Identifying Practices that Promote Engagement with Mathematics Among Students from Disadvantaged Backgrounds

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Students' post-school options are limited if they have not completed mathematics subjects involving the study of calculus. This paper employs a sociocultural approach to identify institutional practices that might promote sustained engagement with these subjects among students from disadvantaged backgrounds. Drawing on interviews with mathematics teachers and the school guidance counsellor, six themes emerged as potential institutional practices contributing to increased enrolments: curriculum organisation across year levels, staffing of mathematics classes, culture of the Mathematics Department, STEM program, and provision of appropriate tasks and resources.

Students whose post-school aspirations involve university qualifications in areas such as engineering, health sciences, economics or agricultural sciences need to complete mathematics subjects involving the study of calculus in the final two years of schooling. These subjects, often described as Intermediate and Advanced Mathematics subjects, are therefore crucial for opening up individual life chances. Students from disadvantaged backgrounds are over-represented among those who do not meet national and international benchmarks in mathematics (e.g., Thomson, De Bortoli, & Underwood, 2017). They are also under-represented in mathematics related degree programs at university (Ainley, Kos, & Nicholas, 2008). These findings suggest that students from disadvantaged backgrounds are less likely to choose to study Intermediate and Advanced Mathematics subjects than their peers from more privileged backgrounds. Identifying ways to promote students' aspirations and engagement in learning mathematics may be one way of broadening post-school options for students from disadvantaged backgrounds.

In Australia, there is a national trend of declining participation in Intermediate and Advanced Mathematics subjects (Barrington & Evans, 2016). Despite this trend, some schools located in low socioeconomic areas have achieved increased enrolments in these subjects. This paper reports on some preliminary findings from a study that is investigating practices that may have contributed to improved engagement and enrolment in Mathematics B (the Intermediate Mathematics subject offered in Queensland) by students from disadvantaged backgrounds. The aim of the paper is to identify practices that appear to be effective in promoting sustained interest and engagement in mathematics involving the study of calculus, via a case study of one school located in a low socioeconomic area.

Background and Context

Science, Technology, Engineering, and Mathematics (STEM) disciplines have a pivotal role in making Australia globally competitive (Office of the Chief Scientist, 2014). To undertake tertiary studies in these disciplines, students need to successfully complete

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mathematics subjects involving the study of calculus in their final two years of schooling (Intermediate or Advanced Mathematics subjects). The importance of studying these subjects extends beyond the STEM disciplines because they provide the necessary mathematics foundation for an extremely broad range of professions, and therefore open up life chances. From 2006 to 2015, the percentage of Year 12 students who enrolled in Advanced Mathematics and Intermediate Mathematics decreased from 10.6% to 9.6% and from 21.8% to 19.2%, respectively (Barrington & Evans, 2016). This downward enrolment trend is more concerning when enrolments in these subjects in 1995 were 14.1% and 27.2%, respectively (Barrington, 2011).

The issue of declining enrolments in Advanced and Intermediate Mathematics subjects is exacerbated among students from disadvantaged backgrounds. Students from linguistically, culturally, and socioeconomically disadvantaged backgrounds are disproportionately represented among those who fail to meet the benchmarks in the National Assessment Plan – Literacy and Numeracy (NAPLAN) and Program for International Student Assessment (PISA) numeracy tests. In PISA 2015, for example, only 37% of students in the lowest socioeconomic quartile met the national benchmark (as agreed in the *Measurement Framework for Schooling in Australia*) compared to 76% of students in the highest socioeconomic quartile (Thomson et al., 2017). One of the implications of these findings is that few students from disadvantaged backgrounds are likely to undertake higher levels of mathematics in their final two years of schooling, thereby limiting their career choices. This paper addresses following research question: What institutional practices might contribute to promoting sustained interest and engagement in Mathematics B among students from disadvantaged backgrounds?

Theoretical Framework

Rogoff's (1995) three planes of analysis were adopted to construct a person-in-context framework for analysing students' subject choice decisions within overlapping personal, social, and institutional levels.

At the personal level of analysis, *engagement and motivation* constitute one set of affective factors influencing students' aspirations towards mathematics (Watt & Goos, 2017). These factors are underpinned by psychological constructs such as beliefs, identity, self-image, anxiety, emotions, and attitudes (Lomas, Grootenboer, & Attard, 2012). A second set of affective factors derives from *students' perceptions of their ability and achievement*, as these perceptions are related closely to identity and self-image (Sheldrake Mujtaba, & Reiss, 2014).

At the social level of analysis, *teacher beliefs and practices* in mathematics classrooms are strongly related to student engagement (Attard, 2014), confidence and belonging (Darragh, 2013). In several studies, teachers were regarded as the main source of encouragement for students to continue with secondary mathematics in post-compulsory settings (e.g., Noyes, 2012).

At the institutional level of analysis, the influence of *educational structures and processes* on student academic aspirations has been the subject of international debate (e.g., Reiss et al., 2011). Major barriers identified include shortage of qualified teachers (Hobbs, 2013), and the political nature of public discussion around contested curricular aims (Noyes & Adkins, 2016).

The *institutional plane* is foregrounded in this paper in an attempt to identify educational structures and processes that may contribute to increasing participation of students in this subject. Although the focus is on the institutional plane, it is acknowledged that interactions a student has with teachers, fellow students, guidance counsellors, and parents (*social plane*) along with development of affective traits and identity (*personal plane*) contributes to their motivation to study Mathematics B.

Research Design and Methods

The study was conducted in 2017 and employed purposeful sampling to identify schools located in low socioeconomic areas in Queensland that have recorded a sustained increase in enrolment in Mathematics B over the period from 2012 to 2016. A sustained increase in enrolment in Mathematics B was considered to have occurred if the ratio of enrolment in 2016 to that in 2012 was greater than one and the total school population was relatively stable. A further constraint was that the subject enrolment for both years was greater than ten. Data for this paper are drawn from one of the three participating schools to illustrate the approach taken in the study and identify effective practices in this school.

Marigold State High School (pseudonym) was in a low socioeconomic area on the outskirts of large metropolitan city with 82% of the student population in 2017 from backgrounds in the bottom two quartiles for socio-educational advantage (https://myschool.edu.au/). Local issues identified by the guidance counsellor that might impact on student engagement with schooling included high unemployment, mental health issues, drug and alcohol dependency, and intellectual disability among parents. Student performance on numeracy in the NAPLAN for Year 9 in 2017 was lower than, but not significantly different from, the Australian average. The student population was approximately 1,500, of whom 10% were from Indigenous backgrounds and 11% were from a language background other than English.

Participants were five mathematics teachers (including the Mathematics Head of Department), the school guidance counsellor, 13 students across Years 10 and 11 nominated by their teacher because they are planning to study Mathematics B (Year 10 students) or had already commenced studying this subject (Years 11 students). The mathematics teachers and guidance counsellor participated in individual semi-structured interviews that lasted between 16 and 32 minutes. Interviewees were asked about their backgrounds, information about mathematics in the school (e.g., how classes are arranged, advice given to students, and strategies they think have led to an increase in enrolments in Mathematics B). Students participated in semi-structured group interviews with fellow students from the same class that lasted between six and 17 minutes. Questions focussed on students' past experiences of mathematics and factors that had influenced them to study Mathematics B. Interviews were audio recorded and transcribed. Additional data included lesson observations of Year 10 mathematics and Year 11 Mathematics B classes taught by the interviewed teachers and school documents relating to subject selection. As the *institutional plane* is foregrounded in this paper, data collected from the mathematics teachers and guidance counsellor are drawn on to identify institutional practices that might contribute to the observed increased enrolment in Year 12 Mathematics B from 33 students in 2012 to 42 in 2016.

An inductive content analysis was employed to identify educational structures and processes within the institutional plane that may contribute to increased participation in Mathematics B. This analysis was initially conducted for the interview responses from the Mathematics Head of Department (HoD), then applied to responses from the other teachers and guidance counsellor. Categories were refined or expanded to accommodate any different responses.

Institutional Practices Contributing to Increased Enrolment in Mathematics B

Six themes emerged as institutional practices that might contribute to increased enrolments in Mathematics B at Marigold State High School: *curriculum organisation across year levels*, *staffing of mathematics classes*, *culture of the Mathematics Department*, *STEM program*, and *provision of appropriate tasks and resources*. These factors (summarised in Table 1) are discussed in turn to build a rich picture of the approach taken at the institutional level to increase students' motivation to study Mathematics B.

Table 1
Summary of Institutional Practices Contributing to Increased Enrolment in Mathematics B

Institutional practice	Description of practice
Curriculum organisation across Year levels	A clear pathway from Year 7 to Year 10 to prepare for Mathematics B in Year 11
Staffing of mathematics classes	Strategic choice of teachers for mathematics classes, and mentoring for new teachers
Culture of the Mathematics Department	A collaborative environment that extends to the classroom
STEM program	A well-structured STEM program to encourage participation in senior science and mathematics subjects
Provision of appropriate tasks and resources	Inclusion of problem solving tasks in each lesson and use of resources to promote engagement and consolidation.
	Access to a wide range of resources provided by the Mathematics Department

Curriculum Organisation Across Year Levels

Students with a potential interest in studying Mathematics B are provided with a clear pathway from the time they enter the school in Year 7 (since 2015), although there is also flexibility. A single Year 7 Extension class is based on student performance in Year 5 across literacy and numeracy in NAPLAN: "predominantly upper two bands in reading ... about 50% of them are upper two bands in numeracy" (Mathematics HoD). There are two similar extension classes in Year 8 where the "upper two bands" students are together for English, Mathematics, Science, Social Science and Physical Education, and two mathematics extension classes in Year 9 and Year 10. The Year 10 Extension Mathematics classes follow the Year 10A Australian Curriculum: Mathematics (ACARA, n.d.). The Mathematics HoD uses a range of information to select students for extension classes, and described how she selected students for the Year 9 Mathematics Extension class:

> I use as many pieces of information as I can. Parents have the opportunity to request it. Teachers' recommendations. But also, on NAPLAN data and I also run an end of semester, Year 8 test and an end of year, Year 8 test and I use that data as well as their subject data achievement scores as well. I don't want them streamed within themselves. I want to have students in there who have achieved at upper two bands in year 7 but also students who are just below that. (Mathematics HoD)

As many students as possible are given the opportunity to follow a pathway that prepares them to study Mathematics B. For example, the current Year 10 cohort is smaller than other cohorts because of the introduction of the preparatory year in Queensland in 2007, which effectively increased the school starting age by six months resulting in what is sometimes described as the "half cohort". Despite the small cohort, Marigold State High School has maintained two Year 10 Extension mathematics classes:

> … with the small cohort I've still kept two extension classes, even though our data would suggest I shouldn't, because I want to give as many kids the opportunity to excel at Year 11 as possible. I sort of had one and a half classes worth, so I thought let's put a few more kids in. Give them a different environment. Give them the opportunity to see what is possible. (Mathematics HoD)

The Mathematics HoD also recognises that some students' career aspirations change in Year 10 and allows students to change from the extension class to the core class and vice versa:

> Yes, and even now, in second semester, Year 10, there's movement happening now that SET plans are happening. [Senior Education and Training Plans are prepared by all Year 10 students in Queensland as part of the subject selection process for their final two years of schooling.] I've got some kids - students who want to move from core to extension. (Mathematics HoD)

This flexibility extends to subject choices at the end of Year 10:

> I don't have any of those hard rules that some other schools have about having to get a B in extension or having to get a B in core or anything to get into Maths B. I don't have those rules and I've had several students in the past who've proven it's worth not having those rules. (Mathematics HoD)

Staffing of Mathematics Classes

All the teachers who teach mathematics at Marigold State High School, except one, are qualified mathematics teachers. The Mathematics HoD is strategic about how she allocates teachers to classes. She ensures that those teaching senior classes also take junior classes "because I believe that in the junior school, that's where it starts, the thinking about what they are going to do in Senior" and that new mathematics teachers are mentored:

> I strategically place them [new mathematics teachers] on year levels where there is an experienced person to show them the ropes … Then that person - a new person, you know, it influences all their teaching further down the line.

An additional criterion is employed in allocating teachers to extension classes:

> I try to have my senior teachers also on junior school share the extension teachers around - extension classes around amongst people who I consider to be, I guess, passionate about mathematics. That's it. I think that's a criterion to take an extension class, that you're passionate about mathematics. ... You're on there because you love mathematics. (Mathematics HoD)

Culture of the Mathematics Department

There as a belief amongst those interviewed was that students at Marigold State High School were capable of studying Mathematics B but their choice to study this subject and be successful was often influenced by other factors:

> Oftentimes students don't choose it [Mathematics B] or don't succeed at it, not because they don't have the basis from Year 10. It's because of their home situation or their part-time work situation or the influence of their friends that prevents them from passing Maths B. ... To me it's a lifestyle decision rather than a "I just don't get the work" decision. (Mathematics HoD)

> I think access to technology is a sticking point for us so it's good that we have stuff to lend out that they don't have to be disadvantaged based on socioeconomic status. They like to have technology

> that they can still be using, and we can't make the assumption that they're just going to have it or be able to get it, because money is such an important thing here. (Teacher 2)

The atmosphere in the mathematics staffroom is positive and this is seen as by one teacher as being transferable to the classroom: "I think because it's such a positive environment to be in as a staff member, it's easy to bring that positivity to the classroom and then that rubs off on the kids" (Teacher 2). One possible outcome of the culture of the Mathematics Department extending to the classroom is the building of supportive classroom environments in which students are encouraged and work collaboratively in order to learn from each other:

> Those that are having some success, if they have a bit more and then they realise they're in a class with other people that are having success, that can also help them sort of support each other I think too. I think sometimes the ones that are in the core classes, if they're bright or doing well, don't have that link with the other students that - where they help each other and so on … I always think that you do need to have that sort of culture I suppose, in the classroom, that you're working at that higher level. (Teacher 3)

STEM Program

The HoD Learning and Teaching initiated a STEM program at Marigold State High School several years ago with a view to encouraging students to study science and mathematics in the final two years of schooling. The program includes a STEM day for Year 6 students from feeder schools, a Year 8 STEM day, a Year 9 STEM camp, and a robotics program. This focus on STEM is supported by the selection process for the Year 8 "upper two bands" class.

> Any students that have shown a desire or an interest in STEM subjects in particular. If they're - maybe they might be slightly - not as academic as some of their peers but they've really shown an interest in robotics or something, then we might try to get them into the extension class if we can. (Teacher 3)

One teacher described the importance of the STEM program in the following way:

> We're from a really low socioeconomic area here, and a lot of the kids from our school, parents haven't even finished high school … their parents don't know about the opportunities that are there. If we get them opportunities to go and do all these different things, then they think, "Oh I can do that" - because they're bright kids, they just don't know what they're capable of. You give them those experiences, and they just excel. (Teacher 5)

Marigold State High School has experienced increased enrolments in science subjects over the last few years, and currently has two chemistry classes and a physics class in both Year 11 and Year 12. At the time the study was conducted (August), there were 20 students in the Year 11 Physics class. The increase in enrolments in Mathematics B was attributed by one teacher to the increased interest in science: "They're choosing [Mathematics B] because 'I want to do Physics in 11 and 12 and go to uni and follow in the sciences, and to do that I'll need that level of maths to support me'" (Teacher 3).

Provision of Appropriate Tasks and Resources

The approach to teaching mathematics at Marigold State High School is strongly led by the Mathematics HoD, and includes some problem solving in every lesson:

> We've really stuck with having - trying to have warm ups that involve some reasoning and problem solving in them each lesson. … If we're doing a past NAPLAN question, for example, students try to do it themselves and work with a partner and compare answers and see how they've worked it out. Those types of discussions amongst students are happening in most classes, whether they're core or extension. (Mathematics HoD)

The use of “hands on” activities, games and other resources such as Maths 300 were encouraged to both consolidate and extend learning. One of the teachers described how activities were embedded in some of the Year 7 units:

> Like the algebra unit in Grade 7 has all these board games added in, like do this lesson and play this board game, so you just grab it from the storeroom and go. The algebra lessons are really fun because there’s all these board games and activities that you can be doing that make it more interesting for the kids. (Teacher 2)

Teachers at the school designed these units *for* the students at the school: “A lot of the stuff is already there for us and we’ve designed it ourselves so it’s suitable for our context” (Teacher 2). This teacher attributed the increase in enrolments in Mathematics B in part to the activities employed in the junior extension classes:

> It tends to be I think because the teachers are enjoying teaching the maths in an interesting way, the kids are enjoying the maths and seeing that they can do well in it, so Maths B seems like a natural choice. (Teacher 2)

Marigold State High School appears to be reasonably well equipped with certain types of resources for teaching mathematics, such as those mentioned earlier. Access to appropriate technology is important for students studying Mathematics B and Mathematics C (Advanced Mathematics). Graphics calculators are widely used in these subjects but many students at the school are unable to afford a scientific calculator or basic resources, let alone a graphics calculator:

> I have 10 scientific calculators all numbered so I don’t lose any I have a big box – I learnt that from [Teacher 1] – full of pens and pencils. With some of our kids it’s a big deal that they’ve made it to school, I’m not going to yell at them about not having a pen or a calculator. I’d rather just have the stuff I can lend them so that they can access the curriculum, have the learning. (Teacher 2).

The Mathematics HoD has tried to ensure that access to technology does not prevent students from choosing to study Mathematics B:

> The P & C bought a couple of class sets [of graphics calculators] and the rest I've paid through years of just getting class sets. They’re in boxes in the library and the teachers borrow out. That’s for Year 10s. The 11 Maths Bs - everyone Maths Bs and Cs has one borrowed through the textbook hire scheme in Year 11 and Year 12 Maths B. I don’t want a student think they can’t do Maths B because a parent can't afford a $200 calculator. (Mathematics HoD)

Concluding Remarks

There is widespread debate on what are the most significant factors influencing students’ academic aspirations and decisions regarding subject choices. The value of Rogoff’s (1995) person-in-context perspective is that it highlights the important linkage between students’ individual cognitions and embedded contextual influences at different levels – personal, social, and institutional. Student’s academic aspirations, manifested through subject choices, are seen as being socially constructed through prolonged negotiation involving multiple sources of social/institutional influences and personal cognitions that are interdependent and mutually constitutive.

The case study reported here focused on factors within the institutional plane of analysis and identified a number educational structures and processes that have been highlighted in the literature. For example, the staffing of mathematics classes was organised strategically so that both junior secondary and extension classes would have access to experienced, qualified mathematics teachers. Similarly, a high degree of flexibility in curriculum organisation allowed as many students as possible to follow a pathway into Intermediate and

Advanced Mathematics. The default position in this school seemed to be one of high expectations and a belief that students are capable of excelling in mathematics, if given the opportunity. Clearly, there are elements of Rogoff's (1995) social plane of analysis at work here, seen especially in the positive culture of the Mathematics Department and the problem-solving approach to mathematics pedagogy. This observation highlights the inseparability and interdependence of the three planes of analysis – although only one, at the institutional level, was foregrounded in our case study. Analysis of data from other participating schools will further illuminate the significance of these interlocking factors affecting students' aspirations towards studying mathematics.

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