Student Perspectives of Engagement in Mathematics

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Engagement in mathematics education is an important factor in a successful student experience. This paper reports findings from a study of Year 5 student perceptions of engagement during a two-week, inquiry-based learning (IBL), problem-posing investigation. The study triangulated data from semi-structured interviews, video observations and student work samples to understand the student's perspectives of IBL; however, this paper reports the interview data. The findings indicate that most of the students were behaviourally, emotionally, and cognitively engaged during the IBL investigation, and that the investigation provided an opportunity for students to experience levels of competence, relatedness, and autonomy need satisfaction.

Over the past decade, inquiry-based learning (IBL) has become increasingly more prominent in educational policy and curriculum as countries look to increase student engagement and achievement (Artigue & Blomhøj, 2013). More recently, there has also been increased interest in the use of IBL in mathematics education (Dorier & Maaß, 2020). In response to declining achievement and engagement in mathematics and science, the European Union invested heavily in research into, and the development of, IBL. The 4-year international project, Promoting Inquiry in Mathematics and Science Education Across Europe (PRIMAS), examined inquiry-based pedagogy and sought to develop best practices for implementing IBL in mathematics and science (PRIMAS, 2013). Several studies have subsequently indicated the positive effect of IBL on student achievement and student motivation in mathematics (Dorier & Maaß, 2020).

In Australia, the emphasis on IBL in mathematics was encouraged by the Office of the Chief Scientist (2013) and highlighted to improve learning in mathematics. Although some research projects have looked at different aspects of IBL such as: teacher training (Fielding-Wells et al., 2017); learning environments (Brough, 2012); and, student motivation and engagement (Dorier & Maaß, 2020); little has been done to implement IBL in education systems more broadly. Whilst there are criticisms of IBL (Sweller, 2011), there is also a considerable amount of evidence that supports it as an approach that actively engages students in their learning and supports transfer to other learning contexts (Sullivan, 2011). More specifically, inquiry in mathematics has been found to support the development of meaning making and collaborative norms in mathematics classrooms. It has also been recognised for its potential to develop understanding, interest and engagement in mathematics, independence and creativity in solving problems, and student ability to transfer their learning to authentic problems (Laird et al., 2019).

How to engage students meaningfully in mathematics is a long-standing issue and the need to improve their engagement across all age levels remains a concern. Engaging students positively with mathematics early in primary school is a necessary first step, with Attard (2012) suggesting that engagement at this level is "crucial if students are to develop an appreciation for and understanding of the value of mathematics learning" (p. 22). Indeed, active participation is a component of the Framework for Engagement with Mathematics (Attard, 2012). We later refer to this framework in the Discussion to understand better student engagement.

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Engagement is multifaceted but is commonly conceptualised in three ways; behavioural, emotional, and cognitive (Fredricks et al., 2004).

- Behavioural engagement refers to what the students are doing; participation, effort, persistence, and on-task behaviour. It can be identified by observing student's self-directed behaviours such as asking questions, raising their hands, participating in discussions, and actively engaging with their peers (Fredricks et al., 2004).
- Emotional engagement involves enjoyment and interest, and incorporates student attitudes, interests, and values. It is a consideration of students' willingness to take on challenges, their sense of belonging, and focuses on both positive and negative aspects of student reactions to school, teachers, and activities. It considers whether students are experiencing boredom, happiness, sadness, or anxiety and the impact of these emotions on learning. The idea that emotion can affect the cognitive processes in humans is well developed (Tyng et al., 2017), and it can positively or negatively influence a student's perception, attention, learning, memory, reasoning, and problem-solving ability (Fredricks et al., 2004).
- Cognitive engagement focuses on self-regulated learning and personal investment in learning. It considers intrinsic motivation and how students control and manage tasks, maintain effort despite distractions, display flexibility in problem solving, make connections between ideas, and exert effort to develop complex ideas and develop understanding (Fredricks et al., 2004).

Research regarding engagement is often intertwined with motivation (Grootenboer & Marshman, 2016), with motivation being referred to as "the underlying reasons for a given behaviour" (Fredricks & McColskey, 2012, p. 765). This study used the three dimensions of engagement (behavioural, emotional, cognitive), and the self-system model of motivational development (SSMMD) (Ryan & Deci, 2017), to understand engagement and motivation. The SSMMD focuses on three fundamental motivational needs: competence, autonomy, and relatedness, and assumes that if "schools provide children with opportunities to meet these three needs, students will be more engaged" (Fredricks & McColskey, 2012, p. 765).

The effect of disengagement in mathematics has significant future implications for individual life opportunities and success (Attard & Holmes, 2020), as well as economic implications more broadly (e.g., employment opportunities; contribution of mathematics to the knowledge economy). This paper reports on one aspect of the study which sought to understand student engagement by investigating student perceptions of their levels of engagement as they created their own mathematics investigations, based on a video stimulus provided by the researcher. Two key questions underpinned the research: "How do Year 5 students perceive engagement in mathematics during an IBL mathematical problem-posing investigation?"; and "How do Year 5 students perceive their ability to problem-pose using a video prompt as stimulus during an IBL mathematical problem-posing investigation?" This paper presents the findings on the first question (i.e., the impact problem-posing on student engagement).

Theoretical Framework

The theory which underpinned this study, and supported the paradigmatic choices, is cultural-historical activity theory (CHAT). The origins of CHAT date back to Vygotsky's insights into the effect that social and cultural experiences have on and subsequently developed by Leontiev, and then Engeström, to form a theory that assists researchers to understand social environments, such as school classrooms learning (Koszalka & Wu, 2004). CHAT defines learning as "a process of constant interaction with the environment and others. Knowledge is constructed by individual learners, built on historical experiences, within his or her context, knowledge is not transferred, rather it is constructed differently in all individuals" (Koszalka

& Wu, 2004, p. 494). CHAT aligns with a social-constructivist view that knowledge is socially constructed, with no single reality (Merriam & Tisdell, 2016). CHAT contributes to our understanding of learning in this study as the students are engaged in a social activity, where they are constructing their own understanding of mathematics, rather than having it transferred to them via the teacher or a textbook. From this perspective, learning occurs best when a learner is engaged in the experience. In this way constructivist research aims to develop rich, contextual understandings about the world through the point of view of those living it.

Method

A qualitative, single instrumental case study approach was used, adopting the perspective that there are multiple realities worth representing (Merriam & Tisdell, 2016). Case study methodology provides the researcher a platform to investigate the various perspectives of the participants and identify patterns, relationships, and themes. The use of a single instrumental case study was appropriate in this study as it investigated one class and developed understandings based on the student perspectives from that one 'bounded' class. The researcher led a two-week open, mathematical investigation which required students to develop their own investigation questions based on a video prompt. The video prompt centred on a tennis theme and was created by the researcher to provide students with a wide scope for the creation of appropriate investigation questions. Seventeen students worked in collaborative pairs, or groups of three, to investigate their own questions and present their findings.

Data Collection and Analysis

Data were collected through semi-structured interviews with students (Merriam & Tisdell, 2016), video observations, and student work samples. The students were interviewed to identify their perceptions of engagement in mathematics during the IBL mathematical problem-posing investigation. The students were interviewed in a quiet space in pairs and were grouped with their collaborative partners wherever possible. However, two groups of three were divided to make three interview pairs. Students were interviewed in pairs to ensure they felt comfortable and safe to share their thoughts and to help eliminate any anxiousness or apprehension regarding their participation in an interview. The interviews were audio recorded and transcribed by the researcher. Thematic analysis was used to identify, analyse, and interpret patterns within the data. Thematic analysis "provides accessible and systematic procedures for generating codes and themes from qualitative data" (Clarke & Braun, 2017, p. 297). Following thematic analysis, the themes were then triangulated (Flick, 2018) using student work samples, video observations, and literature related to the phenomenon.

Participants

The research was conducted at an independent school in South-East Queensland, Australia. The Year 5 class (9.5-10.5 years of age) consisted of 17 students: 8 boys and 9 girls, and one participating teacher. 16 out of 17 students participated in a semi-structured interview, one student was absent and was thus unable to be interviewed. The school teaches the Australian curriculum through student-centred, individual pathways and students are engaged in a range of pedagogies throughout each day. These students learn mathematics using a commercial mathematics program, which includes student online learning and a suggested pedagogical approach that incorporates support for the delivery of personalised learning to each student. The program is organised in a modular format, and students work on individual pieces of learning on a computer and worksheets. Students engage in online tutorials, and answer questions based on their readiness, and take fortnightly paper tests to identify growth and areas for improvement. The teacher provides additional support through mini workshops as needed.

Other areas of the curriculum are taught through integrated units, focused language lessons and discovery learning based on personal interests. Students regularly experienced posing questions for personal investigations.

Findings and Discussion

Three themes emerged from the data regarding the student's perceived engagement in mathematics during the IBL mathematical problem-posing investigation: collaborative learning; enjoyment and interest; and cognitive engagement and learning transfer.

Collaborative Learning

The students indicated that working together and actively engaging with their peers was something that made learning more engaging and supported the development of their understanding. The comments suggested they felt a sense of competence and relatedness during the investigation. For example (pseudonyms are used for student names):

> Freya: Having different people in my group that we could all understand, so I can share with them what I wouldn't normally share with them so then it made me personally understand it more.

> Koby: It's been really fun and umm, engaging. Like we're working, we are collaborating, and we are like talking together. And we are figuring out problems, like not just looking at a screen [referring to commercial program], most of the time we were like organising stuff, not organising stuff, but like writing things down, figuring it out on paper.

> John: But I like it in groups to be honest because students who say they know a question, or I know a question that other people don't, I can help them with that, or they could help me with this.

Competence is associated with the perception of academic ability and self-efficacy and posits that all individuals need to experience themselves as effective individuals in their interactions (Ryan & Deci, 2017). Throughout the peer learning environment of the investigation, the students were offering explanations, justifying their thinking, and providing peer support, which assisted their classmates to understand at a deeper level. This provided the opportunity for those students to feel competent, while increasing the sense of belonging for all students. A sense of belonging or relatedness was further evidenced by their choice of words such as, "communicate", "collaborate", "working together", "talking together", "socialise", and "bonded" when describing their experience. Having a sense of belonging in a certain environment, or in a particular activity, has been associated with increased levels of engagement (Skinner et al., 2008). Active participation, which is associated with behavioural engagement, is considered imperative to the achievement of positive academic outcomes and is a component of the Framework for Engagement with Mathematics (Attard, 2012). While experiencing levels of relatedness and competence need satisfaction, the students also explained that the element of choice impacted their engagement, Gemma's comment highlights this:

> Gemma: If the teacher's kind of going, do you want to do this? Or do you want to do this? If you can have lots of options, it keeps me engaged. Like what we did, we had options to make a tournament or build a tennis court or something like that, we had different options.

Learning environments that offer choice and provide students with the opportunity to be creative have been shown to be engaging (Attard, 2012; Attard & Holmes, 2020). Offering choices to students provides them with a sense of autonomy over their learning. The third element of the self-system model of motivational development (Ryan & Deci, 2017) emphasises the need for teachers to allow students to demonstrate autonomy within the classroom environment (Fredricks & McColskey, 2012). Experiencing a sense of autonomy in school settings has been linked to "better academic outcomes such as classroom engagement, persistence, achievement, and learning" (Skinner et al., 2008, p. 768).

When analysing the video observations for behavioural engagement, the researcher looked for on-task behaviour such as the students being engaged in writing, discussions with teachers or peers (listening, explaining), and positive gestures and postures. Out of the 17 students participating in the study, 15 of them were observed being behaviourally engaged almost all the time. During the lessons, the students were observed writing and calculating, having discussions, and seeking help from the teacher when required. Occasionally, one of these students, needed redirecting to the task; however, this was generally towards the end of a session. Two of the 17 students, who were working together, were observed to require continual redirection from the teacher and were rarely focused without direct teacher support. Although the groups were strategically organised by the classroom teacher and Eric (one of the two students) reported that he found the investigation "fun" because they could, "carve our own paths", it is possible that the autonomy offered in the investigation did not support learning for these two students.

Enjoyment and Interest

The second theme that arose from the data was related to emotions associated with the investigation and the idea of having fun. The word "fun" was found fifty-one times in the transcripts. The students reflected on their regular mathematics lessons using emotive language such as, "boring", "bland", "bored" and described the two-week investigation as "fun", "funner [sic]", "interesting", and "awesome". This aspect of engagement is known as affective or emotional engagement. Emotions have been shown to play a significant role in how students lose engagement or become dissatisfied and frustrated in schooling (Skinner et al., 2008). When students feel negative emotions such as boredom, it affects their willingness to actively participate and influences their overall perception of that subject. The students also explained that the investigation offered an element of challenge, helped them to connect mathematics to real-life events, and provided the novelty of doing something different. For example:

> Nick: Well, it was kind of out of the blue when you showed us the tennis video. Also, I thought how can this relate to maths? And when we actually go into it, I realise how like, how much maths is involved in in everything. I would just look at these flowers and say they aren't really maths, but now I can see there is math in them.
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> Lucy: Because it was like, it was different, and I like different. And so, it was really fun, really engaging. Yeah, just, it was really different.
>
> Lara: It was just a really great experience to just enjoy a different way of math. The experience, it was fun, enjoyable and challenging at some points.

The positive emotions that the students experienced may be related to the academic content, available choices, challenge (Attard, 2012), their friends, teacher, or the novelty of doing something different (Fredricks et al., 2004). Recent research on the psychological needs outlined by self-determination theory (Ryan & Deci, 2017) has included the potential need for novelty (Benlahcene et al., 2020). The need for novelty "refers to the innate desire to experience new things that have not been experienced before or that differ from a person's daily routine" (Benlahcene et al., 2020, p. 1291). González-Cutre and Sicilia (2019) found that, beyond the three basic needs of autonomy, competence, and relatedness, novelty was significantly associated with positive outcomes, motivation, and satisfaction of students. Within this study many of the students indicated that they enjoyed the investigation because it was "unique", "different", or "different to what we normally do"; therefore, the novelty factor needs to be considered as one of the factors that may have impacted emotional engagement.

The students experienced a range of positive emotions including interest, enjoyment, fun, and inquisitiveness. Furthermore, the interview data indicated that all students were interested in participating in a similar investigation in the future, reinforcing the earlier claim that this was a positive experience for them. Skinner et al. (2008) explain that emotional and behavioural engagement are closely linked and that theories related to engagement and motivation suggest that "it is engaged emotions, such as interest and enthusiasm, that fuel engaged behaviours, such as effort and persistence" (p. 767). As previously mentioned, the video observations indicated that 15 of the 17 students were observed to be behaviourally engaged; however, it is difficult to observe emotional engagement and thus it must be inferred from demonstrated behaviours (Fredricks & McColskey, 2012). Therefore, the self-reports of emotional engagement collected through the semi-structured interviews are triangulated with the behavioural engagement observations to support the finding that the students were emotionally engaged during the IBL mathematical problem-posing investigation.

Cognitive Engagement and Learning Transfer

During the interviews the students explained that they were able to use the knowledge and skills previously acquired while working on their investigations in new scenarios. The investigation offered the students an opportunity to practically apply previously learnt skills, build confidence, and challenge themselves intellectually. This aspect of engagement is known as cognitive engagement, which emphasises self-regulation and personal investment in learning (Fredricks et al., 2004). The qualitative data from the interviews, video observations, and student work samples together demonstrated that 15 of the 17 students were cognitively engaged. Many students explained that the investigation provided an opportunity to practise learnt skills, which helped them to feel more confident in their mathematical understanding:

> Milly: Maybe [I learnt] a few things like, but mostly just practising the things that we already knew. And like, putting it to the test and using it.
>
> Koby: Practicing stuff that I already knew. But I felt like I had grown, I learned. I had boosted my confidence on that stuff that I was still learning…because I practiced stuff that I don't really practice anymore. So, I feel like that I got a lot better, like at times tables.
>
> Lucy: It was helpful in many ways, but mostly practising and like, trying to know the maths you already know but like knowing it better and understanding it.

The interview data provided evidence that the IBL mathematical problem-posing investigation was an opportunity for the students to develop their conceptual understanding, a key component of cognitive engagement (Fredricks et al., 2004). Additionally, the students practised their skills, reviewed their knowledge, and transferred their understanding through practical application. In his review of Australian mathematics education, Sullivan (2011) outlined six key principles for effective teaching of mathematics with one of the key principles highlighting the importance of transferring learnt skills. Haskell (2001) explains that learning transfer happens when students recognise past learning and apply and extend that learning in a different situation.

An emphasis on cognitive transfer aligns with the expectations of the Learning Continuum of Critical and Creative Thinking (CCT) within the F-10 Australian curriculum, which expects learners to transfer knowledge into new contexts (Australian Curriculum, Assessment and Reporting Authority, 2016). The inability of students to transfer concepts, skills and procedures is one that concerns many educators and managers in work environments (Dixon & Brown, 2012). Students often fail to recognise that their prior learning can be used to solve similar real-life problems because such problems differ from the structured situations often presented in school (Dixon & Brown, 2012). Paige's comments about the investigation, and "usual math" reflect a previous lack of opportunities to transfer mathematical learning to real-world situations or investigations:

> Paige: Um, it was very different, because it's a different world, different math learning, because you'd always have to think about money, and like how much it costs and your budget. So that's very different to the ones that we do on our levels [referring to Maths Pathway]. And you learn like how to, you learn new things, like what some people actually do this for, like to organise tournaments, like in different sports, and they actually have to plan this out every time. So, it's like, wow.

The requirement to transfer knowledge highlights the need for a variety of learning engagements within the classroom, so that students can transfer their understanding, apply and develop their mathematical skills, and connect mathematics to real-life contexts. The IBL mathematical problem-posing investigation provided an opportunity for students to do so.

Conclusion

This paper focusses on student perceptions of engagement in mathematics during an IBL mathematical problem-posing investigation. The findings indicate that all students perceived themselves to be emotionally engaged (n = 17), while almost all (n = 15) were behaviourally and cognitively engaged. The students suggested that the investigation provided them with opportunities to make choices, work autonomously within their group, support peers in their learning, build peer relationships, and challenge themselves. These findings align with Ryan and Deci's (2017) self-system model of motivational development, which is based on self-determination theory and focuses on fundamental motivational needs: competence, relatedness, and autonomy. Novelty was found to be an additional important factor in student engagement.

Although the findings are presented as three separate themes, they are interconnected, affecting each other in various ways. Students who are actively participating, asking questions, engaging in discussions (behaviourally engaged), and self-reporting or demonstrating interest and enjoyment (emotionally engaged) may or may not be cognitively engaged. When one aspect of the environment or learning engagement is altered, all three types of engagement are influenced (Fredricks et al., 2004). Various combinations and levels of engagement may exist, and when designing learning environments, all three dimensions of engagement should be considered holistically with consideration to the multidimensional and complex field of engagement in learning.

There are many factors that may influence engagement or disengagement, such as prior experiences, the teacher, learning needs, and personal interests. However, it was beyond the scope of this project to delve into each aspect that may or may not have been a contributing factor. The use of student voice and the triangulation of video observations and student work samples did, however, provide insights into the ways engagement in mathematics learning can be enriched from the student's perspective.

The limitations of this study include the small case size and timeframe: the study was conducted in one class with 17 students, over a two-week period. The students had not created mathematical investigations or problem-posed before and were limited by the two-week timeframe. Future research directions could include a longitudinal study to provide greater insight into different aspects of engagement during an IBL mathematical problem-posing investigation, and further explore the relationship between engagement and learning during an investigation.

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