A WHOLE OF CURRICULUM APPROACH TO IMPROVING NURSING STUDENTS’ APPLIED NUMERACY SKILLS

Keywords: nursing students, applied numeracy, medication administration, curriculum, quality enhancement

ABSTRACT

Background: Nursing students often perform poorly on numeracy tests. While one-off interventions have been trialed with limited success, a whole-of-curriculum approach may provide a better means of improving applied numeracy skills.

Objectives: to assess the efficacy of a whole-of-curriculum approach to improving nursing students’ applied numeracy skills.

Design: two cycles of assessment, implementation and evaluation of strategies were conducted following a high fail rate in the final applied numeracy examination in a Bachelor of Nursing (BN) programme. Strategies included an early diagnostic assessment followed by referral to remediation, setting the pass mark at 100% for each of six applied numeracy examinations across the programme, and employing a specialist mathematics teacher to provide consistent numeracy teaching.

Setting: one Australian university.

Participants: 1035 second and third year nursing students enrolled in four clinical nursing courses (CNC III, CNC IV, CNC V and CNC VI).

Methods: Data on the percentage of students who obtained 100% in their applied numeracy examination in up to two attempts were collected from CNC III, IV, V and VI between 2008 and 2011. A four by two Chi² Contingency table was used to determine if the differences in the proportion of students achieving 100% across two examination attempts in each CNC were significantly different between 2008 and 2011.

Results: The percentage of students who obtained 100% correct answers on the applied numeracy examinations was significantly higher in 2011 than in 2008 in CNC III ($\chi^2 = 272, 3; p < 0.001$), IV ($\chi^2 = 94.7, 3; p < 0.001$) and VI ($\chi^2 = 76.3, 3; p < 0.001$).

Conclusions: A whole of curriculum approach to developing applied numeracy skills in BN students resulted in a substantial improvement in these skills over four years.

INTRODUCTION

To date, there is no widespread consensus on how to define numeracy within nursing. In this paper we have adopted the definition of Coben (2000, p. 35), who suggests that a numerate person knows in which situations mathematics should be used, what type of mathematics to use and how to do the calculation, how accurate the calculation needs to be, and how to interpret the answer in relation to the context. To be numerate in nursing therefore necessitates more than the ability to perform accurate drug calculations, instead requiring declarative knowledge (the what), procedural knowledge (the how to), and conditional knowledge (when, where and why it should be applied) (Glaister, 2005). Throughout this paper we have used the term ‘applied numeracy skills’ to encapsulate our understanding of what being numerate in nursing entails.

Unfortunately, students are increasingly entering tertiary education programmes with inadequate numeracy skills (Sabin, 2001; Taylor and Galligan, 2006), creating problems when graduates require these skills, which are vital to ensure competent and safe practice by
Health professionals. Medication-related incidents are the second most common incident reported in Australian hospitals (Roughhead and Semple, 2009), and the most prevalent medical/nursing error worldwide (Weeks et al., 2012). Medication calculation errors may decrease the clinical effectiveness of a drug, and increase the incidence of adverse drug events, morbidity, mortality and health care costs (Classen et al., 1997; Eastwood et al., 2011; Hussain and Kao, 2005; Runciman et al, 2003; Tissot et al., 1999). Additionally, errors in calculation and medication administration can threaten a nursing career (Coben, 2010).

However, nurses often perform poorly on numeracy tests (Oldridge et al., 2004). Experience does not necessarily improve applied numeracy skills, as qualified nurses as well as nursing students often struggle with such skills (Dilles et al., 2011; Eastwood et al., 2011; Grandell-Niemi et al., 2006; McMullan et al., 2010; Wright, 2006). To address this issue some nursing accrediting authorities have determined that 100% mastery of medication-related calculations and administration is required of nursing students upon registration in order to ensure patient safety (M. Cleary, 2008 pers. comm.; Nursing and Midwifery Council, 2007). Hubball et al. (2007, p. 94) suggest ‘[w]hen learning outcomes are externally mandated (or strongly encouraged), it is important that institutions have effective road maps for their implementation.’ This paper will examine relevant national and international attempts to address this global concern and will present the results of longitudinal research that examined the efficacy of a whole-of-curriculum approach to improving Bachelor of Nursing (BN) students’ applied numeracy skills.

Various studies have examined methods of improving student nurses’ applied numeracy skills (Glaister, 2005; Greenfield et al., 2006; Kohtz and Gowda, 2010; Koohestani and Baghcheghi, 2010; Rice and Bell, 2005). For example, Glaister (2005) found that computerised learning was significantly more effective at transferring procedural knowledge than either integrative learning, or a combination of the two, although there were no significant differences between scores on other types of knowledge acquisition. However, following a review of two randomised controlled trials of the online learning programme “Authentic World”, Ainsworth et al. (2012) reported that use of this computer programme created a small negative effect on numeracy that was statistically significant in one of the trials. Another approach included the use of revision sessions (Hutton et al., 2010). While these did improve post-intervention numeracy scores, the differences were statistically significant in only three sections of the test, and post-interventions scores were relatively poor.

There have been several attempts to assess the effectiveness of dimensional analysis teaching methods on numeracy skills, with conflicting results. For example, Kohtz and Gowda (2010) found no significant difference between the scores of nursing students allocated to dimensional analysis and conventional teaching methods over a 2-year period. Conversely, Koohestani and Baghcheghi (2010) found students taught using dimensional analysis had significantly higher post-intervention scores than those taught using conventional methods three months following the intervention, although the number of participating students was small (n=42) and the statistical analysis did not take cluster randomisation into account. Rice and Bell (2005) also investigated the efficacy of dimensional analysis with a small sample and the comparison group differed in their baseline characteristics, receiving less tutoring than the intervention group, which confounded the results. Thus the relative effectiveness of the two teaching methods is unclear.

Vincent (2004), in her discussion of numeracy projects in Australia aimed at primary and
secondary school settings, suggested that a scaffolded, whole-of-school approach was needed to lift the nation’s numeracy performance. Keimig (1983) also rated comprehensive learning systems more highly as a means of improving learning than standalone preparation programmes or isolated interventions. Several attempts have been made to take a more holistic approach to numeracy development in nursing students. For example, Galligan et al. (2010) developed a unit of study covering numeracy and information technology skills that was embedded in the nursing programme. The project was evaluated via pre and post-intervention data for 2008 plus aggregate post-test data from previous years, however, the direction of the change post-intervention differed between questions, and no statistical tests of significance were applied to determine which results differed significantly. Thus there is little data to demonstrate that the intervention was successful in its aims.

Only one paper has reported on a whole-of-curriculum approach to the development of numeracy skills in nursing students (Elliott and Joyce, 2005). This approach included a:

- basic calculation test in first year with an ‘informal’ 75% pass mark to establish a skill baseline, followed by feedback to encourage students with difficulties to seek help.
- medication calculation examination in second year with an 85% pass mark. Students were allowed three attempts, and were offered remedial work to improve their skills.
- medication calculation examination in third year with a 100% pass mark. Students were allowed three attempts.

The authors reported on the proportion of students who failed those tests by year of the degree, but did not provide historical data on fail rates prior to the implementation of their intervention; therefore it is not possible to determine if their new approach influenced numeracy skills in their students. To date no longitudinal study of a whole-of-curriculum approach to the development of applied numeracy skills in nursing students has been conducted that incorporates pre and post-intervention data for comparison.

**BACKGROUND**

The large failure rate in a final year undergraduate nursing applied numeracy examination in 2008, as well as dissatisfaction by academics with the effort required to assist students to gain competency in numeracy skills, led a nursing department in one Australian regional university to review its approach to the teaching and assessment of numeracy in a three-year Bachelor of Nursing (BN) programme. Teaching and assessment of numeracy skills at this time was situated within six on-campus clinical nursing courses (CNCs). A course for the purposes of this document refers to a requisite component of study delivered over one university semester. Students who were enrolled full time had to complete two CNCs per year. Table 1 outlines numeracy content and assessment across the programme. Resources such as online practice exam papers and answers were provided in all clinical courses to enable students to revise their numeracy skills. In addition, students enrolled in CNCs I-IV could attend non-compulsory numeracy tutorials. Failure to gain mastery in the final numeracy re-sit exam meant that students failed the course. With the exception of the CNC V examination in 2008, which was a practical test applied whilst students were on their clinical placement, the applied numeracy exams were administered as paper-based contextualised in-class tests that included questions on basic numeracy, drug and intravenous fluid calculations, and medication administration. The students were required to demonstrate a combination of declarative, procedural and conditional knowledge.
Issues and actions for change

As part of a wider initiative to enhance curriculum quality through a whole-of-curriculum approach to embedding key skills in the BN (van de Mortel and Bird, 2010), a review of numeracy teaching was conducted in late 2008. The review team included programme coordinators, academics responsible for the delivery of the numeracy teaching and assessment, clinical teachers and representatives from the Teaching and Learning Centre, and Academic Skills Development Unit. This approach is consistent with Coben and co-authors’ (2008) recommendations on best practice to achieve integration of numeracy into healthcare education. Hubball et al. (2007), and van de Mortel et al. (2010) also suggest that academic staff are more likely to engage with quality enhancement processes or less likely to resist change when the approach is ‘bottom up’ as opposed to ‘top down’, ie. when academic staff are involved in the development of the change as opposed to having change imposed upon them by management. Additionally, according to Fisher et al. (2003), unless a systematic approach is taken to implementing curriculum improvements, change efforts are relegated to the level of individuals and are unlikely to be sustained or effective. Fisher et al. (2003) suggest that faculty have a collective responsibility to create systemic and sustainable curriculum reform.

The numeracy review determined that:

- students had global deficits in medication administration including numeracy skills, ability to use medication resources to administer medicines, and knowledge of relevant terminology.
- patterns of assessment and provision of resources was inconsistent across the programme.
- some clinical units had comparatively low pass marks for the applied numeracy examination.
- the terminology used by different course assessors differed.
- the availability of numeracy learning assistance varied across the four campuses.
- there was a 12-month gap between assessment in the second year exam and final third year exam that allowed students to forget what they had learnt through lack of practice.

An action plan was developed to address these issues (Table 2).

Table 2

When deciding on the mixture of strategies to develop numeracy skills the following points were considered:

- Benseman et al. (2005, p. 81) suggest that numeracy should be taught by experts rather than ‘non-specialists who are allocated the role by default rather than by choice’ so the decision was made to have the numeracy content for the whole programme taught by a specialist.
- Sabin (2001) suggests that ‘early identification of individual numeracy skills should be made…[allowing] for self-directed study or remedial programmes to be implemented at the earliest opportunity;…expectations of future ability should be articulated so that students are made aware of the importance placed upon this aspect
of practice’ (p. 37). Thus in the first instance we implemented a diagnostic test early in first year, and directed students with poor scores to compulsory remedial workshops delivered by a specialist teacher.

- Wright (2007) found that a range of teaching and learning strategies including online mathematical sessions, lectures that explained formulas and how to use them, a drug calculation workbook with answers, and practical sessions improved numeracy calculation skills for student nurses. Student nurse error rates for the group receiving these interventions were reduced in comparison to the group who received only lectures to teach numeracy calculations (Wright, 2008). Bloomfield et al. (2010) also suggests that the use of multiple revision strategies accommodates different learning styles. Additionally, a review of the impact of formative learning opportunities demonstrated that formative assessment can produce significant learning gains (Black and Wiliam, 1998). Consequently, we employed a range of teaching and formative assessment strategies including lectures, tutorials, practice papers, and online practice tools and videos.

Evaluation and further action

An evaluation of the interventions was conducted in December, 2009. While there had been a reduction in fail rates these were still unacceptably high. Further strategies implemented in 2010 to improve the scaffolding of numeracy skills in the programme included:

- Directing students on admission to the programme to a numeracy diagnostic course that included modules and videos to assist students with skill gaps, as well as offering numeracy skill development sessions in orientation week conducted by a specialist in remedial numeracy teaching. Both Starkings (2003) and Sabin (2001) suggest the use of diagnostic tests as a method for identifying at-risk students and appropriate remedial interventions.
- Setting the mastery pass rate at 100% in all CNCs, offering the opportunity to identify early, and provide remediation to, students who were going to have difficulties completing the programme. In addition, according to Ozturk and Debelak (2005) ‘the strong relationship between expectations and academic achievement has been well established both theoretically and empirically’ (p. 1).
- Assessing the content from the previous CNC in the subsequent CNC as well as the new content taught in that course to allow students to practice the skills they had learnt.
- Giving learning contracts to at-risk students attending practice-based placements. Wright (2009) suggests that practicing calculations in a clinical setting further enhances the learning of drug calculations.
- A numeracy manual that contained the key numeracy content from all six CNCs was initially proposed but later developed in the form of an online web-based numeracy support site in 2011.

**METHODS**

Data on the percentage of nursing students who obtained 100% in their applied numeracy examination in up to two attempts were collected from CNC III, IV, V and VI between 2008 and 2011. Data from the first year CNCs were not collected as some course assessors had left the university and thus these data could not be accessed. Confidentiality was maintained for
students in relation to their performance as the data analysis was performed on de-identified data. Ethics approval was obtained from the Human Research Ethics Committee, Southern Cross University, to conduct an analysis of the de-identified data. The ethics committee did not require retrospective consent to be obtained from the students for an analysis of de-identified data.

The Statistical Package for Social Sciences (SPSS Inc., 1989-2008) was used to conduct statistical analyses. Descriptive statistics were calculated on the variables of interest. A four by two Chi² Contingency table was used to determine if the differences in the proportion of students achieving 100% across two applied numeracy examination attempts in each CNC were significantly different between 2008 and 2011. The change in mastery rates in CNC V was examined between 2009 and 2010 as there was no examination in 2008, and in 2011 students only received one attempt due to changes in the timing of attendance at their clinical placement.

RESULTS

Data were collected on 1035 second and third year undergraduate nursing students. The percentage of students who obtained 100% correct answers on the applied numeracy examinations in the units CNC III, IV and VI was significantly higher in 2011 than in 2008 (Table 3), rising from 44.6%, 61.6% and 63.5% in 2008 to 98.1%, 93.4% and 100% in 2011, respectively. There was a non-significant increase in scores on the applied numeracy examinations in the unit CNC V between 2009 and 2010.

DISCUSSION

In this retrospective longitudinal study comparisons were made to the previous approach to teaching and assessment of numeracy in the undergraduate nursing curriculum. The revised teaching and learning methods introduced in this study were successful as the mastery rates of students completing end of course exams improved steadily between 2008 and 2011, culminating with all students enrolled in CNC VI achieving 100% mastery in two attempts in 2011. The cohort of students enrolled in CNC V and CNC VI in 2011 were the first to benefit from the full set of instituted changes such as the diagnostic testing in CNC I, standardized and specialized teaching, remedial support and multiple point assessments. We suggest that our whole-of-curriculum approach improved numeracy mastery rates by offering scaffolded learning supported by the consistency of regular assessment with the clear goal of achieving 100% mastery at each point.

An integrated approach to teaching and learning

Our integrated approach to the development of numeracy skills for this cohort of students relied not just on didactic teaching but a range of teaching strategies that went beyond drilling techniques utilising formulas (Sabin, 2001), in order to assist students to conceptualise and develop accurate methods to problem solve (Weeks et al., 2000). This approach recognised the importance of identifying students who may have had difficulties with gaining confidence in numeracy skill very early in the programme, and then used a number of different methods to meet these needs. Comprehensive numeracy programmes that are integrated within a course have a high potential for improved learning and instructional change, in comparison to the provision of instruction and remedial training at the beginning of a programme (Galligan et al., 2010). While Galligan et al. (2010) were able to achieve improved outcomes for
nursing students in one course in the first year of a programme, our approach has gone one step further, achieving improved learning across an entire programme.

A deliberate decision was made to provide students with formative learning opportunities via online as well as face-to-face environments, as learners may have differing learning styles, experiences, and personal commitments. While online learning tools may provide flexibility, online numeracy programmes alone are considered insufficient to support nurses who have difficulties with drug calculations (Sherriff et al., 2012). The specialist in remedial numeracy - a non-nursing staff member who ran the face-to-face tutorials and remedial sessions in consultation with nurse academics - provided students with opportunities to gain real time answers to their queries, a feature not possible within the online mode. Within these tutorials, the numeracy specialist, besides working through the nursing-related drug calculation problems, provided strategies to assist students to determine if their answers made logical sense or not.

Our team approach involving healthcare professionals and adult specialists working together to effect positive change in numeracy abilities of nursing students, is consistent with best practice recommended by Coben et al. (2008) to integrate numeracy into health care education and training in order to achieve competency in numeracy by pre-registration nurses. The effectiveness of this approach highlights the importance of generating a sense of collective responsibility by nursing faculty for quality enhancement of the curriculum (Fisher et al., 2003).

100% mastery
Students do find the required achievement of 100% causes anxiety and stress. However, through the consistent requirement of 100% mastery students are prepared for this (through precedence) and perform to their capabilities despite their stress levels. This approach is supported by Ozturk and Debelak (2005), who suggest that there is a plethora of evidence that challenging students produces better outcomes. Additionally, using mastery assessment rather than normative assessment may raise accepted standards (Sherriff et al., 2012), and redress the current trend of poor performance in numeracy skills by student nurses, and possibly newly graduated nurses. Further, 100% mastery is reflective of the unforgiving and complex environment of clinical practice after registration (Sulosaari et al., 2011) and gives emphasis to the important place that accuracy in drug calculations has in minimising medication errors.

Repeated assessment
We speculate that the successful outcomes of our suite of interventions may be partly attributed to all CNCs II-V examiners ensuring that prior and newly gained skills in drug calculation ability were tested utilising a similar format, to build on prior knowledge, aid retention, and keep skills current. The repeated testing of students’ competence in numeracy, a total of six exams over the course of the BN programme may at first seem excessive. CNC II-VI examinations assessed not just the understanding of arithmetical operations, for example, how to use division for fractions (Weeks et al., 2000), but the ability to extract information required to set up a problem specific to nursing contexts, and calculate a correct answer. In real clinical practice, skills not utilised can be lost, as noted by McMullan et al., (2010), who found that in their study only 5% of RNs tested, the majority of whom worked in primary care, gained more than 60% for IV calculation infusion rates. Cartwright (1996) also suggests that nurses can lose their calculation skills through lack of practice. Additionally,
repeated assessment overcomes the issues associated with fixed point competence assessment (Coben et al., 2008).

Limitations
This research excluded the first year students (CNC I and CNC II) due to limited access to these results. Not surprisingly, the results do not indicate which intervention is responsible for the progressive improvement in pass marks. It is not possible nor would it be ethical at this point to offer students one intervention over another. Rather, we have instituted interventions that are reflective of prior studies’ recommendations and current teaching and learning practices. In addition, the lack of a control group means that other influences on the numeracy skills of different year cohorts cannot be excluded. Further, these results were observed in a higher education setting, therefore, it is not possible to state whether these results will result in a reduced number of numeracy calculation errors in real clinical practice.

Recommendations
This study represents the results of one university’s attempt to improve nursing students’ applied numeracy skills. A larger study across multiple institutions is recommended to validate the methods used and to assess the transferability of intervention. Future studies should include first year students.

CONCLUSIONS
A whole-of-curriculum approach to developing applied numeracy skills in BN students resulted in a substantial and statistically significant improvement in these skills over four years.

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<table>
<thead>
<tr>
<th>Year/Semester</th>
<th>Course</th>
<th>Content taught</th>
<th>Pass mark</th>
<th>No. attempts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1</td>
<td>CNC I</td>
<td>Basic numeracy skills</td>
<td>80%</td>
<td>2</td>
</tr>
</tbody>
</table>
| 1/2          | CNC II | Medication foundational skills
Principles of safe medication administration
Calculations for parenteral routes, excluding intravenous (IV) calculations                                                                                           | 80%       | 2            |
| 2/1          | CNC III| IV medication and fluid calculations and administration                                                                                                                                                      | 85%       | 2            |
| 2/2          | CNC IV | Complex calculations applicable to acutely ill clients                                                                                                                                                        | 90%       | 2            |
| 3/1          | CNC V  | Paediatric calculations                                                                                                                                                                                         | No exam*  |              |
| 3/2          | CNC VI | Revision of CNC I-V content                                                                                                                                                                                     | 100%      | 3            |

*Medication administration skills were assessed during the clinical placement.
Table 2. Initial action plan to improve numeracy skills in the BN program.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st year students</strong></td>
<td>All students to complete a diagnostic numeracy skill test in CNC I Poorly performing students directed to a remedial program Adopt a standard language for use in numeracy, emphasise the rationales for gaining competency in numeracy calculation skills for nurses</td>
</tr>
<tr>
<td>Curriculum</td>
<td>Mapping of CNC numeracy content to be conducted to strengthen the link between numeracy in all CNCs</td>
</tr>
<tr>
<td>Assessment</td>
<td>Assessment of numeracy skills to be compulsory in all CNCs Provision of opportunities for revision of content taught in previous CNCs Standardize the approach across the curriculum with respect to assessment style, resources, and method of teaching</td>
</tr>
<tr>
<td>Resource development</td>
<td>All CNCs to have a recorded numeracy lecture and tutorial One specialist to deliver numeracy lectures across all CNCs Attendance for students at numeracy tutorials in the two second year units to be compulsory CD-ROM numeracy resource to be consistent between CNCs A glossary of terms to be developed</td>
</tr>
<tr>
<td>Clinical placement</td>
<td>Include numeracy skill acquisition in clinical objectives for all ‘at risk’ students on clinical placement Engender a culture of mastery on clinical placement Support clinical teachers to fail students who do not demonstrate mastery of medication administration on clinical placements</td>
</tr>
<tr>
<td>Students at risk</td>
<td>Improve access to numeracy learning assistance services</td>
</tr>
</tbody>
</table>
Table 3. Proportion of nursing students with 100% correct answers over two attempts at the Medication Administration examination.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Year</th>
<th>No./total students (%)</th>
<th>Chi^2</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNC III</td>
<td>2008</td>
<td>103/231 (44.6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>80/183 (43.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>157/172 (91.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>263/268 (98.1)</td>
<td>272</td>
<td>3</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>CNC IV</td>
<td>2008</td>
<td>122/198 (61.6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>123/160 (76.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>149/161 (92.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>242/259 (93.4)</td>
<td>94.7</td>
<td>3</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>CNC V</td>
<td>2008</td>
<td>No exam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>164/171 (95.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>146/147 (99.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>No second exam</td>
<td>3.76</td>
<td>1</td>
<td>NS</td>
</tr>
<tr>
<td>CNC VI</td>
<td>2008</td>
<td>115/181 (63.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>127/171 (74.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>126/144 (87.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>147/147 (100)</td>
<td>76.3</td>
<td>3</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

NS = Not significant