A Snapshot of Gender and Mathematics Anxiety in Years 5 to 8

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Studies such as the 2012 Programme for International Student Assessment (PISA) indicate that there are gender differences among students in measures of mathematics anxiety. In this paper we explore students' mathematics anxiety levels and intentions to choose mathematics in Year 11 and to choose a career that includes an emphasis on mathematics. The data are examined to identify any differences across a sample of students in Years 5 to 8, with a focus on gender and year level.

In 2009, the G20 leaders acknowledged one of the key priorities for global recovery was improved standards in mathematics and numeracy (International Labour Organization [ILO], 2010). Failure to improve mathematics and numeracy standards was identified as a threat to the strength of economies (Organisation for Economic Cooperation and Development (OECD), 2012). Low achievement in mathematics has been linked to lower school completion rates, unemployment, poor financial decisions, and poor health (English & Gainsburg, 2016). However, studies such as Mack and Wilson (2015) continue to highlight how the numbers of students opting for STEM subjects continues to decline. In particular, they identified that the number of students opting for mathematics continues to decline and also that, of those who do opt for a mathematics subject in Year 11 or 12, the preference is for elementary mathematics rather than intermediate or advanced mathematics. Jaremus et al. (2019) confirmed that female representation and participation in Year 12 STEM subjects was declining and that female enrolments in mathematics, as well as in digital technologies, was of particular concern. There are many reasons cited for such changes as discussed by O'Keeffe et al. (2018). Of concern and of relevance to this paper is the persistence of issues around mathematics anxiety and gender (Sax et al., 2015).

Catholic Education South Australia (CESA) continues to work with academic partners to be informed through data to find ways to counter these issues. In this paper we discuss mathematics anxiety, with a lens on gender and year level. This stems from a larger project that was implemented over three years (2018 to 2020) as part of CESA's STEM Learning Initiative (O'Keeffe et al., 2021). The first two years of the project involved working with teachers and students in schools to develop and implement an inquiry approach to integrated mathematics, science, and technology teaching and learning while also collecting data from students, teachers, and school leaders to gauge the impact of the project. The third year involved data collection only so as to evaluate the sustainability of the project. In this paper, we focus on one aspect of the student survey data collected in both pre- and post-survey modes in 2019. Of particular interest is students' mathematics anxiety levels and the ways in which these were influenced by their engagement in integrated/inquiry approaches to mathematics.

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Background

Mathematics anxiety is defined by Ashcraft (2002, p. 181) as a "feeling of tension, apprehension, or fear that interferes with math performance." Uusimaki and Nason (2004) discuss how mathematics anxiety manifests itself as intense frustration or powerlessness about one's capacity to do mathematics, and how it can be depicted as a learned emotional response. Elevated mathematics anxiety levels are most prevalent in situations where a person needs to communicate their mathematical knowledge, such as in a test situation or working through mathematical problems. For example, Tooke and Lindstrom (1998) suggested that mathematics anxiety surfaces most dramatically when the person is perceived to be under evaluation. The outcome of this is that low achievement is being reported for students when in many cases their low achievement levels may have a greater correlation to their mathematics anxiety rather than to their knowledge and understanding of the mathematical content. This aligns with a reciprocal theory perspective that mathematics anxiety contributes to poor performance which in turn contributes to higher mathematics anxiety (Gabriel, 2022).

It is well documented that the transition between school sectors is a time of upheaval and distress for many students (Hanewald, 2013) and, as a result, is a common time for negative perceptions of mathematics and anxiety to develop or deepen (Attard, 2012; Hanewald, 2013). The 2012 PISA survey looked specifically at mathematics self-efficacy and mathematics anxiety (along with mathematics self-concept among students and student engagement). Some of the key findings of relevance to this paper are that "almost 30% of students reported that they feel helpless when doing mathematics problems" (OECD, 2013, p.80). Of this 30% it was clear that girls and socio-economically disadvantaged students were more likely to have lower self-efficacy levels. The 2012 PISA study also highlighted that 43% of students believed they were not good at mathematics, despite 59% reporting that they get good grades.

In relation to gender, the 2012 PISA data indicated that more boys believe they are better at mathematics than girls, and girls recorded higher levels of mathematics anxiety than their male counterparts in 56 of the 65 OECD countries. Mathematics anxiety also increased, with students in 2012 more likely to be anxious about mathematics than those in the 2003 survey. Thirteen countries, including Australia, showed a statistically significant increase in the mathematics anxiety recorded by their students.

Looking to the 2018 PISA data, girls outperformed boys in reading but remained behind their male counterparts in mathematics. The 2018 data also indicated that girls, across the majority of OECD countries, are more likely to express fear of failure than boys and this gender gap is even more pronounced among the top performing female and male students. Amongst the students who were doing well in mathematics, one in three boys considered working as an engineer or science professional, in comparison to one in five of the higher performing girls (OECD, 2019). Holmes et al. (2018) also pointed to this gender imbalance around career expectation beginning in the middle years of schooling, and suggested that lack of female role models, self-beliefs and dispositions all play key roles. The criticality of the middle years is further echoed by Steinke (2017) who found that, at around age 12, many girls who were considered highly confident and capable female students tended to lose interest in STEM subjects such as science and mathematics.

In Australia, despite considerable contribution in the form of policy activity and programs female participation in STEM careers, uptake of STEM subjects has not altered substantially over two decades (Marginson et al., 2013, Jaremus et al., 2019). Explanations for this gender disparity have changed over time and across disciplines. Previously this gender disparity was attributed to girls/females having less aptitude and interest for STEM careers and subjects and a lower mathematics ability (Panizzon et al., 2018). However, as discussed by Panizzon et al. (2018), substantial research has found little empirical support for these claims. Bøe et al. (2011)

and Archer et al. (2012) have posed that socio-cultural factors and constraints, rather than student ability, have constituted the most powerful explanatory factor behind gender disparity in STEM. Ganley and Lubienski (2016) noted that the gender disparity, though small, was persistent and warrants further exploration as the gaps cannot be explained and increase over time (whereas literacy gender gaps narrow over time). Hence, the initial small gaps lead to *stark disparities* in mathematics-related career pathways, adding to the issue of the gender pay gap.

Research Design

CESA's key aim in supporting teachers and schools to engage in this project was to increase student engagement across science, technology, and mathematics. The intention was to create opportunities for schools to build leadership and teacher capability to transform STEM learning in a manner that privileged and integrated intentional curriculum and capabilities aligned to CESA's learning framework. The project team, in collaboration with CESA's Learning and Technologies Consultants, supported schools to develop a school-specific approach to integrated mathematics, science and/or technology, with a focus on driving pedagogical change through inquiry-based projects. The move towards inquiry-based projects involved professional learning to build teacher confidence and expertise in facilitating, assessing, and teaching discipline knowledge through inquiry. A total of 29 primary and junior secondary schools participated in the project with at least three teachers involved at each site.

As part of the wider CESA project, data were collected from principals, participating teachers, and their students. Principals and teachers were invited to "opt-in" at various stages of the data collection process, including interviews, focus groups and surveys. There was some turnover in staff throughout the project, but each year of data collection is stand-alone and was not contingent on those teachers being involved in previous years. Students whose teachers had opted to participate in the project were invited to "opt-in" to digital pre- and post-surveys and in-person focus groups. This paper reports on one aspect of the student survey data.

Student surveys were carried out at the beginning and end of each school year and had a particular focus on eliciting students' understandings of and dispositions towards mathematics and science. The survey sought to identify students' levels of mathematics anxiety as well as their intentions to choose mathematics in Year 11 and to choose a career that includes an emphasis on mathematics. To establish students' levels of mathematics anxiety, we used the following questions from the PISA 2012 study (OECD, 2012):

- Q1. I often worry that it will be difficult for me in mathematics classes
- Q2. I get very tense when I have to do mathematics homework
- Q3. I get very nervous doing mathematics problems
- Q4. I feel helpless when doing a mathematics problem
- Q5. I worry that I will get poor grades in mathematics.

A five-point Likert scale was used with response categories: strongly agree (5), agree (4), neither agree nor disagree (3), disagree (2), and strongly disagree (1). A higher score for each question corresponds to a higher level of mathematics anxiety. The five responses were summed to give an overall indication of mathematics anxiety. The minimum score that a student could obtain for mathematics anxiety was 5 (no anxiety) and the maximum score was 25 (high anxiety). All surveys were coded to enable data matching while maintaining student and school confidentiality.

A total of 644 students in Years 5 to 10 consented to take part in the various elements of data collection in 2019 and completed the pre-survey; 455 students completed the post-survey. Of the post-survey data, only 179 students (in Years 5 to 8) had completed both the pre- and post-survey and could be matched for comparison. The sample of paired data included 49 students in Year 5, 38 in Year 6, 64 in Year 7, and 28 in Year 8. Note that in 2019, Year 7 was moved to secondary for most CESA schools. All project schools were part of this transition.

Findings

This section presents the student data for levels of mathematics anxiety before and after a two- or three-term focus on integrated science, mathematics, and technology, as well as the ways anxiety correlates with students' intended subject and career choices. Any variances in sample size in the presented tables is because of incomplete surveys, for example, a student who gave year level data but not gender was included in year-level data and not in gender data.

Mathematics Anxiety

Table 1 presents summary data for male and female student mean anxiety levels aggregated across Years 5 to 8, for both the pre-survey and the post-survey. The pre-survey data, collected at the beginning of 2019, indicated statistically significant differences (determined by independent t-tests) between male and female anxiety scores (without separating by Year level). Examining the pre-survey data more closely by year level (not shown in the table) shows that the Year 5 male students were more likely to be mathematically anxious than the Year 5 female students (not statistically significant), but for all other year levels (Year 6 through to Year 8) the data indicates that female students are more likely to have higher mathematics anxiety than male students.

Table 1
Student Mean Mathematics Anxiety Scores by Gender (min score is 5; max score is 25)

	Gender	*n*	mean	standard deviation
Pre-survey	Male	168	12.61	5.70
(p <0.001)	Female	266	15.23	5.46
Post-survey	Male	118	13.47	5.88
(p = 0.014)	Female	186	14.73	5.69

When grouped by school sector only, the mean mathematics anxiety score for primary students in the pre-data was 13.73 (n = 250) in comparison to 14.72 (n = 240) for secondary students. The gap between the cohorts increased at the end of the year; the primary students' mathematics anxiety decreased (mean score 12.70, n = 165 in post-data) while the secondary mathematics anxiety scores increased (mean score 15.71, n = 172). This reflects a statistically significant difference (p < 0.05, using independent t-tests) between the mean mathematics anxiety scores for primary and secondary students. Table 2 shows the data by year level and highlights the increased anxiety across each year level at the end of the year with larger increases evident in Years 7 and 8.

Table 2
Student Mean Mathematics Anxiety Scores by Year Level (min score is 5; max score is 25)

	Year 5	Year 6	Year 7	Year 8
Pre-survey	13.49 *(n = 100)*	13.86 *(n = 150)*	13.96 *(n = 173)*	16.54 *(n = 67)*
Post-survey	12.23 *(n = 68)*	13.08 *(n = 97)*	15.00 *(n = 110)*	17.04 *(n = 62)*

Table 3 presents the data summarised by school sector and by gender. Primary students, both male and female, recorded a decrease in the mean mathematics anxiety over the year while secondary students' mean mathematics anxiety recorded an increase.

Table 3
Student Mean Mathematics Anxiety Scores by School Sector (Primary or Secondary) and Gender (min score is 5; max score is 25)

	Primary		Secondary	
	Male	Female	Male	Female
Pre-survey	12.74 *(n=114)*	14.52 *(n=136)*	12.41 *(n=81)*	15.81 *(n=159)*
Post-survey	12.63 *(n=86)*	12.78 *(n=79)*	14.88 *(n=48)*	16.01 *(n=124)*

There were 179 students who completed all relevant pre- and post- data questions enabling paired t-tests to compare the means. It is evident from grouping by gender and year level (Table 4) that the Year 5 girls exhibited lower mean mathematics anxiety than their male counterparts but that from Year 6 this pattern reversed and the girls consistently recorded higher mean mathematics anxiety.

Table 4
Student Mean Mathematics Anxiety Scores by Year Level and Year Gender (min score is 5; max score is 25; *n* = 179)

	Year 5		Year 6		Year 7		Year 8	
	Male	Female	Male	Female	Male	Female	Male	Female
Pre-survey	12.38	11.24	11.85	15.00	11.20	14.74	-	16.15
Post-survey	12.48	10.76	11.43	14.33	13.00	15.14	-	16.85

Mathematics Anxiety, Subject Choice and Career Intentions

To facilitate cross-tabulation of the mathematics anxiety scores with intention to choose a mathematics subject in Year 11, five groups were constructed with scores grouped as 5–8, 9–12, 13–17, 18–21, 22–25. Five groups were chosen as the original set of questions had five ratings. The relationship between anxiety and likelihood of choosing mathematics at Year 11 in the pre survey is presented in Table 5. There was a correlation ($p < 0.001$) between these, with students who were mathematically anxious (Groups 4 and 5) being the least likely to choose mathematics in Year 11. It is worth noting, however, that there was still a high percentage within these groups who intended to choose mathematics.

Table 5
Intention to Choose a Mathematics Subject in Year 11, by Group (group 1 is least mathematically anxious; group 5 is most mathematically anxious)

Percentage	Group 1 *n = 77*	Group 2 *n = 102*	Group 3 *n = 121*	Group 4 *n = 83*	Group 5 *n = 52*	Total *n = 435*
Strongly disagree	1.3	2.0	5.0	4.9	21.6	5.6
Disagree	2.6	8.8	8.3	16.0	11.8	9.3
Neither agree or disagree	10.5	17.6	33.1	38.3	15.7	24.4
Agree	38.2	38.2	32.2	22.2	37.3	33.4
Strongly agree	47.4	33.3	21.5	18.5	13.7	27.4

In the pre-survey, Table 6 shows that 29.1% of the students were not planning on pursuing a career involving mathematics (combining strongly disagree and disagree). Although the largest percentage of these students were in Groups 4 and 5, there was no significant correlation. It is worth noting that students may not have been exposed to careers involving mathematics as career education and pathways were not traditionally explored in Years 5 to 8.

Table 6
Intention to Pursue a Career Involving Mathematics, by Group (Group 1 is least mathematically anxious; Group 5 is most mathematically anxious)

Percentage	Group 1 *n = 77*	Group 2 *n = 102*	Group 3 *n = 121*	Group 4 *n = 83*	Group 5 *n = 52*	Total *n = 435*
Strongly Disagree	2.7	6.9	12.4	18.5	13.7	10.9
Disagree	17.3	13.7	19.8	19.8	25.5	18.2
Neither agree or disagree	36.0	40.2	35.5	33.3	35.3	35.8
Agree	20.0	24.5	20.7	22.2	21.6	21.4
Strongly agree	24.0	14.7	11.6	6.2	3.9	13.6

Tables 7 and 8 present the post-survey data showing how student intentions changed over the project in relation to choosing mathematics in Year 11 or choosing a career which involves mathematics. As is evident in Table 7, students with the highest levels of anxiety are the ones who are less likely to choose mathematics in Year 11 (p=0.007), but again it should be noted that there was still a large percentage of these groups who indicated that they were more likely to choose mathematics at the end of the year. The students in Group 3 are interesting as they did not rate themselves as being very anxious and yet 25.5% indicated that they were less likely to choose mathematics in Year 11.

Table 7
Student Change, From Beginning of 2019, in Likelihood to Choose Mathematics in Year 11, by Group (Group 1 is least mathematically anxious; Group 5 is most mathematically anxious)

Percentage	Group 1 *n = 52*	Group 2 *n = 70*	Group 3 *n = 96*	Group 4 *n = 44*	Group 5 *n = 42*	Total *n = 304*
More likely to choose	75.0	68.6	63.8	38.6	56.1	59.9
No change	11.5	18.6	10.6	22.7	9.8	19.5
Less likely to choose	13.5	12.9	25.5	38.6	34.1	20.6

Table 8
Student Change, From Beginning of 2019, in Likelihood to Pursue a Career Involving Mathematics, by Group (Group 1 is least mathematically anxious; Group 5 is most anxious)

Percentage	Group 1 *n = 52*	Group 2 *n = 70*	Group 3 *n = 96*	Group 4 *n = 44*	Group 5 *n = 42*	Total *n = 304*
More likely to choose	44.2	38.6	38.3	29.5	24.4	34.9
No change	21.2	21.4	23.4	36.4	24.4	37.4
Less likely to choose	34.6	40.0	38.3	34.1	51.2	27.7

From Table 8 it is evident that the relationship between pursuing a career in mathematics and levels of mathematics anxiety is not as clear. While there is a similar pattern with the highest percentage of students less likely to pursue a career in mathematics coming from the students in Groups 4 and 5, there was no significant correlation. It is interesting that there are almost 100 students who are more likely to study mathematics in Year 11 than pursue a career involving mathematics (59.9% compared with 34.9%).

Summary and Conclusion

In 2018, O'Keeffe et al. reported that mathematics anxiety was prevalent in South Australian schools and the data presented in this paper would suggest that little has changed in recent years. This is not unique to South Australia and follows the global pattern reported through PISA data by Gabriel (2022). Of particular focus in this paper is the way in which gender appeared as a factor. The data shows that, overall, female students still indicate that they have higher levels of mathematics anxiety than male students. This finding supports other studies in this area, including PISA (OECD, 2012, 2019). However, this gender imbalance is not the case for all year levels, with Year 5 female students in this study presenting as less anxious than their male counterparts. This is reflective of the findings of Holmes et al. (2018) and Steinke (2017) who pointed to the criticality of the middle years. This warrants further investigation, especially in light of the connection between mathematics anxiety and choosing mathematics in senior levels of schooling.

The connection between higher mathematics anxiety and choosing mathematics in the senior levels of schooling, though not surprising, was clear and statistically significant. Students who are more anxious about mathematics are less likely to choose mathematics subjects. This has previously been flagged in studies such as Panizzon et al. (2018) and Jaremus et al. (2019) and is of concern as the number of good female role models in senior mathematics subjects will continue to remain low until more female students opt for mathematics in the senior years.

The connection between mathematics anxiety and choice of career involving mathematics was not evident in the data. However the highest percentage of students more likely to choose a career involving mathematics were from the least anxious grouping of students, indicating lowering mathematics anxiety should help increase the number of students being willing to consider a career involving mathematics.

As a final comment, it is worth noting that in a previous study O'Keeffe et al. (2018) warned of a potential for mathematics anxiety of Year 7 students to increase once they transitioned to high-school settings. In their 2018 work, O'Keeffe et al. noted that the average mean mathematics anxiety score for males in Year 7 (at the time in primary school) was 12.66 (n = 293, SD = 4.94) and females was 14.46 (n = 325, SD = 4.9). While the data cannot be directly compared as it was not the same cohort of students, it is worth highlighting that the mean score for male Year 7 students in this study (in a high school context) was 15.03 (n = 46) and the mean score for females was 14.98 (n = 63). While the female scores in both studies are relatively similar, the secondary cohort of Year 7 females exhibit a slightly higher mean mathematics anxiety score. The figure for male students is notably higher, and further highlights the need to understand the transition to high school for Year 7 students. This aligns with the work of Attard (2012) and Hanewald (2013) who reminded us that school transitions are a time of upheaval and distress for many students and during these transitions students are more likely to develop negative perceptions of mathematics and increased anxiety in mathematics.

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