

MATHS ANXIETY OVER TWO CAMPUSES IN A FIRST YEAR INTRODUCTORY QUANTITATIVE SKILLS SUBJECT AT A REGIONAL AUSTRALIAN UNIVERSITY – ESTABLISHING A BASELINE

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ABSTRACT

Mathematics anxiety is a well recognized and for many students a performance inhibiting impediment. As part of a larger study we established a baseline of students' maths anxiety at two campuses of a regional Australian University. Students' gender, campus and preferred discipline significantly affected anxiety. Student performance had a curvilinear relationship with mathematics evaluation anxiety, with students in the mid-range of evaluation anxiety obtaining the highest final grades. No relationship between overall anxiety or anxiety associated with mathematics learning was found. The many confounding variables that impact on student anxiety and performance make it difficult to identify the extent to which scores achieved on the different facets of Abbreviated Mathematics Anxiety Scale affects a student's final score in a compulsory first year quantitative skills subject. Nevertheless, a baseline understanding has been established which, at the very least, raises an awareness of potential issues associated with maths anxiety, that can in turn be used to guide any subsequent interventions.

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INTRODUCTION

Over the last few decades there has been a well-recognized, long-term decline in enrolments in the Science-Technology-Engineering-Mathematics (STEM) disciplines at Australian universities House of Representatives Standing Committee on Education and Training (2009). Concurrently, those choosing to enroll in science-based degree programs are increasingly poorly prepared in the enabling sciences, including mathematics and statistics (Brown, 2009; House of Representatives Standing Committee on Education and Training, 2009). Many education researchers and teaching academics, lamenting these trends and their multiple consequences, have noted that a high proportion of students display a pronounced fear or anxiety of mathematics and/or statistics (Baloglu & Kocak, 2006). Students' subject choices reflect their fears as they show an avoidance of subjects that rely on quantitative skills or theory (Ashcraft & Krause, 2007; Ashcraft & Moore, 2009). Yet, at some stage of a science-based degree program, even in the so-called "soft sciences" such as ecology or environmental science, students need to master mathematical and statistical skills. It is at this point the performance of many otherwise capable students suffers, potentially limiting their academic progression and career prospects (Brown, 2009; Hembree, 1990). Given the high demand and low supply of graduates displaying competencies in quantitative skill based subjects it is important that we put systems in place to reverse this situation.

To address the problem of poor engagement with, and fear of, the enabling sciences including quantitative skills, in 2009 the Faculty of Science and Engineering of James Cook University (JCU) undertook a major restructure of its first year of the Bachelor of Science (BSc). This was achieved with funding from the Department of Education, Employment and Workplace Relations through its Diversity and Structural Adjustment Fund. This restructure, simultaneously introduced at two campuses (Townsville and Cairns) situated 400 km apart, included two significant components that addressed the lack in students' quantitative skills. Firstly, the faculty improved its communication to enrolling students about knowledge needed for entry by first year science students. Ambiguous and confusing sets of requirements, especially with regards to mathematics, for admittance into the different disciplinary majors of the BSc, were replaced with uniform and clearly articulated prerequisites that now included senior Mathematics B (or equivalent). Secondly, the faculty developed a new subject, SC1102: Systems Modelling and Visualisation, as a core component of the first year of

the BSc. SC1102 was developed as an inter-disciplinary, case-study based subject designed to build capacity in students' ability to work both within and across multiple disciplines similar to the model described by Matthews, Adams, and Goos (2009). Specifically, the subject demonstrated how knowledge of natural scientific systems can be enhanced through the effective integration of mathematics and computing (e.g. predicting the risk of cyclone occurrence). This was done with the view to heighten student awareness of the advantages of being quantitatively literate. Because maths anxiety is a well-known barrier to development of quantitative skills we were interested in firstly to develop an understanding of the variables that may affect anxiety and secondly to quantify anxiety levels of the BSc student population during their first year of university.

The long history of research on maths anxiety has been previously summarized by Ashcraft & Moore (2009). Despite the voluminous literature on the topic over the last thirty years, contradictions still exist about which students are most likely to exhibit high levels of maths anxiety as against anxiety as a personality trait or generalized high-stakes test or evaluation anxiety Hembree, 1990; Mellamby & Zimdars, 2010). Gender and age were found to be significant predictors of maths anxiety in some studies (Baloglu, 2002; Baloglu & Kocak, 2006; Hembree, 1990) but not in others (Andile, 2009; Sirmaci, 2007). More recently, the level of preparedness or previous experience of mathematics and statistics also emerged as reliable predictors of anxiety Ashcraft & Moore, 2009; Baloglu, 2002; Baloglu & Kocak, 2006). This is why we are interested in the impact of the change in admission prerequisites as one of the interventions implemented at JCU described previously.

Furthermore, no unifying statements can be easily made about the impact of maths anxiety on student achievement (Kyttälä & Björn, 2010). High levels of maths anxiety often result in impaired performance (Ashcraft & Moore, 2009; Hembree, 1990; Payne & Israel, 2010). However in a study spanning 41 countries and boasting a sample size of quarter million students, that investigated the impact of maths self-efficacy, maths self-concept and maths anxiety on performance, anxiety's impact on performance varied significantly amongst the different populations (Lee, 2009). Lee (2009) showed that maths anxiety was a well-delineated, valid construct that was highly correlated with achievement scores. He further hypothesized that all three constructs he studied relate to the societal and educational environment of students since certain populations of students scoring high on the maths anxiety scale also performed well on the maths scores of the Program of International Student Assessment (PISA). Many studies highlight the negative correlation between maths anxiety and maths performance (Ashcraft & Moore, 2009; Hembree, 1990; Payne & Israel, 2010). Yet others detect an opposite effect: some students, often females, scoring highly on various anxiety scales perform better than students with low anxiety levels (Mellamby & Zimdars, 2010). Unlike most other studies that presumed a linear relationship between academic performance and anxiety Keeley, Zyc, and Correia, (2008) following their review of the literature with strong theoretical reasoning hypothesized, and subsequently demonstrated, a curvilinear relationship between performance and statistics anxiety amongst undergraduate students.

The Cairns and Townsville campuses of JCU draw students from two regional populations that differ significantly in their economic base and employment profiles as well as their engagement with higher education. Students choose senior subjects two years before entrance to university thus it will be two years before all students admitted into the BSc will fully satisfy the new entry prerequisites. The two-year changeover period (2010 and 2011 academic years) allows us to establish an "anxiety baseline" to be established against which we can measure the impact of our revised entry requirements. One hypothesis tested in this study was that students enrolling in 2012 will be better prepared and display lower anxiety levels in a core first year maths subject than they do at present. In this paper however, we report on a baseline study of the 2010 cohort with the aim of gaining a detailed understanding of maths anxiety among first year science students completing a compulsory quantitative skills subject at an Australian multi-campus regional university.

MATERIALS AND METHODS

QUESTIONNAIRE DEVELOPMENT

The instrument used for measuring the level of students' mathematics anxiety was part of a more comprehensive survey instrument that we are using to investigate the attitudes and anxiety associated with the study of mathematics and technology of first year science students. The anxiety scale consisted of the Abbreviated Maths Anxiety Scale (AMAS) of Hopko, Mahadevan, Bare, and Hunt (2003) with some minor modifications plus two additional items in consideration of our student

populations and the context of the subject, SC1102, in which the students were enrolled (Table 1). The anxiety scale of Hopko et al. (2003) was selected because its performance is equivalent to other widely used maths anxiety rating scales (Ashcraft & Moore, 2009) and its brevity was considered a significant advantage. Items on our modified AMAS were responded to using a 5-point Likert scale ranging from 1 (*low anxiety*) to 5 (*high anxiety*), with the total score representing the mean response of the eleven items.

Table 1: Comparison of the AMAS as developed by Hopko et al. (2003) and the modified AMAS administered in the current study. Items unique to our study are asterisked. Instructions given to respondents are also shown. Items relating to the learning maths anxiety (LMA) and maths evaluation anxiety (MEA) subscales are identified in the far right column. One item (#) was excluded from both subscales (See text for discussion).

AMAS (Hopko et al. 2003)	Modified AMAS	
Please rate each item in terms of how anxious you would feel during the event specified. Use the following scale and record your answer in the space to the left of the item: Scale: 1 = Low Anxiety through to 5 = High Anxiety	How much do you agree with these statements about your study? (Circle the most appropriate answer - place a line through the question if you are unable to answer) Scale: 1 = Strongly disagree through to 5 = Strongly agree	
thinking about an upcoming maths test 1 day before	I feel anxious thinking about a maths test coming up the next day	MEA
watching a teacher work an algebraic equation at the front of the class	I feel anxious watching a teacher work an algebraic equation at the front of the class	LMA
	I feel anxious watching a teacher work with a graph at the front of the class *	LMA
taking an examination in a maths course	I feel anxious when taking an examination in a maths course	MEA
being given a homework assignment of many difficult problems that is due the next day	I feel anxious about a maths assignment that is due in the next class	MEA
listening to a lecture in maths class	I feel anxious when listening to a maths lecture	LMA
listening to another student explain a maths formula	I feel anxious when listening to another student explain a maths formula	LMA
	I feel anxious when listening to another student explain a maths graph*	LMA
being given a pop-quiz in maths class	I feel anxious when being given a not-for-credit "pop" quiz in maths class	#
starting a new chapter in maths class	I feel anxious when starting a new chapter in a maths book	LMA
having to use tables in the back of a maths book	I feel anxious when using the tables in the back of a maths book.	LMA

Whilst it is common practice to use both affirmatively and negatively worded items, all our questions were affirmatively worded because we wished to avoid the frustration and confusion that may be caused by oscillating between affirmatively and negatively worded items. Since the AMAS was

interspersed with items from other scales, many of which pertained to the enjoyment or positive actions or emotions about mathematics, we contend that some of the issues of respondent fatigue and acquiescence bias were thus alleviated (Saris, Revilla, & Shaeffer, 2010). Also, since the questionnaire was to be administered at least twice to the same student we did not want the questionnaire to be a catalyst for negative thinking (Pierce, Stacey, & Barkatsas, 2007).

For each participant we collected information about gender, first language learnt, their domestic or international status, number of years elapsed since leaving school, the science discipline that most interested them and which campus each respondent attended. Students' final grades, including any withdrawals from the subject were extracted from the university records. Mid-term test results for both campuses were available from the class records. All categorical variables had two outcomes e.g. gender (male, female), but the "time since students left school" had 3 categories (less than one year; one to five years (inclusively); more than 5 years).

The questionnaire was printed and administered in hard copy format to students at the start of the first lecture for the subject SC1102. Conditions required by the project's ethics approval were fully observed.

STATISTICAL ANALYSIS METHODS

A factor analysis with a rotated varimax solution was used to investigate the results of the modified AMAS questionnaire. Cronbach's alpha was used to measure the internal consistency of items. Kruskal Wallis tests of significance were employed to investigate the affect of categorical variables on quantitative responses. Specifically, we performed the two tailed test which has the alternative hypothesis of "at least one of the populations tends to yield larger observations than at least one of the other populations", as described by Conover (1999, pp 290). We note that the Kruskal Wallis test is indeed equivalent to the Mann-Whitney test and thus can be applied to the situation with two populations (Conover, 1999, pp 296). We examined the relationship between anxiety scores and students' performance using regression models that included both a linear and quadratic terms for continuous variables. Dummy variables were created for categorical variables. All interactions between dummy variables and continuous variables (both linear and quadratic) were considered for significance. Exploratory data analysis by way of boxplot investigations and scatterplots were inspected. The subscript "KW" denotes the p-value associated with a KW test, and a subscript of "R2" denotes that a test of the significance of the population R-squared has been undertaken as described in Zar (1984, p 269). Statistical analyses were carried out in SPSS version 17.

RESULTS AND DISCUSSION

OUR STUDENT COHORT

The student cohort comprised 191 students with 138 in Townsville and 53 in Cairns. Not all participants responded to all questions, thus in the comparisons below not all categories total this. There were 25 (13%) international students with 21 (11%) of these from Townsville and 4 (2%) from Cairns. The cohort had twice as many females as males, and this ratio was similar among the domestic and international subpopulations.

Of the students surveyed 91 (48%) had completed secondary school in the year prior to enrollment, a further 67 (35%) students completed it in the previous five years, and 31 (17%) students were classified as mature aged, having left school more than 5 years prior to entering university. In Cairns there were 14 mature aged students enrolled (27%), which is more than double the Townsville percentage (12.4%, n=17). The ratio of male to female mature aged students was higher in Cairns than in Townsville (77% and 52% respectively).

When students were asked to identify "which area of science interests you the most", the biological and environmental sciences were chosen most frequently. Some students however chose two disciplinary areas and so not to discard valuable information we split students into two groups: those with a preference that included at least one of maths and/or physics (the maths-physical sciences group n=12, 8.7%) and those whose preferences included neither (the biological/earth/environmental sciences group). The maths-physical sciences group was biased towards males (73% male). For the majority of our students English was their first language (87%) with at least 13 other languages dispersed between the remaining participants.

ANXIETY AMONG THE 2010 COHORT

The eleven-item modified AMAS had high internal consistency with Cronbach's $\alpha=0.910$, conforming very closely to the α of 0.90 reported by Hopko et al. (2003) for the original nine-item AMAS. Factor analysis of the 11-item modified AMAS identified two factors equivalent to anxiety associated with maths evaluation (MEA) and anxiety associated with maths learning (MLA) as also described by Hopko et al. (2003). For computation of the factor scores we removed item nine of the modified AMAS as this item loaded equally on both factors – MEA and MLA. Cronbach's α for the two subscales was 0.826 for MEA and 0.885 for MLA.

We examined how each of the six factors (gender, campus, domestic/international status, years since leaving school, disciplinary interest and language learnt from birth) affected overall anxiety (i.e.: mean score of the 11-item modified AMAS).

Gender affected the overall anxiety scale ($p_{KW}=0.001$) with the boxplot for females displaying a tendency for females' anxiety levels to be shifted higher than that of males. This finding supports other studies that identified significantly higher anxiety in female students than in male students (Hembree, 1990; Hopko et al. 2003; Hyde, Fennema, & Lamon, 1990; Kytälä, & Björn, 2010). However other studies have failed to demonstrate a gender difference in maths anxiety (Andile, 2009; Baloglu, 2002; Haynes, Mullins, & Stein, 2004; Sirmaci, 2007). The literature provides no clarity as to the reasons for any of the observed gender differences in maths anxiety.

Differences in anxiety levels ($p_{KW}=0.021$) between the Townsville and Cairns campuses were noted but were not accepted as significant under our strict Bonferonni adjusted significance level ($0.05/6=0.008$). Additional exploratory data analysis revealed that the middle two quartiles of the distribution were slightly higher for Cairns students, suggestive of their elevated anxiety compared to Townsville students. In light of this it is important that we consider if the two campuses represent significantly different populations requiring different teaching methods and tutorial support.

Other notable differences between the Cairns and Townsville student populations studying for the BSc. included: a higher ratio of part time and external students in Cairns (16% versus 5%); a higher ratio of mature aged students and a lower ratio of international students in Cairns. These differences may, to some extent, be explained by differences in the two regions' engagement with higher education and economic security (caused by different employment profiles and economic base). It is contentious that any of these factors cause the higher anxiety observed amongst students in Cairns. It is nevertheless important to consider how the two campus populations differ and to note that further research is required to better understand the key drivers affecting anxiety in Cairns.

Between the maths-physical sciences group and the biological/earth/environmental sciences group, significant differences ($p_{KW}=0.008$) in anxiety levels were identified. Such a difference between these two groups of students was expected as high mathematics self-efficacy (ie the belief of being good at maths) is a driving force behind students selecting mathematics and physics based majors (Betz & Hackett, 1983; Hackett & Betz, 1989). The result concurs with studies incorporating a wider base of majors such as the study of Durrani and Tariq (2009) who observed that those undergraduates in the UK that considered themselves more numerically competent also expressed lower levels of anxiety.

Students' anxiety levels were not found to have any dependence on first language, their domestic/international status or years since leaving school. Our student population was highly homogeneous with respect to these factors. Most students' first language was English and domestic students (87%) and recent school leavers (83%) dominated the cohort. With such proportional distribution coupled with the relatively small sample size of 191 respondents, it is challenging to demonstrate small effect sizes. However there are several studies with much larger sample sizes that do conclude an age affect on anxiety (Baloglu, 2002; Baloglu & Kocak, 2006; Hopko et al. 2003). One must note that the number of studies able to investigate the effect of age as against gender and many other student characteristics is limited by the fact that many studies take place in settings, such as senior secondary schools, where student age varies little.

EFFECT OF ANXIETY ON PERFORMANCE

Because the modified AMAS was not fully balanced with regards to anxiety due to evaluation (MEA: 3 items) and anxiety due to mathematics learning (MLA: 7 items) with one item falling in between the two subscales, the relationship between the MEA and MLA subscales and performance was analysed

separately. Using up to second order linear models and taking a forward stepwise approach we identified a significant quadratic relationship between MEA^2 and students' final score (final score = $67.235 - 3.892 (MEA)^2$, $p_{R^2} = 0.002$) (Figure 1). The most important indicator for performance in the mid-term test was preferred discipline. The maths-physical sciences group contributed to a higher mid-term performance value compared to the biological/earth/environmental sciences group (mid-term test = $22.268 + 8.419 Z_1$, $p_{R^2} < 0.0005$, where $Z_1 = 1$ for the maths-physical sciences group and zero otherwise). Mathematics learning anxiety levels contributed significantly to the linear model with the students' final grades with Cairns students scoring higher (final grades = $61.252 + 8.333 Z_2$, $p_{R^2} = 0.017$, where $Z_2 = 1$ for Cairns students and zero otherwise). The mid-term test results were also higher for the maths-physical sciences group (mid-term test = $22.268 + 8.419 Z_3$, $p_{R^2} < 0.0005$, where $Z_3 = 1$ for the maths-physical sciences group and zero otherwise). Although these regressions were significant, the R^2 was very low and explained less than 1% of the total variability. However we were not using the model for predictive purposes but rather to better understand how mathematics anxiety may affect performance from a conceptual standing.

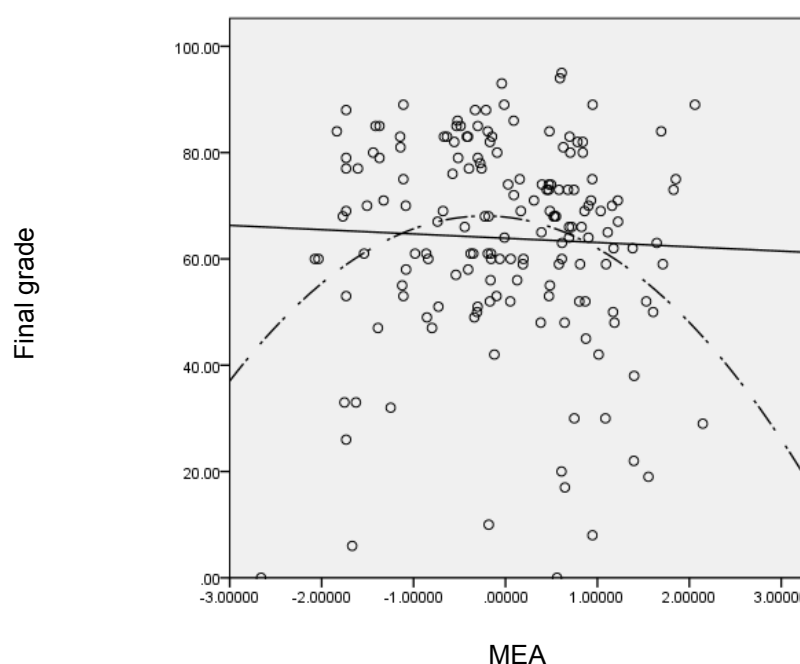


Figure 1: Linear (continuous line) and quadratic (broken dotted line) relationship between final grade and anxiety – MEA subscale.

Keeley et al. (2008) also found that correlation between performance and anxiety, when demonstrated, was linear for the assessments early on in the semester and curvilinear for later assessments. Our findings mirror theirs: the mid-term test was presented in week eight of the 13-week semester whereas the final grade was heavily weighted by performance in the final examination. Thus, there is accumulating evidence that anxiety and performance in summative assessments of mathematics and statistics follows a curvilinear relationship whereas in early or formative assessments a linear relationship may be more common. Students exhibiting high and low level anxiety tend to perform most poorly, and students with mid-level anxiety tend to perform the best in the subject overall (Keeley et al., 2008).

SUMMARY AND CONCLUSIONS

Our objective was to establish a baseline understanding of factors affecting mathematics anxiety of first year science students at a regional, multi-campus university. We also investigated whether students' anxiety at the start of a compulsory quantitative skills subject has a significant effect on performance in the subject. We demonstrated that our student populations were diverse with respect to the mathematics anxiety they experienced. Females scored significantly higher on the modified AMAS than males, students at our Cairns campus scored higher overall and on the MLA but not on the MEA subscale than students in Townsville, and students who preferred the maths-physical sciences were significantly less anxious overall than students preferring other disciplines. Maths

anxiety was an unreliable predictor of performance. While a quadratic equation described the relationship between maths evaluation anxiety and performance of the student population as gauged by final grades, no significant relationship for the population was evident between overall anxiety or mathematics learning anxiety and performance. Amongst students preferring the maths-physical sciences both anxiety subscales exhibited a linear relationship with the mid-term test results. The MLA subscale was significantly related to the final grades of Cairns students.

Our study had a number of limitations. We are unable to assess how much the better performance of the Cairns students was contributed to by the difference in the assessment tasks (including those presented at the final examination), the difference in the case studies used to demonstrate mathematics principles, the rigor of marking, or the physical conditions of the examination venue, etc. As the teaching team was different at the two campuses, other subtle but influential differences may have been present (Teisla, Andersona, Nobleta, Crinera, Rubina, & Dalton, 2011). In future similar studies every effort must be made to standardize subject delivery if a cross-campus comparison of student attitudes and performance is to be made.

The Cairns student population performed better in the subject than the Townsville population. Future research may investigate the proposition that students in Cairns worked closer to the optimum anxiety level that promoted adequate preparation (Keeley et al., 2008) than did Townsville students. The Modified AMAS, while performing as well as the original AMAS of Hopko et al. (2003), was unbalanced with regards to the weight the two subscales contributing to the overall score. Since the relative importance of the two scores' contribution to performance is unclear, further research is required to understand the role that maths learning anxiety plays in promoting or detracting from students preparedness for mathematics evaluation in first year quantitative skills courses.

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