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The impact of targeted mathematics/numeracy tutorials on maths anxiety, numeracy and basic drug calculation exam marks

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Numeracy skills are the foundation of drug calculation skills and are indispensable for practicing nurses. According to teachers and researchers, lack of numeracy skills, maths anxiety, and/or lack of confidence are among factors associated with drug calculation errors (Bull, 2009; McMullan, Jones, & Lea, 2012). This paper reports on a small-scale project to evaluate the impact of voluntary supplementary maths tutorials, delivered by maths learning development lecturers from the Learning Centre, on maths anxiety, numeracy skills and basic drug calculation exam marks. The 27 first year Bachelor of Nursing students who were the primary study group for this study completed a maths anxiety questionnaire and a numeracy test in the second and fourteenth weeks of the tutorials. Participants also completed an evaluation of the communication style and usefulness of the tutorials. A quantitative analysis showed attending tutorials seems to have had a positive impact on both numeracy scores, for which there was a moderate standardised average improvement (Cohen's d = 0.59), and maths anxiety scores, for which there was a small standardised average reduction (Glass's $\Delta_{pre} = 0.265$). As numeracy skills improved, levels of maths anxiety decreased for a number of students. Encouragingly, all but three of the study group passed the drug calculation component of the final exam, and for two of these three, other factors such as limited English proficiency may have played a role in their not passing. Evaluations commented positively on the clarity and inclusive communication style of the tutorials. While the study cannot establish that attending tutorials was the only factor contributing to improved marks and lessened anxiety, the study suggests there is value in early maths support interventions. A supportive, caring learning environment not only helped students to express their concerns and openly acknowledge their areas of weakness, but for several, also reduced their maths anxiety to some extent and improved numerical skills.

Key Words: maths anxiety; numeracy skills; nurses; drug calculation; maths learning; diagnostic maths test; maths support; learning development.

1. Introduction

Accurate drug calculation is a vital skill in nursing practice. Practicing nurses have to deal with numbers in their workplace in many different ways, for example, recording vital signs, reading syringes, as well as calculating and administering drug doses. Drug calculation errors and their adverse effects are not uncommon (Johnston, 2012; Mayo & Duncan, 2004; Wirtz, Taxis, & Barber, 2003). There may be many factors leading to such errors, and lack of numeracy skills, maths anxiety, and/or lack of confidence are possible contributors. Regarding these possible contributors, McMullan, Jones, and Lea (2012) studied the influence of maths anxiety, self-efficacy and numerical ability on nursing students' drug calculation ability and concluded that numerical ability is the strongest factor in predicting drug calculation ability. As a result of the above issues, learning development staff often help to address the numeracy skills of nursing students in ways that aim to help them overcome maths anxiety and develop confidence to successfully manage maths/drug calculations (Butters, Kerfoot, Murphy, & Williams, 2013; Ramjan et al., 2014), and this paper presents the results of a small-scale study of an intervention with these aims.

2. Background

As a member of Unitec Institute of Technology's Learning Centre team, the maths lecturer had been observing apparent links between first-year students' skills in basic numerical operations, their concern about the must-pass maths component of the Human Bioscience exam, and their informal comments indicating maths anxiety. She was interested to explore whether a statistical analysis would support connections between these three aspects as well as indicating the efficacy or otherwise of the tutorials in improving numeracy and reducing maths anxiety. As learning support resources are often constrained, it is important to ensure that initiatives for specific groups of students are having a positive impact. At the same time, there are internal and external demands to evaluate the impact of our work and report on our contribution to student learning to colleagues and stakeholders. However, as Wilkins (2015) points out, it is often difficult to demonstrate objectively the value of learning development interventions because attendance of students at voluntary learning opportunities can be erratic, and also because learning sessions occur in parallel with subject courses. Consequently, learning developers cannot claim credit for all improvement in student performance (Manalo, Marshall, & Fraser, 2009). Nevertheless, it is useful to look for evidence to see what patterns emerge, even if we have to hedge the conclusions that can be drawn from findings. It is clear that many other factors come into play when we try to measure learning or attitudinal gain, but that is true for any educational intervention. Difficulty in making causal claims does not negate the value of gathering and analysing data in both quantitative and qualitative forms to see whether learning development initiatives seem to have been of benefit to particular groups and therefore are likely to be of benefit to future students, and in this study, the use of a pre-numeracy test has allowed for some of the possible confounds to be controlled for to some extent (see Section 5.4).

There has been a longstanding positive relationship between Department of Nursing staff and the whole Learning Centre team. The Human Bioscience lecturer recognised that regular maths support was essential if many students were to pass the drug calculation component of the exam so she actively requested Learning Centre help. The importance of forming and maintaining relationships between subject lecturers and learning developers has been seen as important in helping students develop numeracy skills (Butters et al., 2013).

In their first year, Bachelor of Nursing (BN) students learn about drug calculation in small, group-based practical laboratory sessions supported by a laboratory manual in which there are follow-up tasks they need to complete. These students have to pass the drug calculations component of the Human Bioscience course in order to pass the whole course. It is a must pass requirement and use of calculators is not permitted.[1] To support student learning in this component of the course, staff from the Learning Centre have been delivering voluntary additional maths tutorials for a number of years. Students self-select for different timeslots offered to suit the range of different BN first year timetables. Prior to this study, comparisons of marks of attendees and non-attendees seemed to show that the tutorials had been beneficial. Anecdotally, some students had commented that decreased anxiety in relation to maths/numeracy resulting from attendance at tutorials had improved their confidence when taking the drug calculation exam.

To verify the anecdotal observation mentioned above, the objective of this project was to look at student self-assessment of maths anxiety, as a personal factor which may be affecting learning, to see what (if any) relationships exist between this and basic drug calculation test results. The main research question was: Can a semester of targeted mathematics/numeracy tutorials facilitated by Learning Centre staff make a positive difference to Bachelor of Nursing first-year students' maths anxiety, numeracy skills and basic drug calculation exam marks? The subquestions were: firstly, what is the impact of tutorials on maths anxiety? Do these tutorials reduce maths anxiety in a significant way? Secondly, what is the impact of tutorials on numeracy skills? Is there a significant improvement in numeracy skills after attending these tutorials? Thirdly, what is the relationship between maths anxiety and numeracy skills? Finally, what is the relationship between numeracy skills and drug calculation exam marks?

3. Literature review

The numeracy skills of nursing students have been a concern for nursing educators and have had the attention of several researchers. This work consistently shows that there are generally observed gaps in the basic mathematical skills of practicing nurses and nursing students (Bayne & Bindler, 1988; Bindler & Bayne, 1984, 1991; Blais & Bath, 1992; Eastwood, Boyle, Brett, & Fairhall, 2011; Jukes & Gilchrist, 2006; Rainboth & DeMasi, 2006). According to the literature, the basic mathematical skills required for drug calculation in nursing courses are addition, subtraction, multiplication, and division of whole numbers; fractions; decimals; percentages; and metric conversions (Bindler & Bayne, 1984; Blais & Bath, 1992). It is commonly assumed, or perhaps hoped, that the students entering nursing courses in tertiary institutions will have these basic mathematical skills, although literature suggests otherwise. For example, Bayne and Bindler (1984) tested the basic mathematical skills of nursing student groups over a number of years and found that from 9% to 38% of students did not achieve the pass level of 70% for at least one part of the test. More recently, McMullan et al. (2012), in a study of second year undergraduate nursing students, found that 55% of students failed to achieve the 60% pass score in a basic mathematical calculation test. Blais and Bath (1992) also tested the mathematical skills required for drug calculation by nursing students and found that 89% did not achieve the pass level of 90%. In a similar study, Jukes and Gilchrist (2006) found that 91% of students failed to achieve the 90% pass score in their basic mathematical drug calculation test. In a recent study, Eastwood et al. (2011) found similar results that 82.7% of students failed to achieve a score of 90% or more in the drug/basic mathematical calculation test. In their study, they reported 38.9% arithmetical errors, which were slightly more common than conceptual errors (36%), as opposed to the earlier report by Blais and Bath (1992) that the most frequent errors were conceptual (68%) rather than mathematical (19%) or measurement (13%).

Drug calculation abilities rely mainly on basic numerical abilities followed by other factors such as previous experience with mathematics and/or drug calculations, age and gender (McMullan, Jones, & Lea, 2010; Røykenes & Larsen, 2010). In their study of both nursing students and registered nurses which included factors of age, status and experience, McMullan et al. (2010) found a strong positive correlation between numerical and drug calculation abilities.

[1] The demands are even higher in second year, where students have to score 100% in the drug calculation component of further courses before they can proceed to clinical practice.

In addition to basic numerical skills, the concepts of 'maths anxiety' and 'maths confidence' are both used in the literature to describe factors that can also affect mathematical calculation abilities. For example, McMullan et al. (2012) used both of these terms in their study; Bull (2009) focussed on maths anxiety; while Wilkins (2015) investigated maths confidence. This research study focuses on maths anxiety because anxiety seems to be an underlying factor that can affect the development of confidence. In addition, it appeared to relate better to the feelings expressed by students when they talked about their feelings and experiences while learning maths concepts and doing maths tasks. Regarding maths anxiety, it is common in the literature to follow the definition given by Richardson and Suinn (1972), who defined maths anxiety as "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (p. 551). This suggests that maths calculation abilities cannot be separated from maths anxiety, and this result is of particular importance in this context as Bull (2009), Glaister, (2007) and Walsh (2008) have confirmed the existence of maths anxiety in nursing students, and Pozehl (1996) found that nursing students had higher levels of maths anxiety than non-nursing students. Furthermore, Bull (2009), Glaister (2007) and McMullan et al. (2012) have found that maths anxiety and negative attitudes towards maths have negatively affected students' performance in drug calculation tests. In order to address maths anxiety, nursing educators thus need to foster a supportive learning environment using multiple teaching strategies to reduce maths anxiety and develop maths skills (McMullan et al., 2012).

Given the above-identified issues, a number of researchers have investigated the impact of various types of pedagogical interventions on both the numeracy skills and confidence / maths anxiety levels of nursing students. This research reveals that some level of success in relation to both numeracy skills and maths confidence / anxiety improvements can be achieved with targeted interventions (see, for example, Bull, 2009; Rainboth & De Masi, 2006; Ramjan et al., 2014; Wright, 2008; and the review article by Hunter Revell & McCurry, 2013). However, despite this wealth of findings, there is room for further research in this area. In particular, can the impact of maths tutorials on students' levels of maths anxiety be better quantified? The study by Ramjan et al. (2014) for example, simply relied on positive qualitative feedback from some students to draw the conclusion that confidence levels had improved, while the study by Rainboth and DeMasi (2006) used an 11 item Likert scale with a single statement about anxiety. The use of a maths anxiety scale (see Section 4.2) could, therefore, provide a better measure across a whole cohort of students of the impact of support tutorials on students' levels of maths anxiety. In addition, previous studies have looked at the impact of a certain level of intervention on students' results, which leaves open the question of how much improvements might vary depending on the amount of support received. Finally, there is value in determining how replicable successful interventions are with different cohorts of students in different educational contexts. Consequently, this study considers not only the impact of varying amounts of targeted voluntary tutorials on the numeracy skills and drug calculation abilities of nursing students, but also the extent to which appropriate interventions could reduce maths anxiety among these students as measured by a maths anxiety scale, and what impact that reduction might have on nursing students' drug calculation test results. The focus was on a group of first year students as various authors have emphasised the importance of early intervention (Bull, 2009; McMullan et al, 2012; Rainboth & DeMasi, 2006). In our setting, voluntary tutorials, as an early and supplementary intervention, had been run for a number of years and it more generally seemed worthwhile to investigate the contribution, if any, that these might be making to student learning and confidence.

To achieve the above objectives of both reducing anxiety as well as increasing numeracy skills, the literature recommends that nursing educators review the basic mathematical skills of nursing students (Rainboth & DeMasi, 2006) and consistently use one drug calculation method throughout the curriculum to decrease confusion and reduce mathematical errors (Bath & Blais, 1993; Hunter Revell & McCurry, 2013; Rainboth & DeMasi, 2006). It is also recommended that educators integrate numeracy in the context of practical clinical problems (Ramjan, 2011; Wright, 2009). It is clear from the literature that students benefit from multifaceted teaching strategies which include use of technology, online activities and resources, hands-on activities in clinical practice, problems and visual prompts (Ramjan et al., 2014; Wright, 2008). It is argued that this addresses the diverse learning styles and needs of students (Wright, 2008).

Consistent with the above literature, the supplementary tutorials offered to first-year BN students had the following characteristics. Multiple repeated tutorials were offered to accommodate student timetables, work and family commitments, diverse needs, abilities, anxiety levels and learning styles. The focus was on providing a supportive environment in which students felt comfortable to ask questions and actively participate. The standard one-hour length of session was often extended if students wished to stay longer and sessions were offered in semester breaks. Students were able to bring their children to class if necessary. A variety of teaching strategies including review at the beginning, hands on activities using health-related realia such as jars, tubes of ointment and cartons, collaboration on a white board, and in-class worksheets were used, in line with some of the strategies outlined in Hunter Revell and McCurry (2013). Also, the structure of the tutorial and activities in it allowed students to work in pairs, small groups or one-to-one with the lecturer. Students were also able to book one-to-one or small group follow-up sessions with the lecturer, and some took advantage of this. Given that these tutorials were supplementary to degree course work, the lecturer provided suggestions for additional practice, including relevant websites, but left this to students to pursue if other commitments allowed.

4. Methods

4.1. Participants

The voluntary supplementary tutorials offered by the Learning Centre were advertised to all Bachelor of Nursing first year students enrolled in the Human Bioscience course at a New Zealand institute of technology. Out of 173 enrolled students, 119 attended tutorials and 77 attended more than 3 sessions. A number of students gave consent to participate in the study, but then were not present for all tests and questionnaires. As a result, 27 students form the basis of this study, as they gave consent and participated in all assessments. It emerged that these 27 students had each attended at least five tutorials. Variable attendance is a common experience when learning opportunities are voluntary and additional to an assessed program (Wilkins, 2015). The research project was not mentioned at the time of advertisement of the tutorials to minimise any sense of pressure to participate as it is important that students did not link participation in this project to their success on the Bioscience course. The study was commenced after approval from Department of Nursing staff, the Research Ethics Committee of the polytechnic, and written informed consent from participants.

4.2. Mathematics anxiety scale

There are many tools to assess maths anxiety and a well-recognised one is the 98-item Maths Anxiety Rating Scale (MARS) developed by Richardson and Suinn (1972). Due to its length, many researchers have found it too extensive to use which has led to the development of many shorter scales (Alexander & Martray, 1989; Hopke, Mahadevan, Bare, & Hunt, 2003; Plake & Parker, 1982; Suinn & Winston, 2003). One such shorter scale was developed by Betz (1978) who revised and created a tool to measure maths anxiety from the Mathematics Anxiety Scale, one of the nine scales of the also well-recognised Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976). Betz's revisions consisted of the removal of two of the original 12 questions, as well some rephrasings to make the instrument more suitable for tertiary students. The Betz questionnaire has been found to have good internal reliability, with Betz reporting a split-half reliability of 0.92, and other studies reporting Cronbach's alphas of 0.72 and 0.90 (McMullan et al., 2012, p. 180). McMullan et al. (2012, p. 180) also report studies finding a test-retest reliability of 0.87 over a two-week period, and correlations of about 0.70 with the MARS scale. Consequently, it would appear that the Betz questionnaire has good psychometric properties, and given its brevity and adaptation to tertiary classrooms, and its apparently successful use in the McMullan et al. study with nursing students, it was believed to be a good maths anxiety questionnaire for this study.

The Betz questionnaire (see Appendix A) was minimally adapted to amend some Americanisms that might confuse New Zealand students. The 10 items of the questionnaire consist of five positively and five negatively worded items. Each item was scored using a 5-point Likert type scale where 1 = 'strongly disagree' and 5 = 'strongly agree'. Scores for positively worded items were reversed and then anxiety scores calculated and converted to percentages[2] so a high score represents high anxiety. Participants completed the same questionnaire in the second and again in the fourteenth week of tutorials.

4.3. Numeracy skills test

The numeracy skills test used in this study focuses on basic maths skills required for drug calculation in nursing courses as mentioned in earlier studies (Bindler & Bayne, 1984; Blais & Bath, 1992). It was developed through analysis of the BN course book and previous tutorial experience with nursing students which provided insight into their difficulties with these skills. The test consists of 15 short answer questions, divided so that the first 4 questions were about addition, subtraction, multiplication and division of whole numbers, the next 6 were about the same operations on decimals, then 2 questions on metric conversion, 2 on simplifying fractions, and the last on converting a fraction to a decimal. The numeracy test was scored 1 for correct and 0 for each incorrect response and final tallies were converted to a percentage. Therefore, scores range from 0-15 (0-100%). Each participant completed the numeracy test twice: before attending the tutorial in the second week, and in week 14, after attending the tutorials, they took a similar test but with different numbers.

Prior to this study, evidence of the positive impact of the tutorials had been provided by a qualitative evaluation at the end of the voluntary maths support tutorials using the questionnaire in Appendix B, and the students' scores in the maths component of their human bioscience examination. The researcher was interested to use quantitative measurement tools to determine the impact of the tutorials. In addition, responses to the qualitative evaluation were also considered as a component of the data collected for the study.

5. Findings

5.1. The impact of tutorials on numeracy skills

The results of the two numeracy tests show a range of 13.3% to 100% before the tutorials which narrowed to 60% to 100% after the tutorials (Figure 1). This shows the numeracy scores of students were diverse before the tutorials, also indicated by the high standard deviation (Table 1). There were 27 participants but there are fewer dots on the graph (Figure 1) as a number of participants had identical scores. Numeracy scores improved for 16 students (Figure 1). The group of students whose numeracy scores improved significantly are those whose scores are furthest from the diagonal line (Figure 1). Scores did not improve for 11 students (Figure 1). Apart from one, all these students scored above 86.7% before the tutorials so there was not much scope for improvement and the decrease may be due to the impact of minor errors. The improvement in students' mean numeracy scores from 72.1% to 88.4% (Table 1) is statistically significant at the 0.001 level (paired sample t-test: $p = 0.0007$). Also the effect size of 0.59[3] suggests a medium impact of tutorials on the numeracy score.

[2] Anxiety percentage = 100% × total anxiety score/50 since for 10 questions on a five-point scale, the maximum score is 50. Note that the minimum score is 10, so the minimum anxiety percentage is 20%.

[3] An effect size (e.g. Cumming, 2012; Magnusson, n.d.) provides a standardised way of quantifying the amount or size of the impact of one phenomenon on another. For group differences, the effect size is typically quantified as the size of the difference in group means relative to the variation in the population as measured by a standard deviation. Using an effect size, we can begin to see if the effect is significant in a practical as well as a statistical sense.

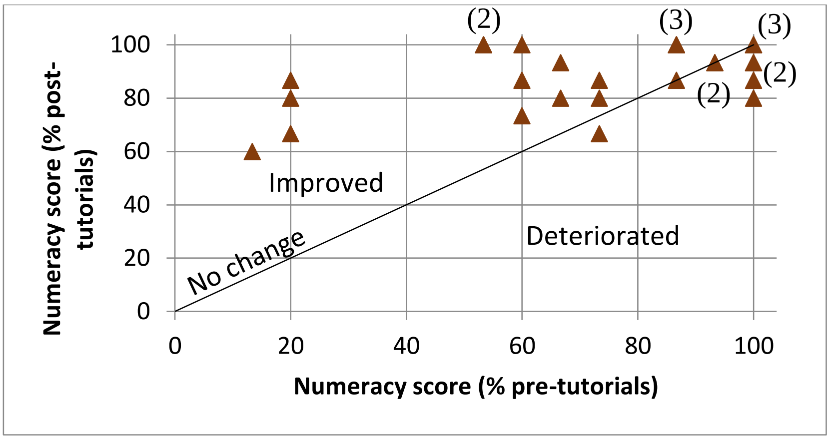

Figure 1. A comparison of before and after numeracy scores ($n = 27$) shows that most students improved (i.e. fell above the diagonal line indicating no change), with the biggest gains being achieved by the students with the lowest initial scores. The numbers in brackets next to some points indicate the number of students achieving that particular before and after score combination when that number is greater than one.

Table 1. Measures of the improvement seen in numeracy scores of the 27 students who attended five or more tutorials and who completed the before and after numeracy tests. (*M* = mean, *SD* = standard deviation.)

Pre-tutorial numeracy scores *M* (*SD*)	Post-tutorial numeracy scores *M* (*SD*)	Student gains *M* (*SD*)	*p*[a]	Effect size (Glass's Δ_{pre}[b])
72.1% (27.74%)	88.4% (11.78%)	16.3% (23.56%)	0.0007	0.59

[a] p-value from a paired sample *t*-test of the hypothesis that the student gains were statistically significantly higher than zero.

[b] As discussed by Lakens (2013), a number of different formulas for the effect size for paired data can be found in the literature. As recommended by that author, Glass's $\Delta = (M_{post} - M_{pre})/SD_{pre}$ was considered the most appropriate measure here since the pre- and post-standard deviations are very different from each other.

5.2. The impact of tutorials on maths anxiety

Changes in students' maths anxiety, as measured by the Betz questionnaire, from before to after the tutorials are shown in Figure 2. In interpreting this scatter plot, it is important to keep in mind that questionnaires like the Betz one only have a certain amount of test-retest reliability. That is, it can be expected that students' responses will change somewhat from occasion to occasion, even if there has been no real change in the phenomenon being measured. For the Fennema-Sherman Maths Anxiety Scale on which the Betz questionnaire is based, Dew et al. (cited in Lim & Chapman, 2013, p. 27) found a test-retest reliability of 0.87 over a two-week period. Pearson's r for the before versus after anxiety data shown in Figure 2 is a little lower than this, with a value of 0.78. Assuming the Fennema-Sherman test-retest reliability applies to the Betz questionnaire, this suggests that the scatter seen in Figure 2 is likely to be largely explained by random variations in the way the students completed the questionnaire at the two sittings. However, apart from the scatter, the data also appears to be on average below the "no change in anxiety line", suggesting that on top of the random variation in student responses, there was an additional overall average reduction in anxiety scores. A paired sample *t*-test revealed that this is indeed likely to be the case, though the effect size was quite small[4] (see Table 2).

[4] To put the anxiety changes shown in Figure 2 and Table 2 into context, a one category level change (e.g. from "agree" to "neutral" or from "strongly agree" to "agree") in the response to one question on the 10 item questionnaire leads to a 2% change in anxiety score.

Also of note in Figure 2 is that the maths anxiety scores ranged from 28% to 100% before attending the tutorials and showed a similar range of 26% to 96% after the tutorials. The very similar standard deviation of the anxiety scores (Table 2) also suggests that there is not much difference in the variation of anxiety scores of the group before and after attending the tutorials. Nevertheless, Figure 2 shows that there are some students whose anxiety scores significantly decreased (i.e. 6 had a reduction of 18% or more, indicating that they had on average at least a one category level change on at least 9 out of 10 questions[4]). It is also noteworthy that the mean pre-tutorials anxiety score of 66.2% is much higher than the 37–46%[5] Betz (1978) found in her three study groups, suggesting the group investigated in this study had fairly high levels of maths anxiety present. A further 8 participants had smaller decreases in anxiety scores, while anxiety scores increased or remained unchanged for the other 13.

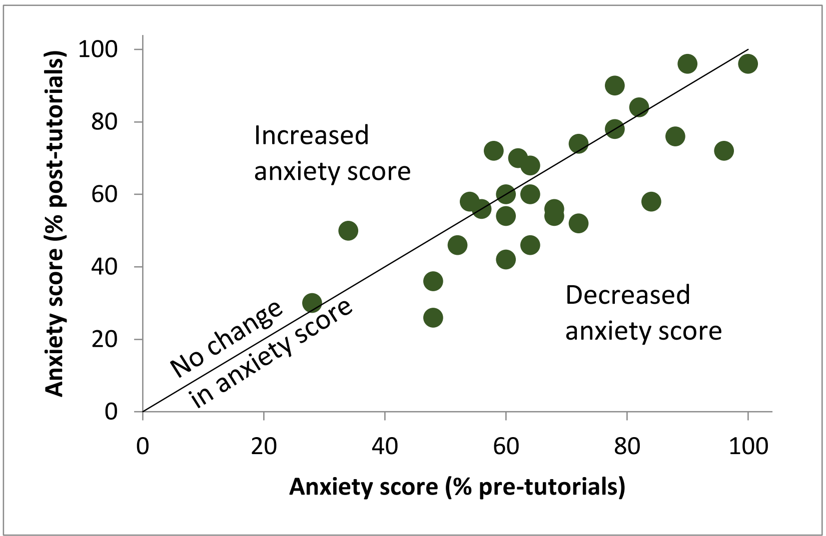

Figure 2. A comparison of before and after anxiety scores with the "no change in anxiety" diagonal line suggests there was a reduction in the average anxiety for the group. Those students with scores furthest from the line had the most change in score.

Table 2. Measures of the changes seen in anxiety scores of the 27 students (M = mean; SD = standard deviation.)

Pre-tutorial anxiety scores *M* (*SD*)	Post-tutorial anxiety scores *M* (*SD*)	Reduction in anxiety *M* (*SD*)	p^a	Effect size (Cohen's d^b)
66.2% (17.34%)	61.5% (18.46%)	4.7% (11.84%)	0.024	0.265

[a] p-value from a paired sample *t*-test of the hypothesis that the student gains were statistically significantly higher than zero.

[b] Here, $d = (M_{post} - M_{pre})/\sqrt{(SD_{pre}^2 + SD_{post}^2)/2}$ was used as the pre- and post-standard deviations were almost identical (see Eq. (7) in Dunst et al., 2007).

5.3. Relationship between maths anxiety and numeracy skills

Before assessing the question of whether the increase in numeracy skills arising from attending the tutorials had an impact on students' maths anxiety, it is first important to establish to what

[5] After first taking into account that Betz (1978) used a scoring system the reverse of the one used in this paper. That is, items were scored so that the higher the score, the lower the maths anxiety.

extent maths anxiety and numeracy skills were related before the tutorials. This is done in Figure 3(a), where it is evident that before the tutorials, there was a moderate negative relationship between anxiety scores and numeracy skills (n = 27, Pearson's $r = -0.536$, $p = 0.0017$). That is, anxiety scores tend to be lower for students with higher numeracy scores. Figure 3(a) also indicates that there was a wide range of both numeracy and anxiety scores.

It was hoped that after attending tutorials, that there would be a concomitant increase in numeracy scores and decrease in anxiety scores. Figure 4 supports this hope, showing a statistically significant correlation between a decrease in anxiety score and an increase in numeracy score (n = 27, Pearson's r = 0.45, p = 0.009).[6] A comparison of Figures 3(a) and 3(b) provides further insight in the nature of the changes, revealing a small shift downwards (which would indicate a decrease) in anxiety scores, together with a clear shift to the right (increase) in numeracy scores. Figure 3(b) shows that the number of students in Quadrant D with anxiety scores below 60% and numeracy scores above 80% has increased after attending the tutorials.

It is also interesting to note from Figure 3 that for each level of numeracy scores, the anxiety scores vary considerably and students with high levels of numeracy (100% score) had many different levels of anxiety. This variation further suggests that as expected, other factors were affecting the relationship between numeracy skills and maths anxiety, such as previous negative maths learning experiences or anxiety about the forthcoming exam.

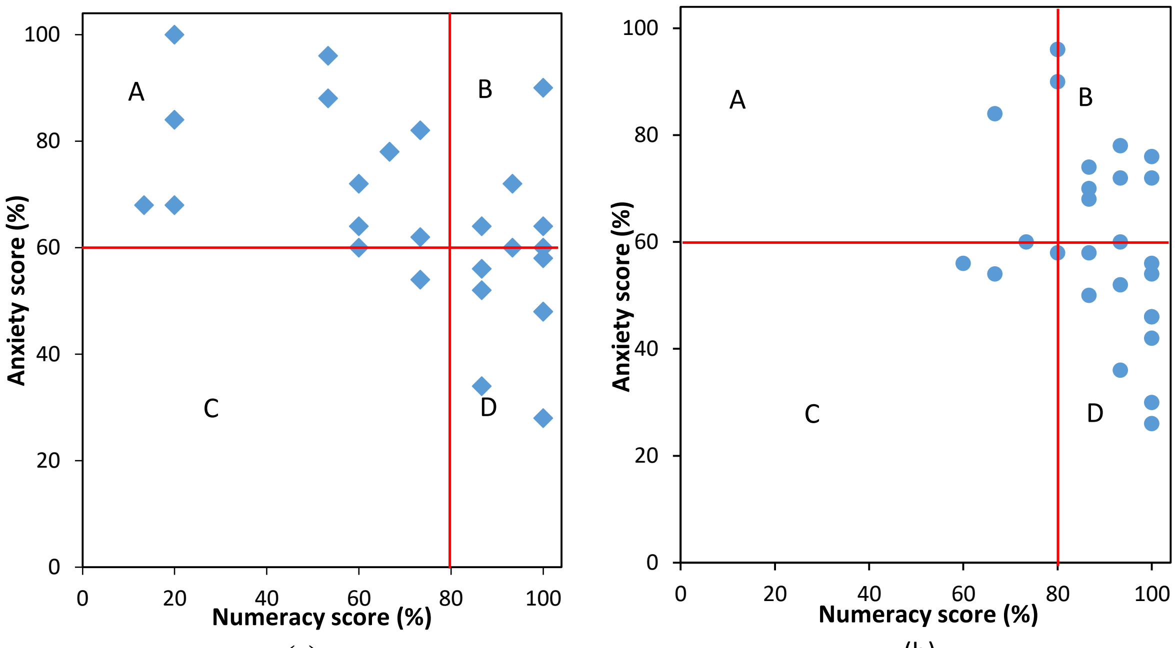

Figure 3. The relationship between anxiety score and numeracy score (a) before and (b) after tutorials suggests there has been a movement from quadrant A ("low numeracy-high anxiety") to quadrant D ("high numeracy-low anxiety"),[1] though a significant proportion of students also shifted from quadrant A to quadrant B, meaning that while their numeracy levels had improved, their anxiety levels were still relatively high.

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[6] Though it should be noted that some students' level of anxiety increased somewhat even with an improvement in their numeracy scores, while some students had substantial reductions in anxiety with no apparent improvement in their numeracy score.

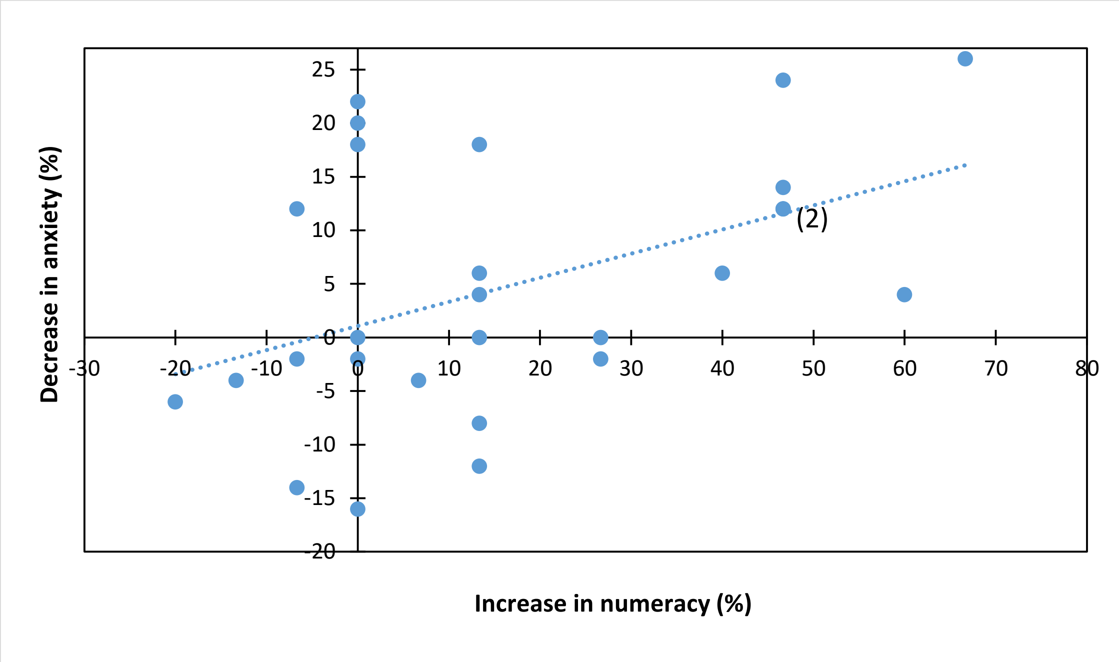

Figure 4. A statistically significant correlation between the decrease in anxiety score versus the increase in numeracy score was found (n = 27, Pearson's r = 0.45, p = 0.009), with the dotted line showing the linear regression through the data. Here, a positive decrease in anxiety corresponds to a reduction in anxiety score, while a negative decrease corresponds to an increase in anxiety score. There are 26 dots, so two students had the same improvement in both numeracy and anxiety scores as indicated by the label. Note also that each 6.7% increase in numeracy score corresponds to a student getting an extra question correct.

5.4. Relationship between numeracy scores and drug calculation exam marks

Figure 5 shows that numeracy skills seem to have supported nursing students in achieving their drug calculation exam marks, but one can see a range of drug calculation exam marks even with similar numeracy scores. Only three of the 27 study participants achieved below 50% and therefore failed the drug calculation exam, though two of these students still had numeracy scores below 80% after the tutorials, suggesting that they still might not have achieved an adequate level of competency. Further investigation into these students also revealed that two of these three students had very low numeracy scores before attending the tutorials and English was not their first language. As a result, although their numeracy scores improved a lot, these students reported that they found it hard to interpret the questions and compute the answers within a time limit.

On completing the analysis, we were interested to compare results with those students who were not part of the final research group as they might be able to provide a control for various possible confounds. We had data for an additional 28 students who had consented to participate and who had taken part in the pre-numeracy and pre-anxiety tests, but attended only a small number of tutorials and were not present for all data-gathering activities. We had drug calculation scores for these students so were able to use this dataset as a comparison group. On average, students in the research group attended 14 hours of tutorials, while the average attendance of students not in the research group was 6 hours. Consequently, a comparison between these two groups has the potential to be used to determine the impact of differing numbers of hours of tutorials attended.

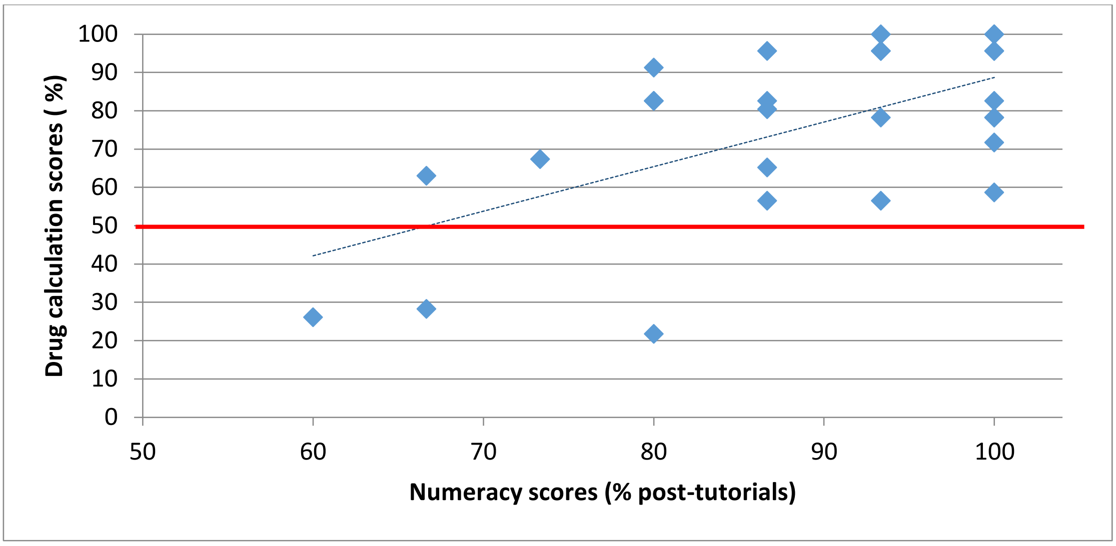

Figure 5. Drug calculation exam score versus numeracy score at the end of the semester. The pass mark was 50% (the red line) and the dotted blue line is the linear regression through the data (Pearson's $r = 0.61$).

However, as students were not randomly allocated to the study group and the non-study group, it is important to first establish whether or not these two groups were equivalent to start with on important variables such as pre-numeracy and pre-anxiety scores, otherwise any direct comparison on final drug calculation score would be confounded.[7] In this regards, Table 3 shows that the two groups were *not* statistically significantly different initially in terms of these variables, which suggests that the statistically significant difference of 13.1% in average drug calculation exam mark can likely be attributed to the difference in the number of hours of tutorials attended rather than a difference in the starting abilities and levels of maths anxiety of the two groups.

Table 3. Measures of the changes seen in drug calculation scores of 27 students (research group) compared with 28 other students (non-research group). (*M* = mean, *SD* = standard deviation.)

	Pre-tutorial anxiety scores *M* (*SD*)%	Pre-tutorial numeracy scores *M* (*SD*)%	Hours attended *M* (*SD*)	Drug calculation scores *M* (*SD*)%
Research group	66.22 (17.34)	72.10 (27.74)	14.00 (3.39)	75.20 (22.56)
Non-research group	62.86 (16.67)	70.00 (25.37)	6.06 (3.15)	62.11 (30.57)
	$p^b = 0.47$	$p^b = 0.77$	$p^a < 0.001$	$p^a = 0.039$

[a] One-tailed *t*-tests.

[b] Two-tailed *t*-tests.

[7] Though it is possible that differences in the groups could be controlled for through the use of regression techniques, which will in any case be used next to better quantify the impact of hours of tutorials controlling for differences between students in pre-numeracy and pre-anxiety levels.

A more detailed measure of the impact of the number of tutorials attended on final drug calculation exam mark, controlling for differences in pre-numeracy and pre-anxiety scores and possible interactions between the independent variables,[8] can be obtained with a multivariable regression analysis. After exploring different linear models, it was found that the best model to explain the variance in drug calculation scores (adjusted $R^2 = 0.519$), calculated using *Mathematica 10.3*, was:

$$\begin{aligned}\text{drug calculation exam (\%)} = 11.25 - 0.36 \times \text{preanxiety (\%)} \\ +1.00 \times \text{prenumeracy(\%)} + 3.65 \times \text{hours} \\ -0.039 \times \text{hours} \times \text{prenumeracy(\%)}.\end{aligned}$$

(See Appendix D for tests of significance and confidence intervals for the regression coefficients.) This model predicts that *on average*, for a student with a given pre-anxiety and given pre-numeracy score, their exam mark increased by:

- 3.65% for every hour of tutorials they attended if their pre-numeracy score was zero,
- 2.87% for every hour of tutorials they attended if their pre-numeracy score was 20%,
- 1.70% for every hour of tutorials they attended if their pre-numeracy score was 50%,
- 0.53% for every hour of tutorials they attended if their pre-numeracy score was 80%.

Note however, that the results of regression analyses can be biased by points with high influence (e.g. Howell, 2010, pp. 540-1); that is, by "outliers" lying near the extremes of the independent variable. In this case, a student who scored only 20% on the pre-numeracy test but 91.3% on the exam, and a student who scored 100% on the pre-numeracy test but only 21.7% on the exam could be such points (see Figure 6). After removing these points from the analysis, the best fit was achieved by a model which considered the impact of the number of hours of tutorials on final exam mark, controlling for pre-numeracy score alone. As this model also achieved a statistically significant regression coefficient for hours (one-tailed *t*-test, $p = 0.034$), this supports the conclusion that the number of hours of tutorials attended did have a positive impact on final drug calculation exam result after controlling for pre-numeracy level. However, as the regression coefficient dropped from 3.65 to only 0.835 for this model, this indicates the sensitivity of the model to these high influence points. However, whether in particular the student who scored only 20% on the pre-numeracy test but 91.3% on the exam represents an outlier biasing the results, or represents a fairly typical outcome for students with this level of pre-numeracy and hence supplies evidence of the strength of the approach for the very weakest students, cannot be answered without more data.

Being four dimensional, the regression model reported above is hard to visualise. To obtain a general visual guide as to what is going on, consider Figure 6 which simplifies the impact of number of hours of tutorials to three categories, the research group, who averaged 14.0 hours of tutorials, and two other groups, one of which attended 6 or fewer hours of tutorials, and another group which attended 7.25–11.75 hours of tutorials. The key things to note from this figure are first, most students who scored 80% or above in the pre-numeracy test managed to pass the drug calculation exam with or without attending tutorials. Second, while many of the research group were successful in passing, despite initially low numeracy scores, this is not the case for those who were not part of the final research group.

Further insight into this complex model can be obtained from Figure 8 in Appendix E, which shows the impact of pre-tutorial anxiety on drug calculation scores and pre-tutorial numeracy scores for both the research group and the non-research group. Although the reported results are quite promising, further research with a larger group of participants would be necessary to confirm the trends reported here.

[8] The impact of number of hours of tutorials attended could be expected to also depend on pre-numeracy and pre-anxiety – the lower the pre-numeracy score, the more room for improvement there would be, and the higher the initial maths anxiety, the greater the potential for making a change that would lead to an impact on exam marks.

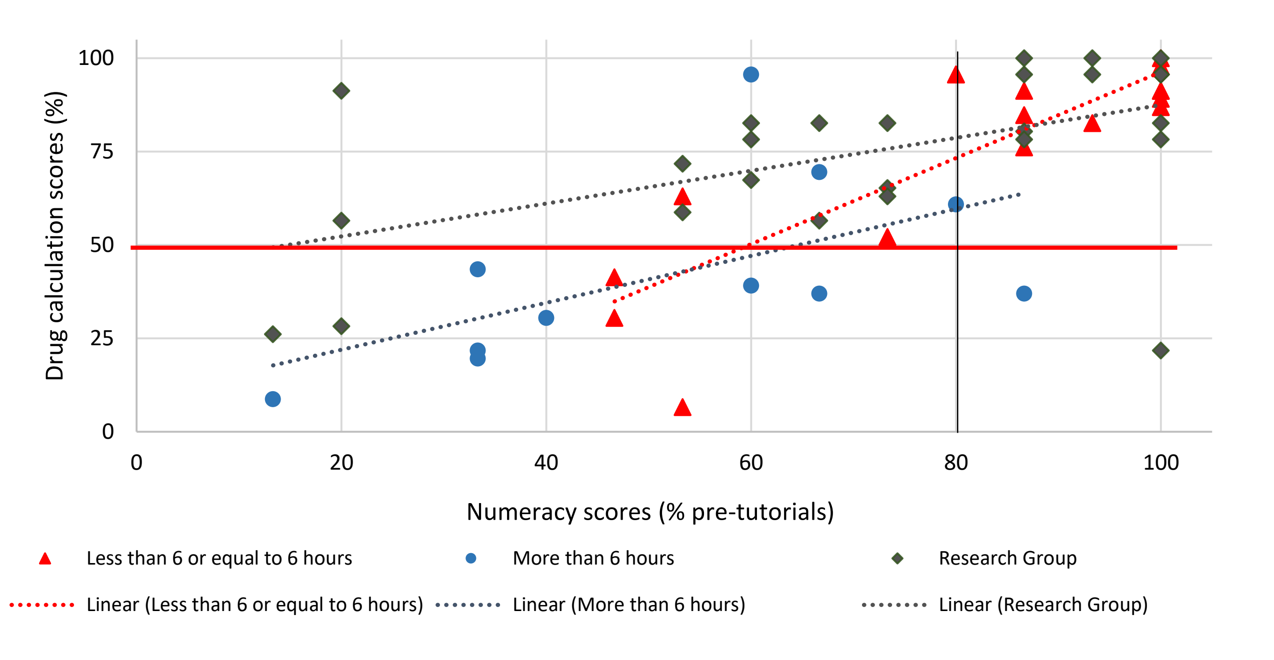

Figure 6. Pre-tutorial numeracy scores of 55 students, including the research group, who sat the pre-numeracy test and the drug calculation exam at the end of the course. The "more than 6 hours" group attended 7.25–11.75 hours of tutorials (M = 9.4 hours), while the Research Group attended 5.0–20.25 hours of tutorials (M = 14.0 hours). The solid red line shows the pass mark of 50% for the drug calculation exam, while the dotted lines are the linear regression curves through the various sets of data.

6. Qualitative feedback

In addition to the quantitative data reported above, Learning Centre workshops are followed by qualitative evaluations by students which in this case included seven trichotomous statements and three open questions (see Appendix B). All the questions/statements in evaluations were related to communication, the conduct and atmosphere of the tutorials. Students' positive responses to these statements and their comments in response to open questions suggest they valued the proactive approach of the lecturer and the opportunities to collaborate with peers. For all seven statements, feedback was 100% positive, with students reporting they felt engaged and were comfortable to ask questions and contribute.

7. Discussion

The findings suggest that numeracy skills, maths anxiety and drug calculations skills are interrelated, as found by other researchers (e.g. McMullan et al., 2012). The focus of tutorials was to help students develop good numeracy skills and reduce maths anxiety so they could tackle the drug calculation exam confidently. For the research group, the goals were met as 24 out of 27 students (89%) passed the exam. A number of previous researchers have underlined that good numeracy scores are the foundation of drug calculation skills (Blais & Bath, 1992; Juke & Gilchrist, 2006; Roykenes & Larsen, 2010). However, a score of 60% in the numeracy test after the tutorials did not necessarily mean that a student was able to pass the drug calculation exam, which seems to support the assumption that nursing students should score close to 100% in a basic numeracy skills test (Bindler & Bayne, 1984) before attempting a drug calculation test.

This study also re-affirms the association of maths anxiety with numerical abilities/drug calculation abilities as found by other researchers (McMullan et al, 2012; Bull, 2009; Glaister, 2007; Walsh, 2008). The association between numeracy scores and drug calculation scores was similar to that found by McMullan et al, (2012). Anxiety levels were very high at the beginning of the tutorials and pre-numeracy test scores varied considerably, but in the second numeracy test the range of scores was narrower yet the range of anxiety scores was still wide. High maths anxiety relates to students' poor performance in maths related tasks (Bull, 2009). A small number of students had numeracy scores between 80 and 100%, but still reported a high level of anxiety, which increased somewhat even after the tutorials. Again the research shows anxiety can affect students' numerical abilities and this can be seen in the fact that the performance of some highly anxious students went down in the second numeracy test. This suggests that there may be other factors associated with maths anxiety as well as numeracy scores. Overall, the data suggests a shift from high anxiety and low numeracy to lower anxiety and higher numeracy, but more data would be required to confirm this.

The reason for providing voluntary maths tutorials was to address perceived weaknesses in the numeracy skills of students entering the programme. Experience had taught the Nursing educators that weaknesses in basic numerical skills should be addressed as early as possible; an observation supported by literature (Rainboth & DeMasi, 2006; Pozehl, 1996). An underlying assumption of the researcher was that improving numeracy skills would decrease students' maths anxiety, as had been anecdotally reported in previous years. The fact that the tutorials took place outside of the BN Human Bioscience course was seen as advantageous, as the learning development lecturer was not the person who was ultimately going to assess the students. However, the high levels of anxiety shown by some students in the study, even after attending the tutorials and despite good numeracy scores, indicate other factors influencing students' levels of anxiety. One factor may be the high stakes of the maths component of the drug calculation exam where failure meant students would not be able to enter second year, while another could be general anxiety associated with exams (McMullan et al., 2012; Bull, 2009). It may also be the case that some students felt more confident in the group learning environment, and this confidence may have faded in the individual-focused exam environment. It was observed that the number of unconscious or careless mistakes increased under test-like conditions.

Answers to the open questions in the anonymous qualitative evaluation provide some background. They suggest that students appreciated the opportunity to review the basics together and then do follow up practice using worksheets. They felt comfortable because others seemed to be at the same level that they were. In particular, students highlighted the step-by-step walk-through approach to each question and being asked to explain how and why they arrived at particular answers. As Pozehl (1996) notes, the teaching environment and lecturer approachability are also important. Following these tutorials, students said they felt comfortable to ask questions and contribute. One student commented in the evaluation, "it was so good to realise I'm not an idiot and to find that I can actually do this kind of maths". Another student commented, "I have enjoyed re-engaging with maths after many years and exercising my brain".

The main limitation of this study is the fact that improvements in numeracy skills and maths anxiety may have been motivated by factors other than attendance and participation in tutorials as these were not controlled for. Factors such as help from others outside the class, use of recommended additional study resources, and individual study initiatives may have influenced the findings. A second limitation is the small scale. Because the number of eventual participants was smaller than the researchers hoped, this has limited some aspects of statistical analysis and therefore limits the ability to make more general claims about the applicability of the results to other settings. Where the study may make a contribution is in the focus on recognising the early gaps in numeracy and the associated maths anxiety in first-year nursing students, as well as lending support to the role for learning development lecturers in addressing these concerns. Taken together with the positive feedback gathered in the student evaluations, the results presented here provide a more detailed picture of the impact of tutorials on student skills, in this case numeracy skills as well as the impact improving these may make on maths anxiety, an affective concern for ability to learn. The study may also reveal the more general usefulness of using quantitative methods to gauge the impact of learning development interventions because of the way results may reinforce, or potentially challenge, qualitative perspectives and vice versa.

8. Conclusion

Working together with subject lecturers, learning development staff can make a difference to outcomes and attitudes towards student success in learning maths. Nursing educators should not presume that all nursing students possess basic numeracy skills. It is useful to identify gaps in basic skills as early as possible and plan interventions with support staff if available at an early stage. A supportive, caring learning environment with a lecturer who is not their assessor helps students to express their concerns and openly acknowledge their weaknesses. Overall, from the results of this study it can be concluded that maths anxiety can be reduced to some extent, and the numeracy skills of students can be improved by using multiple teaching strategies to address the diverse learning needs in a supportive, caring learning environment.

Acknowledgements

The authors would like to acknowledge the thought-provoking advice about options for analysing and presenting our data provided by Dr. David Rowland.

Appendix A. Math Anxiety Scale

Name:

ID number:

For each statement circle a number 1-5 which indicates whether you strongly disagree (SD) (1), disagree (2) (4), neutral (N) (3), agree (A) (4) or strongly agree (SA) (5).

		SD	D	N	A	SA
1	I have usually been at ease in math courses.	1	2	3	4	5
2	I have usually been at ease during math tests.	1	2	3	4	5
3	It wouldn’t bother me at all to take more math courses.	1	2	3	4	5
4	I usually don’t worry about my ability to solve math problems.	1	2	3	4	5
5	I almost never get uptight while taking math tests.	1	2	3	4	5
6	I get really uptight during math tests.	1	2	3	4	5
7	I get a sinking feeling when I think of trying hard math problems.	1	2	3	4	5
8	My mind goes blank and I am unable to think clearly when working with mathematics.	1	2	3	4	5
9	Mathematics makes me feel uncomfortable and nervous.	1	2	3	4	5
10	Mathematics makes me feel uneasy and confused.	1	2	3	4	5

Appendix B. Learning Centre Evaluation

Workshop: Nursing Maths and Drug Calculation Tutorials **Date:**

Presenter:

About the sessions *(**Please** tick one)*	**Yes**	**Partly**	**No**
I felt welcomed and included			
The presenter communicated clearly			
The open session structure allowed me to learn at my pace			
I felt engaged in the sessions			
The activities /materials were relevant and helped me better understand the topic			
I felt comfortable to ask questions and contribute			
The sessions helped me develop my maths skills			

What helped you develop maths skills?

How could the session be improved?

Any other comments?

Thank you for your feedback

Appendix C. On the cut-off used for "high anxiety"

As noted in Section 3, Richardson and Suinn (1972) defined maths anxiety as: "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (p. 551). Consequently, one way to determine what a sensible boundary between "low anxiety" and "high anxiety" might be would be to look for a level of anxiety beyond which there was a significant increase in the fail rate. For this cohort with the adapted Betz questionnaire, Figure 7 and Table 4 suggest that an anxiety score of 60% is suitable as only 1 out of 23 students with pre-anxiety ≤ 60% failed the drug calculation component of the exam, but 13 out of 32 with pre-anxiety > 60% failed the drug calculation component of the exam.

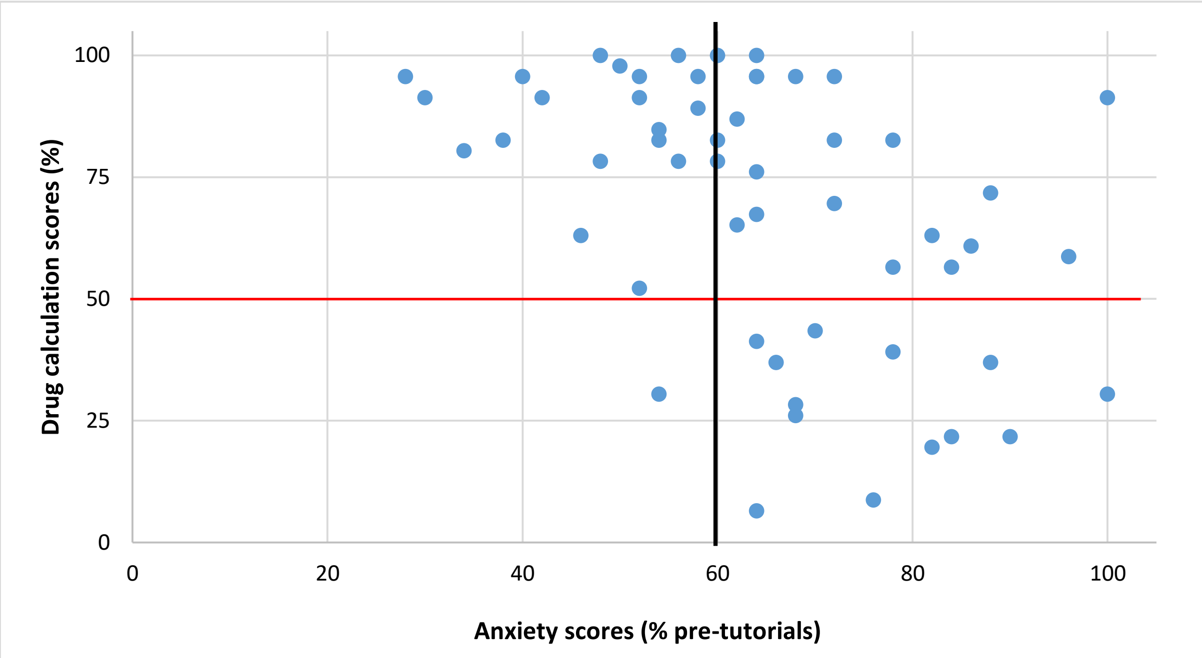

Figure 7. The relationship between anxiety scores on the pre-tutorial questionnaire and scores in the drug calculation component of the final exam for both the research group (n = 27) and non-research group (n = 28). Note the much higher fail rate amongst students with pre-tutorials anxiety scores of greater than 60%.

Table 4. Performance in the drug calculation exam by pre-tutorial anxiety score.

Drug calc / Anxiety	No. Pass (≥ 50%)	No. Fail (< 50%)	Mean (SD)(%)
Low anxiety (≤ 60%)	22	1	84.22(16.89)
High anxiety (> 60%)	19	13	57.27(28.39)

Appendix D. Further statistics on the linear regression model reported in Section 5.4

Table 5 provides the statistics on the general linear model reported in Section 5.4. Note that due to the limited amount of data available, there is considerable uncertainty in the regression coefficient which describes the impact on marks of the number of hours of tutorials attended and the regression coefficient of the interaction between hours of tutorials and pre-numeracy, as indicated by the wide 95% confidence intervals.

Table 5. Table of general linear model, calculated using *Mathematica 10.3*. The *p*-values are the results of two-tailed *t*-tests. The adjusted $R^2 = 0.519$.

Regression coefficient	Estimate	*t*-Statistic	*p*-value	95% Confidence Interval
Constant	11.2498	0.5194	0.6057	(-32.249, 54.7486)
Pre-anxiety	-0.3585	-1.8915	0.0643	(-0.7392, 0.0221)
Pre-numeracy	0.9975	4.7439	0.0000	(0.5752, 1.4200)
Hours	3.6497	2.9634	0.0046	(1.1760, 6.1235)
Hours x pre-numeracy	-0.0387	-2.2880	0.0263	(-0.0727, -0.0047)

Appendix E. Impact of pre-tutorial anxiety on drug calculation scores and pre-tutorial numeracy scores

Figure 8 shows that students who failed the drug calculation component of the exam all had a high level of anxiety (above 60%) except for one. Apart from two, all had low numeracy scores before attending the tutorials. However, in the research group, most of the students with high anxiety and low numeracy scores before attending the tutorials managed to pass the drug calculation component of the exam, which is not the case for the non-research (comparison) group.

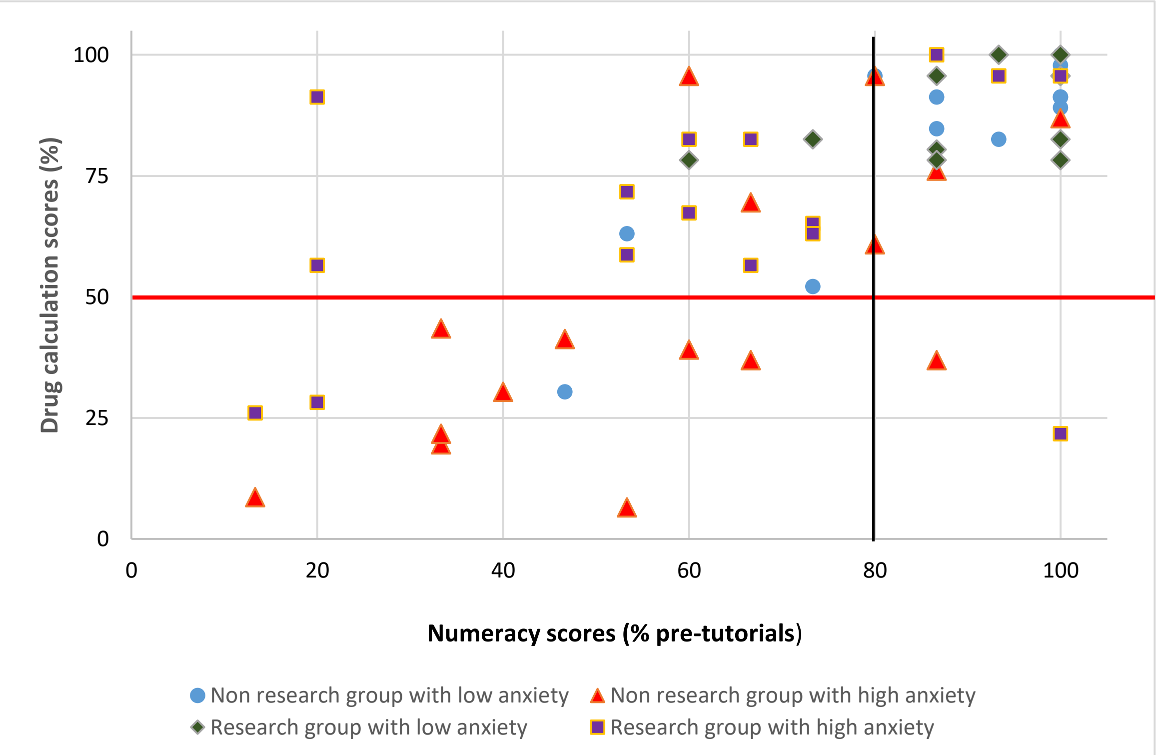

Figure 8. The impact of pre-tutorial anxiety on drug calculation scores and pre-tutorial numeracy scores for both the research group ($n = 27$) and non-research group ($n = 28$).

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