitable given the unknown variations in primary school mathematics lesson. Also, as was noted previously, the conceptualisations of cognitive engagement are more diverse than behavioural and emotional engagement, and the definitions are varied and tend to include aspects that are also seen as part of the other two dimensions. It is envisaged that after these criteria are trialled with some empirical data, then it will be possible to refine them further.

Limitations and Discussion

There are clearly a number of limitations with the data collection tools and processes outlined in this paper, and a number of these have already been noted. The emotional engagement survey specifically relies on students being able to know and report their emotional responses after the lesson. This might be further complicated if the students are younger, or if there is some time gap between the lesson and the administration of the instrument. Also, it seems likely that students emotional response will be largely related to their later experiences of the lesson (i.e., they may not recall as clearly their emotional responses from the initial activities of the lesson). Finally, it is highly relied on that students will be able to make distinctions between the words 'enjoyed', 'interesting' and 'fun'. Apart from these practical concerns, it is also possible that aspects of emotional engagement are not captured by the survey items, and this will be monitored through the initial data analysis.

The behavioural engagement checklist is limited because it relies on the researcher observing and evaluating 'all' behavioural features present in the moment. Also, the recorded data is quite crude as in how many students are displaying the noted behaviours, but it is expected that they would give a perspective on the general engagement of the class in response to the lesson. Of course, if the lessons were video-recorded, or if there were more observers, then the complexity and volume of data and analysis would be improved.

Finally, the nature of the cognitive engagement is less clear and lacking precise definition. This is largely due to the lack of theoretical and conceptual clarity in the literature. However, given that the student work samples can be analysed after the event without the pressure of time, it is expected that thoughtful consideration will be possible.

While the tools and processes outlined in this paper are in the early stages of development, they are designed to be grounded in a robust theoretical framework. In this way, it is hoped that they will be useful to understand engagement in mathematics education.

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