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Using student feedback to improve student attitudes and mathematical confidence in a first year interdisciplinary quantitative course: from the ashes of disaster!

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Today's scientist is faced with complex problems that require interdisciplinary solutions. Consequently, tertiary science educators have had to develop and deliver interdisciplinary science courses to equip students with the skills required to solve the evolving real world challenges of today and tomorrow. There are few reported studies of the lessons learned from designing and delivering first year compulsory interdisciplinary science subjects at regional universities. Even fewer studies assess the impact that teaching interventions within interdisciplinary courses have on students' attitudes towards mathematics and technology, and mathematics anxiety. This paper discusses the feedback received from the first student cohort of a new compulsory, 1st year interdisciplinary science subject at a regional Australian university which resulted in curricular revisions. These revisions included a greater emphasis on the subject relevance and increased student support in tutorials. Assessment practices were also dramatically modified. The change in student attitudes and anxiety levels *a priori* and *a posteriori* to the interventions was measured quantitatively and qualitatively. Post intervention, female and non-mathematics major students had grown in mathematical confidence and were less anxious. It is important that positive and negative research findings are reported, so science educators can learn from one another, and can better prepare their students for the challenges they will face in bringing interdisciplinary solutions to contemporary real world problems.

Keywords: mathematics; anxiety; confidence; engagement; interdisciplinary

1. Introduction

Our world is filled with complex problems. The challenges of resource scarcity, climate change, food insecurity, pollution, rapid urbanization and disease place great demands for urgent responses from science and scientists. Invariably, the solution to any one of these problems requires an interdisciplinary approach. The ubiquitous tool in the quest for solutions is mathematics. Consequently, science educators are implored to embed high-level mathematics into the training of all twenty-first century scientists [1, 2, 3, 4, 5]. While bridging multiple disciplines poses challenges for tertiary educators, the interdisciplinary bridge between mathematics and the biological, earth and environmental sciences has been especially problematic [5]. Compounding the problem is the need for students to master graphical and computational computer skills. Thus, interdisciplinary science subjects require mastery of science content, mathematical and technological processes. In addition, an intuitive, or what we refer to as the 'sixth-sense', understanding of the process that interleaves the individual disciplines to deliver interdisciplinary solutions is needed.

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At the same time, for many students, the mere anticipation of doing mathematics can elicit physiological and emotional stress and brain activity in the regions associated with the experience of pain [6] causing them to disengage both physically and emotionally. This may be one significant reason why students in recent years have moved from the mathematical and the physical sciences towards the biological, behavioural and other “soft” sciences [7, 8] as studies in those disciplines are perceived by students to be relatively free of the need to master higher level mathematics [9, 10]. Yet, professional practice increasingly demands that practitioners have the ability to interpret and perform sophisticated mathematical and statistical procedures.

These are enormous challenges for tertiary science educators, most of whom have undertaken their scientific training in single discipline environments. It is crucial that we reflect on the impact of different teaching interventions and share our different experiences as we learn to navigate through this evolving maze of interdisciplinary science education.

1.1 Teaching quantitative skills in an interdisciplinary context

In response to calls by national science interest groups [11], universities in developed economies sought to enhance the quantitative skills of graduating students. With few exceptions, institutions typically responded by introducing free-standing, semester-long courses [12]. These courses ranged from first year, introductory, interdisciplinary courses taught in large classes [13, 11, 9] to advanced level courses taught to a small group of academically high achieving students interested in quantitative problem solving [14], often in specialist fields [15]. Only rarely did these interdisciplinary quantitative skills courses form a compulsory part of an undergraduate student’s degree program.

Designs of interdisciplinary courses characteristically involve problem-based learning approaches [16, 17, 14], that necessitate engagement with (i) the discipline within which the problem is situated, (ii) the modelling approach (e.g. process-based, phenomenological) (iii) the mathematical techniques to be used (e.g. algebra, calculus, statistics), and (iv) an appropriate computational software environment. The technology adopted in interdisciplinary science courses is varied but has frequently extended to mathematical and statistical software like MATLAB [18, 19, 20] and R [15], general purpose programming languages such as Python, [21, 13, 11], and basic spread sheeting programs like Excel [22, 23].

Whilst the relevance of interdisciplinary science applications with a mathematics-technology centric has gained increasing recognition and near universal acceptance (see for example [2, 3, 4, 24]), the practical challenges associated with the development and delivery of these interdisciplinary science programs and individual courses remain formidable. Interdisciplinary science educators of large classes must accommodate a diverse range of student interests and abilities, leading to student feedback like - "… this course seems hard to teach because the students have variable backgrounds in statistics and general computing skills … I am surprised we got through as much as we did…"[15]. Interdisciplinary science education has induced question styling and problem presentation that parallels real-life, fuzzy problems. Questions are typically posed as open-ended or “vague” in pursuit of developing the “sixth-sense”, which conspire to student frustration [22]. The addition of a computing component makes the task for many students more onerous: “the course was hard because it involves programming and statistics…”; “…perhaps fewer materials should be covered with extra time on the programming aspect” [15].

Institutional structures also create barriers. A rigid curriculum design at one institution required majors to be housed in one department. This impeded the progression of interdisciplinary science programs [20]. Matthews [9] reported the impacts on individual students of academic programs dominated by individual disciplines focusing on the teaching of content in a single discipline at the expense of building quantitative problem solving skills. Hence, the employment of teaching teams to design and deliver interdisciplinary science subjects is not only good pedagogy but overcomes traditional institutional barriers created by academic programs and majors owned by one discipline.

Despite an increasing body of literature that provides many reasons and models for why and how to introduce interdisciplinary quantitative skills into degree programs, there are few studies that examine the impact of such courses on student attitudes to quantitative problem solving. Sparser still are the studies that investigate the impact of different variables of course presentation (i.e. topic sequencing, assessment, tutorial support) on university students' engagement and attitudes to learning.

Yet, students' attitudes may have a significant effect on the success of learning mathematics and computing [25]. Pierce et al. [25] hypothesize that technology employed to solve real world problems demonstrates the relevance of mathematics to students**,** which then encourages affective and consequently behavioural engagement. Moreover, they hypothesized that using mathematics and mathematical analysis tools leads to increased confidence in mathematics. They propose this approach leads to improved learning in mathematics. To better explore the effect of attitudes, Pierce et al. [25] developed the Mathematics and Technology Attitudes Scale (MTAS), an instrument that considered attitudes of middle secondary students (aged from 14 years) to both mathematics and technology. Their instrument measured five subscales (i) mathematical confidence, (ii) confidence with technology, (iii) attitude to learning mathematics with technology, (iv) affective engagement and (v) behavioural engagement relevant to learning mathematics with technology tools (graphics calculator). By understanding the intercorrelations between these subscales, they argued that educators can more effectively integrate technology to enhance mathematical achievement. The authors identified that correlations are dependent on gender**.** Teaching strategies for males may therefore not be equally effective for females. For example, technological confidence in males was positively associated with their attitude to learning mathematics with technology. However this association did not exist for females.

Lim et al. [19] undertook a more targeted investigation**,** which focused on the impact of an interdisciplinary science subject on attitudes towards mathematics of 26 students**,** who undertook a modelling project in Earth Sciences at the National Taiwan Normal University. They assessed if students' attitudes towards mathematics changed after participating in modelling exercises. Their instrument considered four subscales of attitudes – beliefs, usefulness, enjoyment and anxiety. They found that mathematics enjoyment of Earth Science students improved when mathematics was delivered within a mathematical modelling framework.

Furthermore, engagement with and attitudes to learning and subsequent performance can be affected by mathematics anxiety [26, 27]. Using a survey developed by Hopko et al. [28], Gyuris et al. [27] corroborating the findings of Keeley et al. [29], demonstrated a weak but statistically significant relationship between anxiety and student performance among first year university students participating in a first year, compulsory, interdisciplinary science subject.

Here we report on some of the outcomes of a student-centered and reflection-driven revision of a first year, compulsory, interdisciplinary quantitative skills subject. The course team was particularly concerned with creating an engaging learning environment that alleviated anxiety associated with the subject. They were specifically interested in how students' behavioural and affective engagement, confidence and anxiety responded to different teaching interventions. Hence, the purpose of our reflective process was four fold:

- identify the challenges experienced by the first cohort of students who participated in a new, compulsory, first year interdisciplinary science subject at a regional university in tropical Australia;
- discuss the interventions to subject presentation that were put in place to address these challenges;
- assess within-year, and year-to-year change in student feedback surveys and questionnaires pertaining to attitudes towards mathematics and technology, and mathematics anxiety;
- reflect on the key lessons learnt during this process.

2. Materials and methods

2.1. Our course, SC1102 in context

James Cook University is internationally recognized with research strengths in the biological and environmental sciences. One of the universities most geographically distant from the large population hubs of the state capital cities, the university engages with a large under-served population and caters for a relatively large number of undergraduate students from minority groups [30]. In 2009, 45% of the Faculty of Science and Engineering student body comprised students from non-English speaking backgrounds (3%), Aboriginal and Torres Strait Islander students (1.4%), students with a disability (4.6%), students from low socio-economic backgrounds (17%), and students from regional or remote areas (19%). In 2008, the university commenced a process of curriculum refresh. Consequently SC1102, a course that interleaved the disciplines of mathematics, the natural sciences and computing (Microsoft Excel) was conceived as a compulsory component of the renewed Bachelor of Science program. First delivered in 2010, the 13-week course, in a format of 2-3 lectures and one two-hour tutorial session per week, has an annual enrollment of approximately 200 students per year. The subject is "owned" by the Faculty of Science and Engineering, encompassing the schools of Engineering and Physical Sciences, Earth and Environmental Sciences, and Marine and Tropical Biology. Each school is funded by SC1102s' income in proportion to the school's contribution to the subject. The course team consisted of teaching academics drawn from the schools of the Faculty, the Associate Dean of Teaching and Leaning, two specialist consultants and the course coordinator, who was directly responsible for the development and coordination of the course and for the management of the course team, including the sessional tutorial staff.

The subject was developed with a lead-time of 12 months and with the input of the collective teaching experience of the course team, responded to explicit expectations of Faculty senior management. The teaching team chose the case study approach to fulfill the objectives of both skill development and development in the affective domain of mathematics and qualitative problem solving. The case studies were developed and delivered by staff with considerable experience in teaching to a student body characterized by limited interest in quantitative methods. A purpose designed, high quality course textbook was produced, containing detailed lecture notes and an overview of the computing environment. Tutorial problems were strategically embedded throughout its text to help guide students to the appropriate readings that would assist with solving the tutorial problems. Microsoft Excel was chosen as the technology software as the course team wanted a computing environment that students were able to have on their own computers, and that had wide applicability even outside the strictly academic environment. In addition, Microsoft Excel was thought to be simpler for students to use than more sophisticated programs such as MATLAB or R. To emphasize the relevance of the subject and promote engagement, invited guest lecturers gave examples of how they have used mathematics and technology to enable their research. Assessment by the way of tests and assignments, feedback about performance on those course assessments, and the final examination were planned with the intention to encourage student participation and to improve mathematical confidence.

2.2. Collecting and analysing data about students' attitudes and anxiety

Information about students' attitude and anxiety was collected in 2010 (cohort 1) and 2011 (cohort 2) via the university's standard survey for student feedback about subjects (SFS), and a questionnaire that surveyed mathematics anxiety and attitudes to mathematical and technological learning. In 2010 only, focus group interviews were also conducted.

2.2.1. Student Feedback about Subjects (SFS)

A web-based survey instrument, the university's SFS invites students to anonymously respond to 18 statements pertaining to the quality of the subject (Table 1) and several open-ended questions about the best aspects of the course and opportunities for its improvement. This non-compulsory survey is open to students between week 10 of the semester and the last day of the exam period. Approximately 16% of students responded to the survey in 2010, and 24% in 2011.

2.2.2. Questionnaire on Attitudes and Anxiety about Mathematics and Technology

Our questionnaire (Table 2) for assessing attitudes and anxiety about Mathematics and Technology was motivated largely from the works of Hopko et al. [28], Pierce et al. [25] and**,** to a lesser extent**,** Lim et al. [19]. Our questionnaire had seven subscales**,** with items that pertained to behavioural engagement, mathematical confidence, enjoyment/affective engagement, mathematics evaluation anxiety, mathematics learning anxiety, technology for learning mathematics and confidence in using technologies. In some cases**,** the questions were adapted to better encompass the skills and content of SC1102 (Table 2). Questions on mathematical confidence were expanded to reflect the application of drawing and verbal interpretation of key features of graphs**,** and the writing and interpretation of formulae. Two additional questions were devised about student confidence and students' ability to complete mathematical tasks on assignments. When presented on the survey instrument, questions were randomized across subscales. To be consistent with the SFS with which students were familiar, student agreement was scored on a five point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree)**.** Questions were affirmatively worded to avoid frustration and confusion caused by switching between positively and negatively worded items. Students' gender**,** and whether the science discipline that most interested the student participant included mathematics and/or physics (differentiated below as mathematics majors and non-mathematics majors) were also recorded. The questionnaire was administered in the first and final lecture of the course in both cohort 1 (2010 student group) and cohort 2 (2011 student group). Cronbach's alpha was used to measure the reliability of the questionnaire. Values for Cronbach's alpha were favourable and ranged from 0.79-0.91 for each subscale for cohort 1 and from 0.82-0.91 for cohort 2.

Table 1. Mean and modal scores of student responses for questions on the university student feedback survey (SFS). Items were scored on a Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Item	Cohort 1 mean (mode)	Cohort 2 mean (mode)
1. The staff of this subject motivated me to do my best work	2.93(3)	3.38(4)
2. The teaching staff worked hard to make this subject interesting	3.03(2)	3.32(4)
3. My lecturers were extremely good at explaining things	2.83(2)	3.05(3)
4. The staff made a real effort to understand difficulties I might be having with my work	3.20(3)	3.40(4)
5. The staff put a lot of time into commenting on my work	2.73(3)	3.30(4)
6. The teaching staff normally gave me helpful feedback on how I was going	3.13(3)	3.69(4)
7. The staff made it clear right from the start what they expected from students	2.66(3)	3.55(4)
8. The assessment requirements and criteria were clearly specified	3.07(4)	3.80(4)
9. The teaching and learning experiences of this subject were well organized	2.50(1)	3.25(4)
10. The subject helped me develop my ability work as a team member	2.50(3)	2.75(3)
11. This subject sharpened my analytical skills	2.79(3)	3.61(4)
12. This subject developed my problem solving skills	2.93(4)	3.54(3)
13.This subject improved my skills in written communication	2.47(3)	3.00(3)
14.As a result of this subject I feel more confident about tackling unfamiliar problems	2.79(3)	3.29(3)
15. This subject helped me to develop the ability to plan my own work	2.79(3)	3.24(4)
16.Good learning resources (LearnJCU, web, labs, other) were provided to help me learn in this subject)	3.04(3)	3.76(4)
17. The library provided good access to all of the books, journal articles and other media I needed in this subject	3.17(3)	3.22(3)
18. Overall, I am satisfied with the quality of this subject	2.50(1)	3.05(4)

2.2.3. Focus Groups

Three focus groups in 2010 were established. Each focus group was differentiated by the students' disciplinary major in the fields of (i) Earth and Environmental Science (ii) Marine and Tropical Biology, and (iii) Mathematics and Physics. Open-ended questions were posed to prompt student discussion about aspects of the subject**,** particularly relating to behavioural effort, confidence with and enjoyment of quantitative problem solving, anxiety, and, use of Excel and graphs (e.g. "How did this subject shape your attitude to mathematics and working with numbers?"). The one-hour long focus groups were conducted in November 2010.

Table 2. Items on the Questionnaire on Attitudes and Anxiety about Mathematics and Technology (column 2) modified from previous research (column 3, sources as indicated * 1= Pierce et al. [25] **28**, 2 = Lim et al. [19] **22**, 3 = Hopko et al. [28] **16**. Items with no identified sources were developed *de novo* for use in the current research). Items are grouped into subscales (BE = behavioural engagement, MC = mathematical confidence, AE = affective engagement, MLA = mathematics learning anxiety, MEA = mathematics evaluation anxiety, TL = technology for learning mathematics and TC = technology confidence), but note that on the survey instrument they were presented in random order.

Subscales	Questionnaire on Attitudes and Anxiety	Questions as Presented in Literature*
BE1	I really make an effort with mathematics in my subjects	I really make an effort in my mathematics lessons[1]
BE2	I concentrate hard in mathematics	I concentrate hard in mathematics[1]
BE3	I try to answer all the mathematical questions the lecturer asks	I try to answer questions the teacher asks[1]
BE4	I prefer to test my understanding of mathematics by doing exercises and problems	I test my understanding by doing exercises and problems[1]
BE5	If I can't do a mathematical problem, I keep trying different ideas	If I can't do a problem, I keep trying different ideas[1]
BE6	I try to link new ideas to mathematics knowledge I already have	In mathematics I try to link new ideas to knowledge I already have[1]
BE7	If I make mistakes in mathematical problems, I work until I have corrected them	If I make mistakes, I work until I have corrected them[1]
MC1	I believe that I have a mathematical mind	I have a mathematical mind[1]
MC2	I feel confident that I can handle any difficulties in the mathematics that I will study at university	I know I can handle difficulties in mathematics[1]
MC3	I feel confident that I can do well in mathematics if I work hard	I am confident with mathematics[1]
MC4	I always have the confidence to complete the mathematics in my assignments	
MC5	I always find it easy to complete the mathematics in my assignments	
MC6	I always find it easy to interpret graphs that explain scientific phenomena	
MC7	I always find it easy to interpret formulae that explain scientific phenomena	I find it hard to use mathematics to describe the science of the atmosphere[2]
MC8	I always find it easy to draw graphs to explain scientific phenomena	
MC9	I always find it easy to write formulae to explain scientific phenomena	
AE1	I enjoy learning mathematics	Learning mathematics is enjoyable[1]
AE2	I enjoy mathematics lessons	
AE3	I enjoy learning new things where I can use mathematics	I often use the concepts of mathematics to solve real life problems[2]
AE4	I enjoy discussing the mathematics in my assignments with classmates	I like to discuss mathematics homework with my friends[2]
AE5	I enjoy doing assignments that have large mathematics component	
AE6	I get a sense of satisfaction when I solve mathematics problems	I get a sense of satisfaction when I solve mathematics problems[1]
AE7	When I can use graphs to describe a mathematics answer it makes the answer more interesting	Using a graph to describe a mathematics answer will make the answer more interesting[2]

Table 2. Continued

Subscales	Questionnaire on Attitudes and Anxiety	Questions as Presented in Literature*
AE8	When I can use formulae to describe a mathematics answer it makes the answer more interesting	
MEA1	I feel anxious thinking about a math test coming up the next day	How anxious would you feel when thinking about an upcoming math test 1 day before[3]
MEA2	I feel anxious when taking an examination in a math course	How anxious would you feel when taking an examination in a math course[3]
MEA3	I feel anxious about a math assignment that is due in the next class	How anxious would you feel when being given a homework assignment of many difficult problems that is due the next day[3]
MLA1	I feel anxious watching a teacher work an algebraic equation at the front of the class	How anxious would you feel when watching a teacher work an algebraic equation at the front of the class[3]
MLA2	I feel anxious watching a teacher work with a graph at the front of the class	
MLA3	I feel anxious when listening to a math lecture	How anxious would you feel when listening to a lecture in math class[3]
MLA4	I feel anxious when listening to another student explain a math formula	How anxious would you feel when listening to another student explain a math formula[3]
MLA5	I feel anxious when listening to another student explain a math graph	
MLA6	I feel anxious when starting a new chapter in a math book	How anxious would you feel when starting a new chapter in math class[3]
MLA7	I feel anxious when using the tables in the back of a math book.	How anxious would you feel when having to use tables in the back of a math book[3]
TC1	I am good at using computers	I am good at using computers[1]
TC2	I am quick to learn new computer programs	I can master any computer programs needed for school[1]
TL1	I use mathematical software to help me learn mathematics	Mathematical software helps me in learning mathematics[2]
TL2	I think that I learn more when I use Microsoft Excel in mathematics	I learn more when I use graphics calculators in mathematics[1]
TL3	I always find it easy to use *Microsoft Excel* to learn mathematics	
TL4	I enjoy using a computer to learn mathematics	I like using graphics calculators for mathematics[1]
TL5	I enjoy using Microsoft Excel for mathematics	
TL6	Using Microsoft Excel makes Using mathematical tasks more interesting	Mathematics is more interesting when using graphics calculators[1]

2.2.4. Data Analysis

These data were then used to review and modify the course and to gauge the potential effectiveness of interventions in achieving improved engagement, increased confidence in quantitative problem solving and moderate anxiety. Qualitative data (responses to open ended questions on the SFS and focus group transcripts) were analysed using an informal textual content analysis. In line with Matthews et al. [11], a descriptive approach was taken to analyse numerical data. Likert scale responses on the SFS were analysed using measures of central tendency (mean and mode). Changes within and between years on the attitudinal and anxiety questionnaire were investigated by 95% confidence intervals. A descriptive approach was preferred over traditional significance testing methods as the required Bonferonni adjusted significance level did not detect any significant differences. The number of respondents for each survey by student subgroup has been displayed in Table 3.

Table 3. Number of respondents from each student subgroup according to survey.

	Paired analysis		Between comparison			
			Week 1		Week 13	
	2010	2011	2010	2011	2010	2011
All	65	65	139	177	82	87
Males	27	32	53	75	31	42
Females	37	34	85	101	51	41
Mathematics Majors	7	4	15	21	13	7
Non-mathematics majors	56	60	122	153	68	76

3. Learning and Teaching in SC1102

In 2010 the first three weeks of the semester involved a "quick revision-course" designed to refresh students' knowledge of mathematical concepts and technologies that support mathematics (Excel), providing foundation for the three, three-week long case studies that followed. The only phenomenologically-based case study on statistical climate prediction was presented first. Two process-based cases studies followed, one on sustainable fish harvesting the other on the greenhouse effect. No new material was delivered in the last week.

Assessment items consisted of a timed, invigilated class test (worth 20%, administered in week 8), two take-home, non-invigilated assignments (one worth 10% the other 20%), and an invigilated (or proctored) examination (worth 50%). The class test assessed concepts from the mathematics "quick revision-course", and the first case study. The final examination was conducted in a computing laboratory and assessed both the computing and theoretical aspects of the subject. Weekly tutorial problems were set, but these did not form part of formal assessment. In tutorials the ratio of students:tutors was 10:1.

3.1. What did the feedback say and how did the course team respond

Some students were positive about the course:

> "After understanding what was expected from myself, I vastly improved in my analytical and visual interpretation skill. It was a hard subject but I really believe it is necessary for anyone doing a Science degree as we all have to do reports and analyze data/information/results. I am so impressed with how I have improved during the course."

However, the feedback from the SFS, student focus group interviews and the attitudinal survey suggested the course could be greatly improved. The mean score over the

18 Likert-type question items of the SFS was 2.84, falling short of the neutral midpoint of 3. Mean scores for subject organization (item 9) and overall satisfaction (item 18) were both 2.50 with a modal score of 1 (Table 1). Students verbalized reasons for these scores as:

- "The whole subject was a waste of time. I felt that I learned nothing from the subject. The entire structure of the course doesn't go together and was seemingly random."
- "This course seemed to be poorly structured and jumped from place to place very quickly then returning again without any relevancy."

Students wanted more help with the assignments ("lecturer would not help with assignments"), and they struggled with the open-ended type questions ("assignments were vague, you don't know what they are asking", "need more hints with the assignment", "testing criteria were not well defined"). Students were unsure how to prepare for the exam.

Students felt overloaded with new information about Excel and mathematical methods, sparking comments like "there was too much information too soon". Moreover, students said that "Excel was daunting" and were confused with the different ways for solving a problem using this software. Students thought that the delivery of the tutorials should be improved ("tutors could not help because they were only given answers and not sufficient workings"). Students advised lecture staff to engage more closely with tutorial staff and reduce wait times for tutorial assistance.

The student survey on attitudes and anxiety showed that**,** in 2010**,** the course did not achieve the intended learning environment that moderated anxiety and poor engagement with the subject. From week 1 to week 13**,** behavioural engagement decreased for males and computing confidence decreased for females. Mathematics learning anxiety (MLA) increased during the semester for females, non-mathematics majors and for the cohort overall (Figure 1).

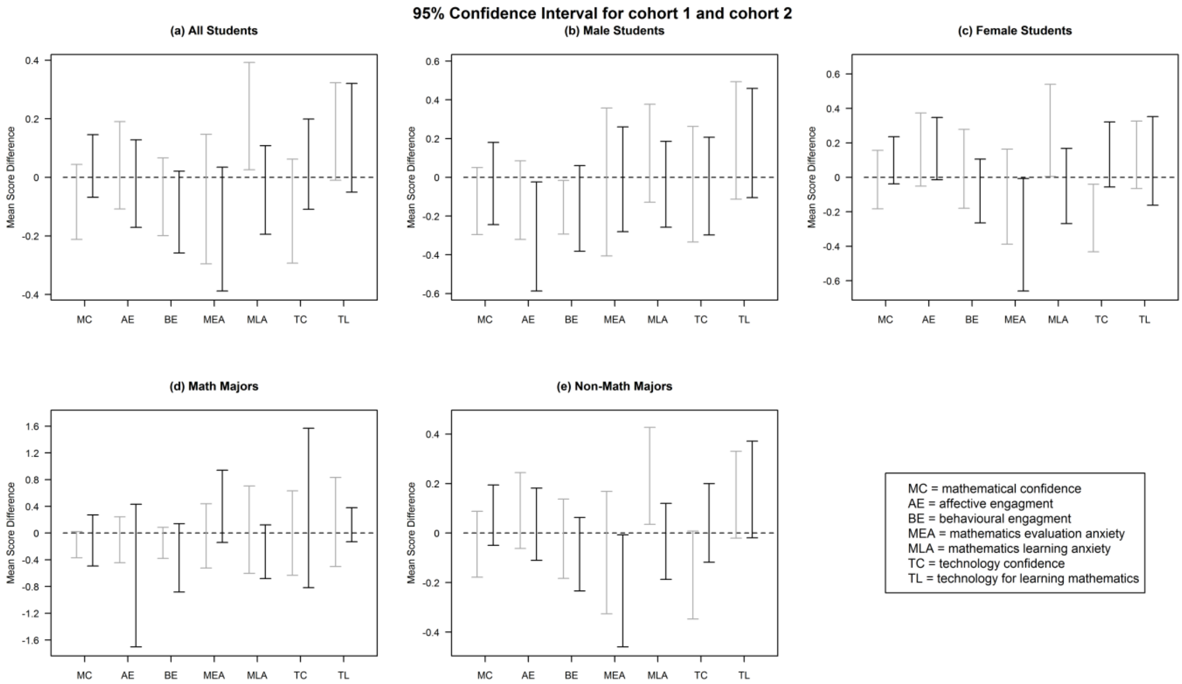

Figure 1. 95% confidence intervals for the mean paired differences (week 13 minus week 1) for each subscale on the questionnaire for cohort 1(grey) and cohort 2 (black). Confidence intervals are displayed separately for (a) all students, (b) male students, (c) female students, (d) math majors and (e) non-math majors.

The course team considered all feedback and reasoned that (i) emphasizing subject relevance, (ii) improving student support via the tutorial environment and (iii) modifying assessment would result in measurable improvements in both student satisfaction with the subject and in attitudes and anxiety.

It was clear that many students' from cohort 1 did not "get" what the subject was about. The course team contended that a subject on "interdisciplinary science" and "mathematical modelling" had little meaning to first year science students. To address this issue**,** the subject name was changed from "Systems Modelling and Visualisation" to "Modelling Natural Systems". A course logo was developed (Figure 2) that portrayed the three components of scientific modelling – science, mathematics and computing – that, when rotated rapidly in PowerPoint presentation, symbolized the overlapping disciplinary boundaries cognisant of interdisciplinary modelling. The logo was used throughout to stress the inter-dependency of these three components to real-world problems. Teaching staff made a conscientious effort to instill the importance of modelling in science by having the primary lecture of the subject devoted to this concept, and consistently reinforced this concept by case studies and guest lecturers.

Figure 2. Course logo developed for SC1102.

The course team thought the case studies would make the subject seem relevant to the initial cohort and this would motivate and engage the students. Clearly this was not the case in 2010. On reflection, the course team considered that opening the course with the parallel demands of mathematics and technology (Excel) in a context-free three-week long quick revision module was counter to engaging and motivating the majority of students. Immediately following with perhaps the most abstract and difficult of the three case studies, created the perfect storm for many of the students**,** ensuring low course satisfaction and heightened student anxiety. Therefore**,** in 2011 the mathematics "quick revision-course" was omitted from formal lectures and replaced with a gradual introduction to general modelling concepts that underpinned the SC1102 case studies**,** creating time for students to familiarize themselves with Microsoft Excel. The science, mathematics and computing came together in week 3, with the start of the process based, sustainable fish harvesting case study. These changes were designed to strengthen the relevance of the course from the student perspective [31]. The slower introduction of concepts and skills (Excel) aimed to build confidence, encouraging students to take full advantage of the tutorials.

Student support was increased: screencasts of tutorial solutions were provided, and fewer but more experienced tutors were engaged. The screencasts allowed for a higher student:tutor ratio of 20:1 and facilitated consistent guidance to both students and tutors. Weekly meetings between the course coordinator and the tutors were conducted, reducing to meetings every two-three weeks late in the semester. The in-class collection and return of assignments – as opposed to a physical drop box system used in 2010 – facilitated additional tutor-student interactions. A policy of one business-day turn around with marking class tests and one-week turn around with marking weekly assignments was implemented in 2011. The course coordinator posted regular weekly updates so that students knew on what to focus each week, thereby fostering engagement and easing time management.

The assessment schedule for cohort 2 was radically revised to engender behavioural engagement and to avoid the negative impact of high-stake, high-pressure assessment events [32, 29] – such as the highly weighted final examination in 2010. In 2011**,** students had 12 weekly assignments (10% in total) and three timed and invigilated on course tests (delivered in weeks 7, 10 and 13, 30% each). At the end of the semester**,** interim scores were calculated. Those students achieving a score of < 65% were required to sit a final examination. The examination was offered as an option to all other students. A second score for all students sitting the examination was calculated with the examination worth 60% and the class tests each 10%. For students taking the exam as an option the final grade was established as the better of the two scores. For students required to sit the examination the second score was taken as the final score.

So the course appeared a more unified subject rather than a disconnected series of modules, the presentation and styling of assessment items was modified. The weekly assignments, class tests and exams were formatted consistently. The course coordinator worked very closely with each of the case study teachers to ensure that question styling was similar across all assessment items**,** and that questions which would take a similar amount of time were allocated the same amount of marks. Also, the expected answer length of questions was more clearly expressed to students.

3.2. How effective was the course team's response

Whilst negative comments like "this course should be discontinued" again appeared amongst the open ended responses of the SFS, comments such as "I think as a subject on the whole it is very well organised" and "the overall learning aspect of the subject was great" were more typical. More specifically, the ratio of positive:negative student responses on the SFS item "please make any further comment about this subject" improved from 5:12 in 2010 to 16:5 in 2011.

For cohort 2**,** the SFS mean score over all Likert scale items was 3.37, with several individual items showing marked positive change when compared to mean scores of cohort 1 (see Table 1). The mean score for subject organization (item 9) and overall satisfaction (item 18) improved from a mean score of 2.50 and mode of 1 for both items to a mean and mode (mean, mode) of (3.25, 4) for item 9 and (3.05, 4) for item 18. Students liked that the staff commented and provided feedback on their weekly assignments and class tests (items 5 and 6). Screencasts of tutorial solutions and weekly announcements posted on the course website may have improved descriptive statistics for learning resources (item 16).

Students found the new assessment scheme encouraged them to keep abreast of new material ("Although they can sometimes be a pain, I found the weekly assignments to be very helpful in both practicing and ascertaining how I was going with the topic and the subject as a whole.", "… the weekly assignments were a good way to stay on track"). Furthermore the two-scheme approach with deriving the final grade helped to reduce some students' anxieties ("I loved the two-scheme policy as it enabled me to be less stressed").

The SFS coupled closely with the attitude and anxiety questionnaire. The anxiety due to evaluation (MEA) for females and all non-mathematics majors decreased during the semester for cohort 2 (Figure 1). The new assessment structure may have also contributed to improved confidence levels for the second cohort ("… the content is very easy for most people to understand at the end of each case study due to the ongoing work that everyone has to do", see also item 14 in Table 2). See Gyuris et al. [27] for a detailed investigation about the impact that changed assessment practice has on the relationship between gender and anxiety.

Further, the course team was pleased that undesirable outcomes that were present in the cohort 1 survey were not evident in the survey for cohort 2 (Figure 1): Behavioural engagement of male students, technology confidence of females, as well as anxiety due to learning (MLA) for females, non mathematics-majors and for the cohort overall, did not change during the semester. However, affective engagement for males decreased during semester for cohort 2 for reasons that our information is unable to explain.

Having established that cohort 1 and cohort 2 were indistinguishable at week 1 in both years for all subscales except for MLA for males, a between-cohort effect was investigated for the remaining subscales and student groups (Figure 3). The 95% confidence intervals indicate that anxiety for females and non-mathematics majors was lower at the end of the course for cohort 2. Specifically, both MEA and MLA were lower amongst females and MLA was also lower for non-mathematics majors. At the end of the course, mathematics confidence was higher amongst females and non-mathematics majors in 2011 than in 2010. Given there exists a body of literature (e.g. [25]) that demonstrates males tend to be more mathematically confident than females, it was deemed a positive outcome that the teaching interventions coincided with improved mathematical confidence in females.

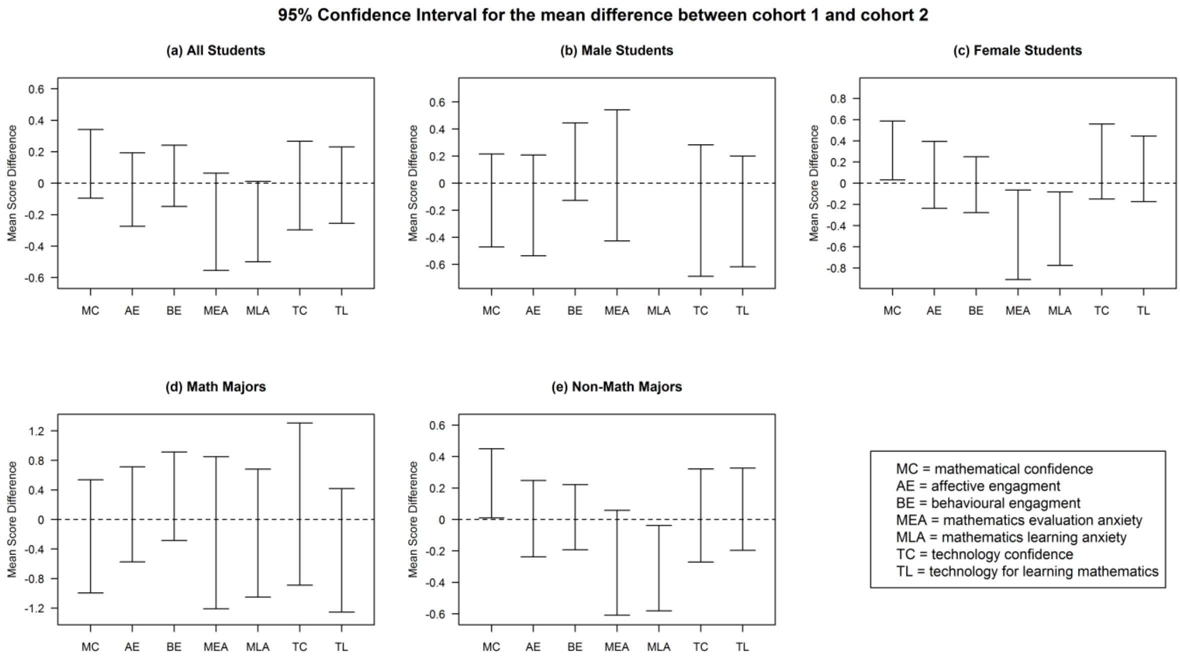

Figure 3. 95% confidence intervals for the mean differences between cohort 1 and cohort 2 at week 13. Confidence intervals are displayed separately for (a) all students, (b) male students, (c) female students, (d) math majors and (e) non-math majors.

4. Concluding remarks

Few would argue the need to develop and deliver interdisciplinary science subjects in a tertiary environment. However, there are very few universities that include an interdisciplinary quantitative skills course as a compulsory component of the first year science program. In an environment where many students actively avoid mathematics**,** such a move can affect mathematics anxiety and attitudes that promote student engagement and motivation for learning. There have been few published studies that critically examine attempts to affectively and behaviorally engage students in developing knowledge and skills in tertiary interdisciplinary science subjects.

Of course, the truest measure of the effectiveness of our intervention would be demonstration of positive changes in student learning outcomes in subsequent courses where students apply the skills and approaches learned in our course. Following the first year of offering the course we communicated with teaching staff of follow-on courses about student performance compared with that in previous years. Unfortunately, staff in frequent, close contact with the students were mostly casual teaching assistants and were not able to provide substantive comparative feedback on student performance. Another measure of the success of the course is student retention and data can be de-aggregated to year levels within individual degree programs. However, considering that our course was part of a wide-ranging curriculum refresh program, changes in retention cannot be attributed to individual courses. Hence, we limited the focus of our research to linking the impacts of changing teaching approaches to students' attitude, engagement and mathematical confidence at the start and at the conclusion of a single course. Furthermore, establishing the cause and effect relationships between individual actions**,** or groups of actions**,** on interdependent variables such as satisfaction, confidence, engagement and anxiety is always fraught with difficulties and will not be attempted here. Nevertheless, the findings herein provide direction for future investment in research. For example, future research could assess if the findings in this paper can be replicated at other regional or metropolitan universities. Moreover, given the descriptive nature of this research**,** it would be worthwhile to employ more rigorous statistical approaches and assess if these trends continue over time, and better still, to measure in particular mathematical confidence and anxiety at several stages during the semester rather than just the first and last weeks of semester. Regrettably, poor course performance is seldom disclosed, let alone published**,** owing to practitioner-researchers' self censoring [33]. Yet, practitioner-researchers, when faced with the ashes of disaster, should be inspired by the lyrics of the song "The Roses of Success" from the musical, Chitty Chitty Bang Bang[1] that is a celebration of success achieved through sheer perseverance.

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[1] http://en.wikipedia.org/wiki/The_Roses_of_Success

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