# A longitudinal study of students undertaking a mathematics major: changes in attitudes, learning behaviours and achievement

**Susan Rachel Worsley**
The University of Queensland, Brisbane, Australia
sue.worsley@maths.uq.edu.au

**Michael Bulmer**
The University of Queensland, Brisbane, Australia
m.bulmer@uq.edu.au

**Merrilyn Goos**
The University of Queensland, Brisbane, Australia
m.goos@uq.edu.au

**Barbara Maenhaut**
The University of Queensland, Brisbane, Australia
bmm@maths.uq.edu.au

How do a student's attitude, learning behaviour and achievement in mathematics or statistics relate to each other and how do these change during the course of their undergraduate degree program? These are some of the questions that were addressed in a longitudinal study at a major Australian university. The study spanned over three years and used a mixed method approach selected from the pragmatism paradigm. The questions were addressed by soliciting comments from students several times during their undergraduate degree programs; through an initial attitude survey, course-specific surveys for up to two courses each semester and interviews with students near the end of their degrees. Attitudes and learning behaviours of the mathematics students that were followed through the three years of research are outlined. The student responses to the completed course–specific surveys are discussed. General responses were obtained from the 645 course-specific surveys that were completed. This research has highlighted differences in attitudes and learning behaviours of students taking mathematics courses, more specifically between those who are majoring in mathematics and those who are not.

**Keywords:** mathematics education, attitudes, learning behaviours, longitudinal study

## Introduction

Students come to university with an array of attitudes and established learning behaviours. Some of these are effective and will serve them well as they embark on their studies while others, if not changed, will be detrimental to their progression and achievement. Though most of the research in the area of attitude has been conducted at the school level, some of this can still be applied to undergraduate mathematics students. In mathematics, students build up their confidence and belief in their ability by having experience of achievement in mathematics (Carmichael & Taylor, 2005). The more the student experiences the ability to solve mathematics problems, the more they believe they will be able to solve. An increased level of

engagement and achievement in mathematics would therefore in itself be expected to be related to further improvements in academic achievement. At university level much of the research carried out on attitudes and learning behaviours of students are for mathematics courses that are typically considered service courses (Carmichael & Taylor, 2005; Suinn & Edwards, 2006) rather than mathematics courses that lead onto majors in mathematics and statistics. Though a fair number of these studies deal with mathematical anxiety (Betz, 1978; Suinn & Edwards, 2006; Townsend, Moore, Tuck, & Wilton, 1998), which is not highly prevalent in mathematics and statistics majors students, there are others that also deal with other forms of attitudes. Some of these other studies also consider enjoyment and value of mathematics as important variables (Alken, 1974) and link these variables to achievement (Watson, 1988) and others look at the importance of seeing relevance in the mathematics that is taught (Anthony, 2000; Matthews, Adams, & Goos, 2009). Variables dealing with the students' perception of the instructor and their handling of the course were more related to the students' value of the course than to their achievement (Watson, 1988).

With regard to learning behaviours of students, previous research has been conducted into the different approaches that students use to study (Fry, Ketteridge, & Marshall, 2003). Following Biggs (1987), we used a framework of three learning behaviours in relation to mathematics: surface approach, deep approach, and achieving approach. A student may use a different approach for different types of learning situations (Fry et al., 2003; Ramsden, 1992). It has been shown that the type of teaching used and the workload volume will encourage different learning approaches by the student (Lizzio, Wilson, & Simons, 2002). If students perceive a high workload and assessment in a course they will be more likely to use a surface approach to learning and if the student believes that they have a good teacher they are more likely to adopt a deep approach (Lizzio et al., 2002). Content overload in mathematics with long assignments may unintentionally encourage a surface approach from students (Lizzio et al., 2002).

The aim of the study was to investigate how attitudes, learning behaviours and achievement in mathematics relate to each other and how these change over the course of an undergraduate degree program. This was a longitudinal study of students through three years of a mathematics degree. Students were surveyed after each semester regarding the mathematics courses they had taken and in-depth interviews were then conducted with twenty students in the mathematics major at the end of their degrees. Lecturers were also interviewed to identify the corresponding mathematical concepts in each course. Analyses of these surveys and interviews were used to address the aim of the study. This paper presents the part of our larger study that considers the changes in attitudes, learning behaviours and achievements in students that were identified by the course-specific surveys (Worsley, 2014). It should be noted that when we use the term mathmematics (students or courses) this also includes statistics.

## Methodology

The longitudinal study consisted of a range of research questions seeking both a broad perspective on undergraduate students' mathematics learning and a deeper understanding of individual student's learning experiences. This paper will focus on changes in attitudes and learning behaviours but here we also describe the broader methodology of the study. This investigation was undertaken over the period of a degree in order to see how these learning behaviours and attitudes related to what students were learning within each course. It was also necessary to consider what was being taught and assessed and how this related to the learning

behaviours that students adopted and the attitudes they displayed. In the study an approach was needed that would enable both quantitative and qualitative data to be collected and analysed, and the findings to be synthesised in ways that would provide the breadth and depth required by the study's research questions. Consequently, the mixed research methods approach was selected from a pragmatism paradigm (Tashakkori & Creswell, 2007; Tashakkori & Teddlie, 1998). This research method allows for collection of both quantitative data, for example, through surveys to produce descriptive statistics that characterise a large sample of participants, and qualitative data, for example, through interviews with a smaller sub-sample in order to probe key issues more deeply. Thus the design of the study flowed from quantitative to qualitative, with findings from the former component providing pointers to guide the conduct of the latter. It also used some of the quantitative data obtained from lecturer interviews to inform questions for the student surveys. The pragmatism paradigm allowed for the data to be analysed from both a deductive and inductive perspective (Tashakkori & Teddlie, 1998).

The main tools in the study were surveys and interviews. In 2009 and 2010 a mathematical attitude survey was conducted with over 1000 students attending their first mathematics tutorial to obtain a picture of general attitudes towards mathematics at the start of a degree. This initial survey was also used as an opportunity to recruit students onto the longitudinal study. This approach led to an expected high attrition rate in the longitudinal study as students from other disciplines, such as Engineering, who were in the first year mathematics courses no longer enrolled in mathematics courses after the first year. Thus starting with all students in mathematics courses it was possible over time to establish a longitudinal group of 21 mathematics major students who completed both first level and third level mathematics course surveys.

Surveys were then sent to participants each semester to ask questions relating to the mathematics courses the students were taking. These surveys asked students questions about their learning behaviours (4 items) and attitudes towards the course and instruction (5 items). Within many of the items there were several subsections. For example, the item on learning activities which asked students "How do you study mathematics content" gave students five study options to rate. The surveys used a 5 point Likert scale and were kept consistent across the year levels. For learning behaviours, a score of 1 indicated no engagement level in the learning behaviour and 5 indicated that the learning behaviour was used all the time. For attitudes, a score of 1 indicated a very negative attitude, 5 a very positive attitude and 3 rated as fair.

Responses to the surveys have been analysed in two ways. The first analysis is a cross-sectional comparison of the attitudes and learning behaviours of major and non-major students in first and second level courses. The second analysis is a longitudinal comparison of the attitudes and learning behaviours of mathematics major students, which examines the responses of this small group of students from their first and third level courses.

Pearson correlations were used to measure associations between attitudes and learning behaviours. Results are shown where there were statistically significant correlations that are of at least moderate size ($p < .05$ and $r > .30$). Paired t-tests were used to make comparisons between survey responses for first level courses and third level courses.

Findings of the study that are beyond the scope of this paper are the interviews and the investigation into what were the lecturer and student perceptions of the nature and difficulty of key concepts in undergraduate mathematics courses.

## Results

In total, 645 surveys were completed by 335 students over four levels of courses, of which 440 were surveys relating to first level courses completed by 311 students. In the third and fourth level courses 39 surveys were received from 23 students. These response frequencies were consistent with the overall populations of mathematics students in the four levels of courses.

A major focus of this research is to identify the attitudes, learning behaviours, and achievement of students undertaking mathematics courses and how these change over time. The majority of students who completed all levels of mathematics were likely to be majoring in mathematics. The surveys were analysed by separating the students into two groups, representing students who either were or were not likely to be completing mathematics majors.

The major group used in the longitudinal study consisted of the 21 mathematics students who completed both first level and third level mathematics course surveys. The non-major group comprised the 263 students who had completed the surveys related to first year courses but did not complete further mathematics courses. Students who did not fall into one of these groups will not be considered here but have been analysed as part of the larger study (Worsley, 2014).

### The "typical" learning behaviours and attitudes in the first level

Table 1 shows the learning behaviours students were questioned about on the courses-specific surveys. There were lower responses for questions on online searches, as this question was not added to surveys until 2010.

The top range of responses relate to attendance of different learning activities. This indicates that students taking mathematics courses generally attend most of the learning facilities provided by the university. Students tended to seek help about half the time and these varied between textbooks and written resources, friend and online. However they did not generally use the lecturer to obtain help.

**Table 1: Learning behaviours of first level students in order of mean response**

| Learning Behaviours | n | Mean (SD) |
|---|---|---|
| Attendance of lectures | 310 | 4.30 (0.93) |
| Attendance of tutorials | 283 | 4.17 (1.17) |
| Course help from text book or other written resources | 309 | 2.97 (1.17) |
| Assignment help from text book or other written resources | 309 | 2.91 (1.22) |
| Assignment help from friends | 309 | 2.89 (1.21) |
| Course help from friends | 309 | 2.89 (1.18) |
| Course help from online searches | 183 | 2.75 (1.06) |
| Assignment help from online searches | 309 | 2.60 (1.13) |
| Learning mathematics by explaining to others | 308 | 2.31 (1.07) |
| Study by searching online for course material | 308 | 2.21 (1.06) |
| Look at mathematics beyond course content | 236 | 2.11 (1.15) |
| Look at mathematics beyond assessment | 307 | 2.01 (1.06) |

| | | |
|---|---|---|
| Assignment help from tutor | 309 | 2.00 (1.14) |
| Read through lecture notes before lecture | 308 | 1.80 (0.97) |
| Course help from lecturer | 308 | 1.63 (0.85) |
| Assignment help from lecturer | 308 | 1.46 (0.81) |

Table 2 shows all the attitudes students were questioned about on the course-specific surveys. There is a lower number received for the learning value questions as there was a programming problem in the first batch of surveys that did not register these responses.

**Table 2: Attitudes of first level students in order of mean response**

| Attitudes | n | Mean (SD) |
|---|---|---|
| Rating of lecturer | 308 | 3.98 (1.02) |
| Relevance | 310 | 3.94 (0.89) |
| Beneficial | 311 | 3.79 (0.85) |
| Rating of course tutor | 214 | 3.78 (1.01) |
| Learning value from Lectures | 181 | 3.70 (1.97) |
| Learning value from tutorials | 165 | 3.49 (1.04) |
| Enjoyment | 311 | 3.25 (1.02) |

All the mean responses to course attitudes were over 3 indicating that students were generally positive towards mathematics. Rating of lecturer was valued as the most positive mean attitude with the rating of tutors not far behind. Students could see the relevance and benefits of their courses but were not as positive with their enjoyment of their mathematics courses.

### Differences between major and non-major groups

Next compared is the two groups, major and non-major students, in first level courses. Here we used the grade point average (GPA) based on a grading system where grades are awarded on a 7 point scale with grades 1 to 3 failures and grades 4 to 7 passes. There were significant differences between the grades of the two groups with a mean GPA of 5.98 for the 48 major students and a mean GPA of 5.33 for the 263 non-major students ($t = 3.98$, $p = 0.0001$).

Table 3 shows similar comparisons for the three learning behaviour where there was also a significant difference. The major students in first level courses tended to look at mathematics beyond the assessment, but obtain less help for assignment and course work from friends than did the non-major group.

**Table 3: Comparisons of learning behaviours with mathematics major students**

| Learning Behaviour | Major group Mean score (SD) | Non-major group Mean score (SD) | *t* | *p* |
|---|---|---|---|---|
| Look at mathematics beyond assessment | 2.28 (0.97) | 1.93 (1.03) | 2.07 | 0.04 |
| Assignment help from friends | 2.43 (1.05) | 2.97 (1.21) | 2.65 | 0.01 |
| Course help from Friends | 2.33 (0.91) | 2.99 (1.20) | 2.46 | 0.02 |

Major group n=48, non-major group n=263

Table 4 shows the three attitudes where there was a significant difference between the groups. These suggest that the mathematics major students are higher achievers and show more positive attitudes than non-major students.

**Table 4: Comparisons of attitudes with mathematics major students**

| Attitude Variable | Major group Mean score (SD) | Non-major group Mean score (SD) | *t* | *p* |
|---|---|---|---|---|
| Enjoyment | 3.65 (0.85) | 3.17 (1.03) | 3.42 | 0.001 |
| Beneficial | 4.10 (0.64) | 3.75 (0.88) | 3.34 | 0.001 |
| Relevance | 4.23 (0.72) | 3.90 (0.91) | 2.91 | 0.005 |

Major group n=48, non-major group n=263

### Learning behaviours and attitudes related to achievement

There was a moderate and significant correlation between learning mathematics by explaining to others and academic achievement ($r = 0.43$, $p < 0.001$). This was the only significant correlation found for the major group in first level courses, with a significant but weaker correlation for non-mathematic majors ($r = 0.24$, $p < 0.001$).

Attitudes related to achievement for both groups in first level courses are shown Table 5. For both groups enjoyment, feeling the course is beneficial, and a high rating of the lecturer and lectures are all significantly correlated to achievement. Only for the major students is the correlation between achievement and the rating of the course tutor statistically significant.

**Table 5: Correlations between attitudes and achievement in first level courses**

| | Major | | | Non-major | | |
|---|---|---|---|---|---|---|
| | *r* | *df* | *p* | *r* | *df* | *p* |
| Enjoyment | 0.52 | 46 | < 0.01 | 0.55 | 260 | < 0.01 |
| Beneficial | 0.31 | 46 | 0.03 | 0.50 | 260 | < 0.01 |
| Rating of lecturer | 0.49 | 46 | < 0.01 | 0.33 | 259 | < 0.01 |
| Rating of course tutor | 0.34 | 44 | 0.02 | 0.11 | 221 | NS |
| Value of learning from lecture | 0.39 | 32 | 0.02 | 0.35 | 166 | < 0.01 |

## A longitudinal study of the mathematics major

We now consider the small cohort of students who represent students completing mathematics majors at the university. There were 21 students who completed a total of 72 surveys over first and third course levels. These were made up of 37 surveys from 5 different first level courses, 34 surveys from 12 different third level courses and 2 surveys from 2 different fourth level courses. As there were only two surveys received from fourth level courses these have been included with the third level courses for analysis. Every student had completed at least one survey from each level. As students had completed varying numbers of surveys ranging from 2 to 7, the mean of each variable was taken over all surveys received for each student and likewise for first and third level courses. This enabled just one result to be taken for each student in the analysis carried out.

Average grades for the students were generally high (mean GPA 6.04 at Level 1 and 5.73 at Level 3) with the majority of students passing all their courses.

### Learning behaviours

There were some learning behaviours and attitudes demonstrated by the majority of these students, irrespective of their achievement, either most of the time or none of the time. These are again referred to as "typical" for this group of students and have been identified by considering the mean of students' response rate for each of the year levels (one and three) and

the overall mean of these two year levels. Though there were 21 students there was not a constant number of responses to each question as not all questions related to each course and not every student answered every question.

Table 6 gives the mean responses to the learning behaviour questions, indicating significant differences. Though students did not generally seek help from lecturers there was an increase in obtaining help from the lecturer in both assignment ($t = 2.24$, $p < 0.05$) and course work ($t = 4.38$, $p < 0.001$) from first level to third level. In third level courses students were starting to use both the tutors ($t = 4.34$, $p < 0.001$) and their friends ($t = 2.47$, $p < 0.05$) to assist with assignments more often than they did in first level courses. However, not all third level students found tutorials helpful, as indicated by some of the comments received. The only learning behaviour that showed a decrease in frequency from first to third level was learning mathematics by explaining to others ($t = 3.25$, $p < 0.01$).

**Table 6: Changes in learning behaviours of major students**

| | n | Level 1 Mean (SD) | n | Level 3 Mean (SD) | |
|---|---|---|---|---|---|
| Attendance of lectures | 21 | 4.24 (0.92) | 20 | 4.60 (0.64) | |
| Attendance of tutorials | 20 | 3.88 (1.16) | 17 | 3.80 (1.45) | |
| Course help from text book or other written resources | 21 | 3.11 (1.08) | 21 | 3.18 (1.25) | |
| Assignment help from course tutor | 21 | 1.69 (0.98) | 21 | 3.11 (1.06) | * |
| Assignment help from text book or other written resources | 21 | 2.95 (1.13) | 21 | 2.93 (1.26) | |
| Assignment help from friends | 21 | 2.28 (1.10) | 21 | 2.91 (1.16) | * |
| Course help from online searches | 8 | 2.18 (0.68) | 21 | 2.77 (1.19) | |
| Assignment help from online searches | 21 | 2.58 (1.01) | 21 | 2.60 (1.21) | |
| Course help from friends | 21 | 2.17 (0.86) | 21 | 2.56 (0.93) | |
| Look at mathematics beyond assessment | 21 | 2.17 (1.31) | 21 | 2.40 (1.00) | |
| Course help from lecturer | 20 | 1.49 (0.67) | 21 | 2.25 (0.89) | * |
| Study by searching online for course material | 21 | 2.21 (0.77) | 21 | 2.22 (1.00) | |
| Read through lecture notes before lecture | 21 | 1.85 (0.79) | 21 | 2.18 (1.14) | |
| Look at mathematics beyond course content | 16 | 2.13 (1.06) | 21 | 2.15 (0.94) | |
| Assignment help from lecturer | 20 | 1.44 (0.81) | 21 | 2.07 (0.90) | * |
| Learning mathematics by explaining to others | 21 | 2.79 (1.23) | 21 | 1.97 (0.50) | * |

### Attitudes

As for learning behaviours, Table 7 shows a summary of students attitudes towards their courses. These students, like the large cohort of first level students, rate the lecturers highly across all year levels. These students were positive towards most aspects of their courses as all values with high response rates give means above three and the majority of standard deviation below one. These mathematics major students tended to be positive about the benefits, relevance and enjoyment of their course as well as the instruction they received from their lecturers and tutors.

There were two notable changes in attitude. The first related to enjoyment where the major students showed an increase in enjoyment from a mean of 3.56 at first level to 4.17 at third level courses ($t = 2.46$, $p < 0.05$). Choosing the third level course as an elective one student's comment indicated fun as the reason for choice. In first level courses there were a few equivocal comments.

In contrast, the perceived relevance dropped from a mean of 4.14 for first level to 3.80 for third level courses ($t = 2.20$, $p < 0.05$). Despite this drop in relevance, however, relevance is one of the attitudinal variables that are given consistently high rating for both year levels.

**Table 7: Changes in attitudes of major students**

| | n | Level 1 Mean (SD) | n | Level 3 Mean (SD) | |
|---|---|---|---|---|---|
| Rating of lecturer | 21 | 4.21 (0.69) | 20 | 4.25 (0.63) | |
| Rating of course tutor | 20 | 3.83 (0.86) | 17 | 4.21 (1.12) | |
| Benefits | 21 | 3.93 (0.65) | 21 | 4.17 (0.65) | |
| Enjoyment | 21 | 3.56 (0.98) | 21 | 4.17 (0.79) | * |
| Relevance | 21 | 4.14 (0.64) | 21 | 3.80 (0.73) | * |

### Learning behaviours and attitudes related to achievement

Pearson correlation coefficients between achievement and all other variables were computed for first and third level courses and two learning behaviours demonstrated statistically significant correlations. The first is reading through lecture notes before a lecture ($r = 0.48$, $p < 0.05$). The second learning behaviour that was related to achievement is obtaining course help from textbooks or materials ($r = 0.51$, $p < 0.05$), which only becomes significant in third level courses.

A few high achieving students made comments concerning independent learning, such as a preference for reading material beyond what was presented in lectures. However, students with more modest achievement levels also occasionally indicated a preference for getting help from written sources rather than lecturers. There were also some high achieving students in first level courses who appeared from their comments and responses to be both social learners and independent learners. The only two attitude variables that correlated significantly with grade achievement were enjoyment and benefits. Enjoyment correlated for first level ($r = 0.47$, $p < 0.05$) and third level ($r = 0.51$, $p < 0.05$) courses while benefits correlated for third level courses only ($r = 0.53$, $p < 0.05$).

## Discussion

### The major and non-major groups of student

There appears to be a difference between the major students in first level courses and the non-major students, not only in their mathematical achievement, but also in their learning behaviours and attitudes. This is shown with the major students' higher levels of achievement and that they were more likely to look at mathematics beyond the requirements of assessment tasks. Also, the major students found more enjoyment and a greater perception of benefit and relevance in their courses than the non-major students. Enjoyment as an attitude has been linked to achievement in this study as well as in previous research (Watson, 1988). These results may be indicators of major students having greater engagement in their mathematics courses. The non-major students tended to use their friends more for assignment and course help than the major students, perhaps indicating a greater preference for social learning. There were some differences in the typical learning behaviours and attitudes demonstrated by both groups, such as in their rating of the benefits obtained from taking their courses, although there were only a few differences between the groups in learning behaviours and attitudes associated with achievement. The differences between the two groups can be considered sufficient to warrant treating the major and non-major students as distinct groups. These

results may also be of interest to related disciplines, such as physics and chemistry, that have large first level service courses with small numbers of these students proceeding to majors within that field.

The learning behaviours associated with achievement in first level courses were explaining mathematics to others and attending lectures. The attitudes associated with achievement in first level courses were enjoyment, benefits, getting value out of the lecture and the students' perceived effectiveness of the lecturer. While it appears to be important for students to enjoy and feel the benefits of mathematics courses, it is notable that their achievement level was linked to attitudes related to lectures, such as the high rating of the instructor and the perceived value derived from the lecture.

**The third level mathematics major students**

Survey responses from these 21 students provided useful insight into changes in learning behaviours and attitudes across the three years of the mathematics major.

The findings presented in this paper showed that these students not only regularly attended lectures but also valued the learning received there and the lecturers who taught them. The analysis of survey responses from this small group of mathematics major students has not shown the relationship between lecture attendance and achievement found in other studies (Cretchley, 2005; Purcell, 2007). This may be due to the small sample size and the nature of the sample – a cohort of mathematics major students, rather than a general population of first-year mathematics students. Though lecturers were rated highly, students did not generally go to them for help in either year level. However, though it was not prevalent, by third level some students were using the lecturers more for help with assignments and the course work than they did in first level courses.

By the time students enrolled in third level courses they were starting to seek assignment help from their course tutor and their friends. Though this may be due to an increase in the difficulty of courses from first to third level, the increase in help-seeking behaviour may also be due to an increase in students' confidence at seeking help. In later courses, with smaller numbers and a greater percentage of students specialising in mathematics the students may find more of their peers interested in mathematics. This finding also highlights the value of social learning and the need to provide students with these opportunities of social interactions in mathematics throughout their degree.

Mathematics major students generally saw the benefits and relevance of the courses they took. This result differs from other studies involving general first level mathematics courses (Anthony, 2000). Though the level of perceived relevance decreased in mathematics major students between the first and third level courses, this could be related to their interpretation of relevance as some courses become less applied and more abstract in later years. Enjoyment did not appear as a consistent attitude across all students but it was related to achievement, as has been found in previous studies (Watson, 1988), and increased from first level to third level courses. Because third level courses tend to be more specialised than the broad first level courses, they may offer students more opportunities to pursue courses in the areas of mathematics they enjoy.

The only learning behaviour that decreased over time was 'learning mathematics by explaining the course material to others'. It may be that the small group of students taking third level courses as mathematics majors is more homogeneous with respect to mathematical

competence than students in large first level courses, and thus students are less likely to be asked for assistance by less able peers. Nevertheless, as noted above, peer interaction in working on assignments together was still valued by these mathematics major students.

In conclusion, while there is an extensive literature on general first-level mathematics courses, this does not necessarily deal with the issues that relate to the mathematics learning experiences of higher-level undergraduate students. The mathematical major students are lost in the broad research of large service courses in mathematics. This work has provided insight into the experinces of these students and highlights the need to consider their attitudes and behaviours towards learning in curricula planning.

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