

Student (dis)engagement in mathematics

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National and international studies show Australian students to be mathematically capable, yet disinterested and disengaged from the subject, perceiving it to be boring, irrelevant and difficult. Inquiry-based learning aims to contextualise mathematical learning in ways which situate it within authentic problems, with knowledge and meaning developed through discourse and representation; however, little research has been undertaken to determine whether inquiry-based learning improves student engagement. A framework based on the work of Kong, Wong and Lam (2003) is used to identify probable variables affecting engagement. The survey data collected from primary students (ages 8-12, n = 209) were compared between those with experience in inquiry-based learning and those without. Engagement scores of students involved in inquiry indicated markedly higher interest, increased attentiveness and decreased frustration; suggesting the potential for inquiry to halt or reverse the pattern of declining interest among students. With current trends of capable but disengaged students, this research may be an early indicator of a way ahead in mathematics education.

Maths is confusing and pointless. (Tahlia, age 11).

Introduction

The mathematical sciences are fundamental to the well-being of all nations. They drive the data analysis, forecasting, modelling, decision-making, management, design and technological principles that underpin every sector of modern enterprise. Mathematics is the foremost enabling science which underpins research, development and innovation in every aspect of society, from business and science through to health and national security (Australian Academy of Science, 2006; 18). The importance of a supply of capable mathematicians in an increasingly technological society cannot be over emphasised; yet international trends indicate that, while the demand for Science, Technology, Engineering and Mathematics (STEM) skills is increasing, in many countries student participation and engagement in mathematics is steadily declining (OECD, 2006). “Australia will be unable to produce the next generation of students with an understanding of fundamental mathematical concepts, problem-solving abilities and training in modern developments to meet projected needs and remain globally competitive” (AAS, 2006; 9).

Lack of ability is not the reason students are not participating in STEM subjects. According to several international studies, Australian students appear to be capable and performing relatively well in knowledge and skills areas (ACER, 2008; Thompson & Fleming, 2004; OECD, 2006). Why is it then that capable students are not participating in the STEM subjects? Findings from the *Maths? Why Not?* report commissioned by the Department of Education, Employment and Workplace Relations (McPhan, Morony, Pegg, Cooksey, & Lynch, 2008) identified five areas contributing to students decisions to not continue with higher level mathematics:

- Self-perception of ability;
- Interest and liking for higher-level mathematics;
- Perception of the difficulty of higher-level mathematics subjects.
- Previous achievement in mathematics; and
- Perception of the usefulness of higher-level mathematics. (p. iv)

One of the recommendations made in the McPhan et al. report is to enable teachers of mathematics to implement pedagogical strategies that engage students.

Yair (2000) argues that a multitude of factors all combine to impact on students' overall engagement with the enacted curriculum in the classroom setting: external contexts, background student variables and instructional variables. Whatever the source, engagement with instruction is necessary for learning, regardless of the method a teacher uses. If students pay attention to instruction, regardless of a teacher's level of expertise or approach, students are likely to learn something. However, if the teaching profession is to retain students in mathematics and actively optimise their learning, engagement of those students is essential. McPhan et al (2006) highlight the necessity for further research into mathematics learning, from early childhood to tertiary level, in order to better understand possible influences on student engagement.

This paper identifies current literature on engagement and reform mathematics and then undertakes preliminary research on student engagement with inquiry-based learning (IBL) in the middle and upper primary years at a suburban Queensland government primary school. The research presented in this paper was undertaken in the attempt to explore factors of engagement and how they may impact mathematics learning.

Engagement

Student engagement has an extensive research base (Fredricks, Blumenfeld, & Paris, 2004) and is shown to be a highly complex and multi-faceted construct. It is possibly as a result of this complexity that little has been done to formally define engagement (Finn & Voelkl, 1993) or to study engagement in terms of interventions in the school setting (Fredricks, Blumenfeld, & Paris, 2004; Finn & Voelkl, 1993). Researchers, psychologists and educators also differ in opinions of what constitutes engagement, how the construct can be measured and what factors combine to result in engagement. However, most research into engagement acknowledges three commonly identified dimensions: affective (sometimes labelled 'emotional') engagement, behavioural engagement and cognitive engagement.

In the schooling context, affective engagement can be considered the beliefs, attitudes and emotions as experienced by students. Aspects of affective engagement have been variously considered as anxiety, interest, and boredom (Connell & Wellborn, cited in Kong, Wong, & Lam, 2003); interest, achievement orientation, anxiety and frustration (Kong et al., 2003); identification with teaching staff or peers, and sense of belonging (Horn-Hasley, 2007). Behavioural engagement is identified by Fredricks et al. (2004) in three ways. The first is as positive conduct; the following of rules and the maintaining of compliant behaviour. The second is through measures of effort, persistence, concentration, attention, questioning and communicating; and finally as school commitment, identifiable through such measures as school representation in extracurricular activities. Connell and Wellborn (1991; cited in Kong et al., 2003) identify cognitive engagement as a measure of psychological investment in learning, a desire to go beyond basic requirements and the desire for challenge. This includes flexibility in problem solving, industry and resilience. There is a distinction in cognitive engagement between students adopting surface strategies, for example, memorisation as distinct from deeper strategies such as integration and justification. In school, cognitive engagement can be considered to include the way in which students attend to information, store information in memory, access knowledge and use that knowledge to solve problems.

It is important that the complexity and inter-relatedness of each of the individual dimensions of engagement be considered and this is very difficult to do in a practical sense (Fredricks et al., 2004; Kong et al., 2003). By way of illustration, a student who works diligently to complete a highly interesting, yet complex problem may be behaviourally engaged and also highly affectively

and cognitively engaged. However, a student working on multiple simple and mundane algorithms may be behaviourally engaged and yet bored, frustrated and mentally unchallenged. Likewise a student slouched in their seat and doodling on a notebook may be attentively listening and quite cognitively and affectively engaged by a presentation but giving the appearance of behavioural disengagement.

A framework for conceptualising and measuring engagement in mathematics was developed by Kong, Wong, and Lam (2003) through research and validation, resulting in the identification of significant markers of engagement. These markers have been adopted in this study as a framework for investigating, categorising and interpreting student engagement, and are as follows:

Affective engagement	Behavioural engagement	Cognitive engagement
<ul style="list-style-type: none"> • Interest • Achievement orientation • Anxiety • Frustration 	<ul style="list-style-type: none"> • Attentiveness • Diligence • Time spent on task • Non-assigned time spent on task 	<ul style="list-style-type: none"> • Surface Strategies (memorisation, practising, test taking strategies) • Deep Strategies (understanding, summarising, making connections, justifying) • Reliance (on teachers/parents)

Research indicates that student motivation and engagement are increased if instruction is authentic or relevant (Yair 2000). Marks' (2000) research defined authentic work as work that is cognitively challenging and connected to the world beyond the classroom, determining that authenticity was a powerful contributor to engagement at elementary, middle and high school levels. Implementing authentic academic work involving engaging students in a process of inquiry to solve problems meaningful and relevant to the world beyond them, and which interest them personally, was found to develop academic engagement; in one study accounting for between 18 and 22% of variance in engagement scores (Newmann, Wehlage & Lamborn, 1992). Authentic activities gain student interest, pose a significant challenge (Yair, 2000) and have greater potential for higher academic demand; providing the potential to engage students more deeply (Bonfenbrenner, in Marks, 2000).

Inquiry-based learning in mathematics

Inquiry can be defined as the pursuit of open questions and is fundamental to the study and practice of the sciences (Edelson, Gordin & Pea, 1999). However, this practice is much less common in mathematics, despite its recognition as an enabling science. In the classroom, mathematical inquiry can be described as an apprenticeship where ways of thinking are developed within classrooms that encourage and support reflective discourse (Cobb, Wood & Yackel, 1993). The teacher's role is to scaffold the students' learning through this process and to encourage autonomy.

Many advantages to learning through inquiry have been documented. McInerney (2006) argues that one of the most significant advantages is that students experience learning in the world around them, stimulating growth of logical thinking and the development of language and deductive thinking. The exposure of students to different points of view, often equally compelling or valid, can bring about cognitive dissonance, with the result that students actively seek to find understanding; potentially explaining why many teachers who have worked with inquiry report an increase in student engagement (Brown, 2004). In this process, students are required to defend, justify, modify, concede or relinquish their position, ideas or understandings, necessitating that they accommodate and assimilate developing understandings. The social interaction that takes place during this process is essential for students' cognitive development and interaction with peers

through group work. By developing their understandings using methods that they construct themselves, students connect their knowledge with existing learnings in mathematics, between mathematics and other subject areas, and between mathematics and the external world. This results in understandings with far stronger cognitive links and a far deeper understanding than rote learning and memorisation of processes.

Inquiry may also be fraught with potential difficulties; the greatest criticism levelled against inquiry is the inefficiency of the method, with too little substantive knowledge being gained to justify the expenditure of classroom time (Kuhn, Black, Keselman & Kaplan, 2000). However, a common misconception regarding “constructivist” theories of knowing is that teachers should never tell students anything directly but, instead, should always allow them to construct knowledge for themselves. Inquiry does not propose that direct teaching should never be used; there are times, usually after people have first grappled with issues on their own, that “teaching by telling” can work extremely well (Schwartz & Bransford, 1998). However, teachers still need to pay attention to students’ interpretations and provide guidance when necessary (Bransford, Brown & Cocking, 1999).

Method

A research study was undertaken in a suburban government primary school in Queensland with aims to explore the following question: *To what extent does inquiry based learning affect the engagement of middle and upper primary aged students?* The research study was embedded in a larger longitudinal study (Makar, 2008) designed to understand practices of inquiry-based teaching and learning in primary school mathematics. The researcher undertaking this longitudinal study was observing and working with 4-6 teachers who were beginning to implement inquiry-based learning (IBL) practices into their classrooms. Each term (approximately 10 weeks, with four terms a year), the IBL project classes undertook an in-depth inquiry lasting from two days to three weeks. For the remainder of the time, students were taught from a commercial program implemented school-wide. Classes which were not engaged in the IBL project were taught from the commercial program.

At the commencement of the third year of the longitudinal project, the students across Years 4 to 7 at the school had varying levels of exposure to inquiry-based learning, depending on which classes they had been in each year. These students constituted the potential subject group. Summary statistics are provided for the sample in the tables below by gender and Year Level (Table 1).

Table 1 Number of Respondents by Gender and Year Level

n=	Year 4	Year 5	Year 6	Year 7	Total n
Male	25	26	23	18	92
Female	36	28	28	25	117
Total n	61	54	51	43	209

Survey Instrument and Administration

Kong et al.’s (2003) survey, *The Student Engagement in the Mathematics Classroom Scale*, consisted of 55 items rated on a five-point Likert scale (1= strongly disagree, 2=disagree, 3=neutral, 4= agree, 5= strongly agree). The Scale provided a useful, validated measure of classroom engagement across the three dimensions of engagement identified through research. The language of the survey questions were revised slightly to allow for the younger age of students and to

incorporate Australian English. For example, “*I think memorising the facts and details of a topic is better than understanding it holistically*”, was revised to “*It is better to memorise facts and details than to understand them.*” The reliability indices of the revised survey were within an acceptable margin of variation with the original survey (see Wells, 2008 for more details).

Surveys were administered to students in the second term of the school year. In all cases, the surveys were administered by the first author to students in their class groups. This was usually done within the classroom, but on occasion, particularly if there were a low number of respondents in a particular class, the researcher withdrew the students to a group area to enable the classroom teacher to continue with the lesson.

Analysis

Student results was analysed without student names to prevent any possible sub-conscious bias in future interactions with students; for example, if they reported a dislike of mathematics, or of their teacher and so forth. For the purposes of reporting, each student number was later allocated a randomly generated name matching their gender only.

The responses of students who were continuing to, and had already taken part in, IBL for at least the year prior to the survey were compared to those of students who had not been part of one of the IBL classrooms at all. This was done in order to identify any differences between IBL and traditional learning without discontinuation of IBL as a factor.

Statistical analyses were conducted to determine whether significant differences could be identified when each dimension was disaggregated by level of inquiry at the $p < 0.01$ level across each of the engagement dimensions. A more conservative p value was used to counteract the increased risk of Type I error variance due to multiple comparisons being made and to increase the power of the statistical tests. The results of these analyses are provided in the summary table below (Table 2) with data organised according to the dimension of engagement. Inquiry level findings are each reported, along with number of subjects (n), mean, standard deviation (SD), test statistic, p value and effect size for significant findings. Eta squared has been calculated to determine effect size and interpreted according to Cohen (1988) in considering 0.01 a small effect size, 0.06 a medium effect size and 0.14 is a large effect size.

Results

Three dimensions of engagement indicated significant differences between students who completed at least one year of IBL and were continuing and students who had not completed any IBL (Table 2). These three dimensions of engagement are elaborated below with student comments to illustrate students' overall feelings about these dimensions (further details can be found in Wells, 2008).

Table 2 Survey results comparing each dimension with student experience with IBL

Dimension of Engagement	Level of Inquiry	N	Mean	SD	t (F)	Sig.	Effect Size (eta squared)
Achievement Orientation	Nil	92	4.42	0.567	-0.798	0.427	
	Previous Year and continuing	16	4.54	0.391			
Anxiety	Nil	89	2.93	0.910	0.952	0.343	
	Previous Year and continuing	16	2.69	1.148			
Frustration	Nil	90	2.66	1.005	3.305	0.001	0.10
	Previous Year and continuing	16	1.78	0.884			
Interest	Nil	90	3.26	0.884	-2.869	0.005	0.07
	Previous Year and continuing	16	3.95	0.894			
Attentiveness	Nil	91	3.54	0.677	-3.233	0.002	0.09
	Previous Year and continuing	16	4.13	0.657			
Diligence	Nil	86	3.66	0.680	-1.819	0.072	
	Previous Year and continuing	16	3.99	0.529			
Surface Strategies	Nil	87	3.08	0.771	1.800	0.075	
	Previous Year and continuing	15	2.68	0.939			
Deep Strategies	Nil	92	3.12	0.727	-1.585	0.116	
	Previous Year and continuing	15	3.46	0.912			
Reliance	Nil	90	3.21	0.708	-0.241	0.810	
	Previous Year and continuing	15	3.26	0.719			

Frustration

Many students reported being frustrated with mathematics referring to it as 'boring' or 'difficult':

Terrance: It is really boring...there's no fun or anything in it.

Sang: I do not like maths because it's hard and boring.

Daniela: I understand but [it] is very boring.

More commonly, students considered mathematics as difficult to understand:

- Tahlia: Some parts of math are confusing and pointless. It is annoying when you don't understand something.*
- Dana: I wish there was an easier way to learn maths because I suck!*
- Mya: Maths is not good, it's horrible, it's confusing.*
- Zeb: I like maths but I just can't figure it out.*

Furthermore, many comments from the upper primary students indicated increasing frustration with mathematics, citing a lack of appeal, depth, locus of control and connectedness to classroom mathematics.

- Jaxon: I want to do the maths problems to way I want to do, instead of the [way that] the teacher wants me to.*
- Payton: I really do not like [name of commercial program] because it just gives you questions and not really gives you time to understand.*
- Ana: I think when we learn math all it is, is $3+70/2=?$ Now go do your page all it is, is explaining, it should be more fun.*

Students were able to suggest improvements, many of which aligned with IBL:

- Ella: I have always liked hands on teaching and I do not like memorising maths.*
- Lynne: [Teacher1] sometimes doesn't make teaching fun because we usually have to copy of long pieces of writing off the board. [Teacher 2] makes work very fun because it's all interactive.*
- Bryan: We need to learn other ways than just [commercial program].*

Interest

The results of data collected on the Interest levels of students in mathematics indicate that students who have taken part in more than one year of IBL and are continuing with it report a mean interest higher than that of those who have not taken part in IBL.

Comments provided by students were extensive with a few simply professing enjoyment of mathematics:

- Elliott: I love maths in any way it comes. I find maths interesting in any way.*
- Jorge: Maths is mostly fun or interesting.*
- Cathy: I love learning new things and old things.*

Many others independently suggested ways in which mathematics could be made more interesting, many specifically referencing interest and IBL:

- Leila: I really like inquiry maths as it's interesting to do especially with the class.*
- Brittney: I liked the inquiry maths because it wasn't just math it was a fun way to get involved and I preferred it.*
- Andrea: The inquiry maths in Year 5 was fun.*

Attentiveness

The ‘attentiveness’ sub-scale measures the degree to which students report paying attention to lessons in class. Involvement in IBL is associated with higher reported attentiveness with a moderate to large difference between mean scores. The mean level of attentiveness for students taking part in ongoing IBL was significantly higher, scoring between ‘agree’ and ‘strongly agree’ on the Likert scale and with a moderate to large effect size. Students identified mathematics lessons lacking the interest to keep them attentive, for example:

Perry: ...it can get boring on some occasions. It just means that I can catch up on my sleep.

Other comments about inquiry

The students that had been involved in IBL made numerous unsolicited comments regarding their preferred learning method, and these are worth noting below:

Deann: I think I learn better using inquiry maths because it is more hands on. I find inquiry maths easier to understand and more interesting than [commercial mathematics program].

India: I like inquiry maths better than [commercial program] because it is more fun and I learn better when I am actually doing it.

Seth: I mostly like inquiries.

Joanna: Inquiry maths is a fun way of learning maths that helps to understand a different type of maths.

Nadia: I like the inquiry maths a lot better.

However, not all students were supportive of IBL, one student had a negative comment to make:

Andre: I'm not very fond of inquiry-based learning because I learn just as much doing maths the normal way; doing it the normal way is faster and easier.

Discussion

Interest and frustration were two factors that showed strong practical differences between groups and there was a very strong inverse relationship between the two. The large differences between the inquiry group and the traditional group suggest great potential for the engagement of students. Fielding-Wells and Makar (2008) report findings which suggest that students find increased interest in mathematical topics in which they: are interested, can relate to, perceive to have value, can identify novelty and/or can experience enjoyment. These findings align neatly with Lepper and Hodell's (1989, cited in Child, 2007) identified sources of intrinsic motivation: challenge (interest, value), curiosity (relatedness, value), fantasy (novelty, enjoyment), and student control, which is present by definition in inquiry.

Fielding-Wells and Makar (2008) and Lepper and Hodell (1989, cited in Child, 2007) identified the importance of providing children with contexts that they could relate to in order to increase intrinsic motivation and engagement. The results of contextualised learning has been reflected in the reports of use of deep strategies in learning, against which student involved in inquiry scored highly against statement such as “*I try to connect what I have learnt with what I see and do in real life.*”

Overall, the inquiry learning undertaken by the subjects in this study appears to have brought about significant change in the way they engage with mathematics. The increased level of interest and decreased level of frustration has the potential to address the critical decline in student engagement with mathematics, and is a most exciting result. Lack of connectedness and inability of students to see a purpose for mathematics are two of the most widely reported reasons for decline in students continuing to higher levels of mathematical studies (DETA, 2007; NCTM, 2000). Inquiry learning may well be a key to transform that decline; if nothing else, it is certainly worthy of continued research.

Limitations

The research presented in this report has endeavoured to contribute further to understandings of student engagement and engagement as it relates to mathematical reform. However, this research, by necessity of the subject pool available, was only conducted in a single school context and from a relatively small pool of potential subjects. Further analyses to consider gender and age differences between students engaged in inquiry would have been useful; however the limited number of students in the inquiry group rendered this impossible. The limited socio-economic spread of students and lack of opportunity to study minority groups was also a limitation. While the purpose of this study was to begin to identify patterns in the engagement of students taking part in inquiry; it would have also been of use to have used a measure of achievement with the students to identify patterns in conceptual development also.

Conclusion

As stated previously, this research project was exploratory in nature and was designed with the purpose of identifying some of the issues with engagement that might be present in primary school students who had been undertaking inquiry-based learning. A further aim was to identify some of the relationships that might be present between individual dimensions of affective, behavioural and cognitive engagement and to determine how these variables might account for student engagement.

The study undertaken here suggests that inquiry-based learning looks to be a significant factor in increased student interest, with the IBL group also reporting a much lower degree of frustration than the non-IBL group. This is of immense importance for educational professionals as it may tentatively indicate that inquiry has the potential to reverse the downward decline of engagement.

Engagement is exceptionally important, for without engagement students have limited opportunity to take part in the curriculum, however, increased engagement of itself may increase the numbers of students continuing with mathematics; yet if they are conceptually unchallenged, the purpose of increased student numbers is voided. It is necessary then that increased interest is aligned to depth of knowledge and that an appropriate balance be determined.

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