Numeracy for Nursing: The Scope for International Collaboration

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There is widespread recognition that numeracy is a key skill for safe and effective professional practice in nursing. Yet despite research studies in various countries which reveal a lack of proficiency within both the student population and amongst registered nurses, there is no international consensus on the nature and scope of numeracy for nursing, or on ways of improving the situation. In this paper I present a brief overview of research and development on numeracy for nursing in several countries. I then outline work in progress on two inter-disciplinary research projects in the UK as a way to explore the scope for international collaboration on numeracy for nursing. I conclude that the time appears to be ripe for collaboration on an international comparative study drawing together and carrying forward research and development in numeracy for nursing: We have much to learn from each other.

Introduction

Numeracy for nursing has a “manifest disaster criterion” (Nokes, 1967). Poor numeracy can be life threatening for the patient. Numeracy is implicated in potential and actual disasters (ISMP, 2008) and in safe and effective practice in nursing. Nurses’ numeracy manifestly matters: to patients, to nurses themselves, to their employers, to the public and to nurse educators. However, studies in various countries reveal a lack of proficiency amongst both students and registered nurses (Bindler & Bayne, 1991; Brown, 2006; Grandell-Niemi, Hupli, Puukka, & Leino-Kilpi, 2006; Jukes & Gilchrist, 2006), and efforts to remediate the situation (Johnson & Johnson, 2002; Sandwell & Carson, 2005; Weeks, Lyne, & Torrance, 2000; Wright, 2005). Widespread concern about nurses’ numeracy finds periodic expression in alarming headlines such as “A third of new nurses fail simple English and maths test” (Daily Telegraph, 5th August, 2006), and there are examples of efforts to remediate the situation through education and training. However, as yet there is no explicit consensus on the nature and scope of numeracy for nursing, or on ways of improving the situation: Numeracy for nursing is still poorly-understood and under-developed.

In this paper I begin by presenting a brief overview of research and development on numeracy for nursing in several countries. I then outline work in progress on two inter-disciplinary research projects in the UK as a way of exploring the scope for international collaboration on numeracy for nursing.

So What do I Mean by Numeracy for Nursing?

Numeracy may be considered as a specific competence for nursing, so before proceeding further it is necessary to define what is meant by ‘competence’ and ‘numeracy’ in this context.

The holistic notion of competence set out in the Organisation for Economic Cooperation and Development’s (OECD) report on The Definition and Selection of Key Competencies (known as DeSeCo) is useful here. DeSeCo defines competence as:

… the ability to successfully meet complex demands in a particular context. Competent performance or effective action implies the mobilization of knowledge, cognitive and
practical skills, as well as social and behavior components such as attitudes, emotions, and values and motivations.

(OECD, 2005, p. 2)

There are many competing definitions of numeracy (Coben et al., 2003), some of which, including the following definition, align with the OECD notion of competence:

To be numerate means to be competent, confident, and comfortable with one’s judgements on whether to use mathematics in a particular situation and if so, what mathematics to use, how to do it, what degree of accuracy is appropriate, and what the answer means in relation to the context.

(Coben, 2000b, p. 35, emphasis in the original)

Many aspects of nursing call for competence in numeracy in these terms, including calculations and judgments involved in tasks such as: monitoring patients’ vital signs and fluid balance; measuring weight and height; nutrition, including infant feeding and monitoring the nutrition levels of elderly and frail patients; demographic profiling; the organization of healthcare work, including staffing and budget calculations; and the area that most people think of when considering numeracy or mathematics for nursing: medication dosage calculation (Johnson & Johnson, 2002; Pirie, 1987). A Venn diagram representing medication dosage calculation as an integral element of the intersecting areas of numeracy, healthcare numeracy and medicines management is shown in Figure 1, below; other areas of numeracy for nursing could be visualized in a similar way.

As nursing practice incorporates the use of new technologies, the nature of numeracy for nursing is changing. In nursing, as in other areas of life, much mathematics is invisible (Coben, 2000a; Noss & Hoyles, 1996; Zevenbergen, 1996). New technology has arguably in some ways ‘demathematised’ some aspects of nursing practice, or at least removed the need for some calculations. For example, the use of personal digital assistants (PDAs) is expanding in nursing, particularly at the point of care (Greenfield, 2007) and medicines may be dispensed in standard dosages; these have the potential to reduce calculation error. However, such new nursing practices also call for numeracy on the part of the nurse: Estimation and checking strategies, for example, are vitally important for judgements as to whether a machine is correctly calibrated, or whether the correct dose of a drug has been prescribed.
Figure 1. Drug calculation as an aspect of numeracy, healthcare numeracy and medicines management (Sabin et al., 2008).

Research on Numeracy for Nursing

Research on numeracy for nursing is still a new area despite pioneering work by Susan Pirie and others in the 1980s (Dexter & Applegate, 1980; Pirie, 1987). There is growing interest and research activity, much of it small-scale, such as evaluations of local initiatives. A literature review by Sabin (2001) confirms that competence in mathematical calculation skills required for clinical nursing practice is widely regarded as a pre-requisite to nurse registration. However, many studies find a lack of proficiency amongst both students and registered practitioners. Sabin examines the strength of the evidence linking achievement in calculation tests with subsequent clinical practice, alongside the demographic and cultural variables that may influence learning, teaching and assessment. He reviews the nature and role of mathematics learning within pre-registration nurse education programmes and in clinical practice. He also reviews the value of context in mathematics learning in professional settings and critiques the rationale for outcomes-based approaches to assessment since these may fail to identify, and may potentially stifle, the development and application of knowledge. On the basis of the review, he advocates an integrated approach to facilitating mathematical knowledge and application in practice and makes recommendations for future practice in the UK, as follows:

1. Early identification of individual numeracy skills should be made […].

2. University-based teaching and learning should employ a range of approaches including workbooks, CAI [computer-assisted instruction], study groups and lectures, identifying and focusing on the key components identified by Pirie (Pirie, 1987) and others.

3. Experiential learning in clinical practice should be supported by linking specific clinical activities with calculation learning and practice.

5. Numeracy should have the same status as other equally important components of professional practice.

6. The elements of mathematics understanding required to address the evaluation and analysis of clinical and statistical data in research should be integrated into pre-registration programmes; particularly those that result in a degree-level award.

7. Remedial programmes should be supported by university-wide facilitation.

8. Just as the mathematics in nursing practice is not disengaged from its context, neither are the students. Acknowledgement of the role of demographic issues such as age, gender, class and ethnicity in approaches to learning and teaching practice calculation is long overdue.

9. Future studies should be focused towards the development of a standardised, structured framework for learning, teaching and assessment that can be employed across the UK nursing education field.

10. The development of a framework, within which education and service can facilitate and assess practitioners’ calculation abilities, is needed.

(Sabin, 2001, pp. 9–10)

The International Picture

Nurse Shortage and Drop-Out from Training

Some examples of research and development published since Sabin’s review indicate that numeracy for nursing continues to be an issue of concern in many countries, often against the background of nurse shortages. For example, there is a national shortage of registered nurses (RNs) in the United States of America which is predicted to continue to grow over next twenty years, with a more severe shortage in some States than others. The US Department of Health and Human Resources Health Resources and Services Administration (HRSA) states that:

to meet the projected growth in demand for RN services, the U.S. must graduate approx 90% more nurses from U.S. nursing programs.

(HRSA, 2004, p. 10)

There is also concern over drop-out rates in nurse training. For example, amongst Hispanic nursing students in the USA:

National research shows a 30% drop-out rate for Hispanics in nursing programs. This has been directly tied to economic hardship issues that involve the need to support the family and an educational preparation that may not have emphasized the knowledge and skills needed to succeed in the selected program.

(Hispanic Times Magazine, 2001)

This situation is reflected in the UK, also: “More than a quarter of the UK’s student nurses dropped out of their courses in 2006” (BBC News 9th April, 2008, http://news.bbc.co.uk/1/hi/health/7337259.stm). It is
not known to what extent numeracy may be a factor in recruitment and retention problems in nurse training but it is likely that it has some bearing on this situation.

Establishing the Extent and Nature of Nursing Students’ Numeracy

Research studies aiming to establish the extent and nature of nursing students’ numeracy include explorations of the mathematical competencies of baccalaureate degree nursing students in the USA. For example, Allen and Papas (1999) assessed entering nursing students’ mathematics competencies and identified and arranged additional customized support for those who needed additional help. Drug dosage calculation is a particular concern and Brown found that a sample of nursing students in the North East region of the USA, even with the use of calculators, were unable to complete a medication examination with at least 85% accuracy within a predetermined time limit. She concluded that although medication dosage calculation errors are cited as one of the most frequently occurring types of error in medication administration, they are seen as one of the most preventable (Brown, 2006).

Improving Nursing Students’ Numeracy

Other studies evaluate attempts to improve nurses’ and nursing students’ competence in numeracy. Numeracy is often built into Nurse Education programmes. For example, in the USA, an evaluation of the efficacy of a teaching strategy in improving beginning nursing student learning outcomes was undertaken by Rainboth and DeMasi (2006). The students who received the intervention had statistically significantly higher scores on the major medication calculation examination than the students in the control group. The intervention group students were satisfied with the method and outcome, a finding that tends to be duplicated elsewhere in evaluations of other such interventions. In Australia an evaluation of an innovation by a teaching team who developed a Safe Administration of Medicines (SAM) website was undertaken by Behrend and colleagues (Behrend, Clark, Hall, & Hill, 2006). The site includes ‘Maths for Nurses’ learning resources which identify the key numerical concepts and provide an explanation of these concepts, together with examples and clinical quizzes to ensure skills are contextualised in workplace practice http://www.unisanet.unisa.edu.au/sam/. Behrend et al.’s evaluation of this site found that successful outcomes had been achieved through web-based on-line numeracy learning. At Christchurch Polytechnic Institute of Technology (CPIT) in New Zealand, Dodds has created another online programme of support for numeracy for nursing (Dodds, 2006) http://www.cpit.ac.nz/subjects/mathematics_and_statistics/programmes_and_courses and there are other examples of such programmes from around the world, including the UK-based Authentic World® http://www.authenticworld.co.uk/.

In Australia, Galligan and Pigozzo (2002) have researched the process of assisting nursing students to solve drug calculation problems using metacognition and error analysis. They found that “nursing students who have difficulties with drug calculations do demonstrate metacognitive and cognitive skills” however, they have identified gaps in these skills. On the basis of their analysis, they have developed strategies involving planning, predicting and identifying errors, in order to enhance students’ problem-solving abilities.

Also in Australia, Gillies (2004) has compared two methods for teaching drug calculation: on the one hand, traditional formula-based teaching methods and on the other hand building on students’ existing mathematical problem-solving skills. On the basis of analysis using quantitative measures, the formula-based approach appeared more effective. However, she found that alternative teaching methods may be more effective in increasing students’ confidence and achieving better long-term recall and transfer of skills.

There is concern about equity and inclusion of minority groups. For example, in Finland, the basic mathematical proficiency and the medication calculation skills of graduating nursing students in Finland
were studied by Grandell-Niemi and her colleagues. They looked at how students experienced the teaching of medication calculation. They aimed to find out whether these experiences were associated with various background factors and the students’ medication calculation skills. They established that the students found it hard to learn mathematics and medication calculation skills. Overall their mathematical skills were inadequate, with one-fifth failing the medication calculation test. There was a positive correlation between students’ grades in mathematics before starting nurse training and their skills in medication calculation (Grandell-Niemi, Hupli, & Leino-Kilpi, 2001).

In New Zealand, Gibson-van Marrewijk is conducting a project investigating factors impacting on student completion, retention, and achievement rates for science modules in applied health programmes, with particular attention to Maori students (http://www.tlri.org.nz/projects/2005/).

In the UK, recent research includes: analysis of the concept of competence in numeracy for nursing (Hutton & Gardner, 2005); a study of techno-mathematical aspects of pediatric nursing practices (Hoyles, Noss, & Pozzi, 2001); development of local support initiatives and materials (Starkings, 2003); and evaluation of teaching and learning interventions (Hall, Jones, Hilton, Davies, & MacDiarmid, 2005; Wright, 2006).

**Approaches to Teaching, Learning and Assessment of Nurse Education**

As yet there has been no systematic national (nor yet international) survey of the ways in which nursing students are educated in numeracy. Anecdotally, it would appear that these approaches range along a continuum from the teaching of decontextualised arithmetic, through the teaching of formulae commonly used in nursing, to problem-solving approaches and task-based activities involving simulation of practice, through to fully contextualized approaches situated directly in practice, known colloquially in the UK as ‘sitting by Nelly’. In the case of numeracy for nursing, ‘sitting by Nelly’ involves working alongside an experienced nurse while he or she undertakes tasks involving numeracy. Any given nurse education programme may offer combinations of these approaches, which may be delivered in the classroom, online, or on the ward or other healthcare setting.

A full review of these approaches is outside the scope of this paper but we know that it cannot be assumed that students will readily transfer knowledge from the classroom to the practice situation (Eraut, 2003; Evans, 1999; Guile & Young, 2003). ‘Sitting by Nelly’ is not necessarily the answer either, since ‘Nelly’ may have become so habituated to the numeracy required in her role that it has become “common sense” (Coben, 2000a)—that is, self-evident to an experienced worker but not to a novice. An example of the sort of problem that may arise is shown in Figure 2. The experienced nurse (on the right) talks her colleague through a medication dosage calculation: “We need Aminophylline 200 milligrams… It comes as 250 milligrams in 10ml. Therefore we need to give 8ml … OK?”. She probably believes she is being clear and helpful but her inexperienced colleague has no idea what she is talking about and is too embarrassed to ask. An opportunity for learning has been lost and the experienced nurse may be unaware that there is any problem.

Two current inter-disciplinary research projects in the UK are seeking to address some of the issues outlined above. These are: ‘Medication Dosage Calculation: a benchmark assessment for nursing’¹ (NHS

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¹‘Medication Dosage Calculation: A benchmark assessment for nursing’ (2007–09). The team was brought together by Mike Sabin, NHS Education for Scotland and Scottish Government and comprises, in addition to Mike Sabin: Dr Keith Weeks and Norman Woolley of University of Glamorgan and Authentic World; Dr Carol Hall, University of Nottingham; Professor Diana Coben, King’s College London; Dr Meriel Hutton, Consultant and Senior Visiting Research Fellow, King’s College London; and Dr David Rowe, University of Strathclyde. The project is funded by NHS Education for Scotland (NES) http://www.nes.scot.nhs.uk/.
Education Scotland); and ‘Numeracy for Nursing’ \(^2\) (King’s College London). Both projects are based on the notions of numeracy as a competence for nursing outlined above. They are being conducted against the background of the new (from September 2008) requirement by the UK Nursing and Midwifery Council (NMC\(^3\)) for nursing students to achieve 100% in a test of “numeracy in practice” before they will be allowed to register as nurses (NMC, 2004). However, there are currently no national standards for teaching or assessment of numeracy during pre-registration nurse training, so tests are likely to vary in validity and reliability. This means the tests may not be measuring what they are intended to measure (i.e., they may be invalid) in terms of content (domain- or subject-specific); construct (indicating an internal trait, attribute, or process); or criterion (factors that can be related to an observable outcome). Reliability implies freedom from measurement errors and consistency between measurements across time, situations and raters. Reliability is necessary, but not sufficient, for validity. In an area with a manifest disaster criterion such as numeracy for nursing, assessment must be both valid and reliable.

### Two Current Projects on Numeracy for Nursing

**Medication Dosage Calculation: A Benchmark Assessment for Nursing**

This ongoing interdisciplinary study aims to create a national benchmark for numeracy for nursing in Scotland against which numeracy for nursing may be assessed, initially at point of registration but potentially thereafter at other stages of nurse preparation and in practice. A robust competence benchmark will allow practitioners to demonstrate achievement, universities to demonstrate effective learning and teaching strategies and employers to support governance and patient safety. If we succeed in creating a benchmark for numeracy for nursing accepted by the profession and other stakeholders, we believe it will be the first of its kind anywhere in the world.

The project is rooted in constructivist and socio-cultural approaches to numeracy for nursing and builds on work by members of the project team (Coben, 2000b; Hall et al., 2005; Hutton, 2000; Rowe & Mahar, 2006; Sabin, 2006; Weeks, Lyne, Mosely, & Torrance, 2001). Initially we are focusing on drug dosage calculation, addressing issues of parity, scope and level in assessing numeracy skills for successful calculation of medication dosages by nurses when they qualify. In the first phase of the study we developed an evidence-based benchmark assessment tool utilising interactive computer simulations that approximate to real world practice, based on the following criteria—such a tool should be:

- **Realistic:**

  Evidence-based literature in the field of nursing numeracy (Hutton, 1997; Weeks et al., 2001) strongly supports a realistic approach to the teaching and learning of calculation skills, which in turn deserve to be tested in an authentic environment. Questions should be derived from authentic settings. A computer based programme of simulated practice in drug calculations, formative testing, with feedback on the nature of errors made, has been shown to develop competency in medication dosage calculation, which can be also demonstrated in the clinical areas (Weeks et al., 2000). Exposure of students to real-world situations is recommended (Weeks, 2001).

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\(^2\)‘Numeracy for Nursing at King’s College London’ (Jan-Sept., 2008). Principal Investigators: Professor Diana Coben, and Dr Jeremy Hodgen, with Sherri Ogston-Tuck and Dr Meriel Hutton; conducted in collaboration with the Florence Nightingale School of Nursing and Midwifery and funded by the Department of Education and Professional Studies Research Committee, King’s College London.

\(^3\)NMC is the UK regulatory body for nursing and midwifery [http://www.nmc-uk.org/](http://www.nmc-uk.org/).
Well no, it’s not OK. I haven’t got a clue how she worked it out… but I don’t want to look stupid by asking how she did it.

We need Aminophylline 200 milligrams… It comes as 250 milligrams in 10ml. Therefore we need to give 8ml… OK?
• Appropriate:

• The assessment tool should determine competence in the key elements of the required competence (OECD, 2005; Sabin, 2001).

Differentiated:

• There should be an element of differentiation between the requirements for each of the branches of nursing (Hutton, 1997).

Consistent with adult numeracy principles:

• The assessment should be consistent with the principles of adult numeracy learning teaching and assessment, having an enablement focus (Coben, 2000b).

Diagnostic:

• The assessment tool should provide a diagnostic element, identifying which area of competence has been achieved, and which requires further intervention (Black & Wiliam, 1998). Thus it should “provide information to be used by students and teachers that is used to modify the teaching and learning activities in which they are engaged in order better to meet student needs. In other words, assessment is used to ‘keep learning on track’” (Wiliam, 2007).

Transparent:

• The assessment should be able to demonstrate a clear relationship between ‘test’ achievement and performance in the practice context (Weeks et al., 2001).

Well-structured:

• The tool should provide:
  o a unique set of questions with a consistent level of difficulty;
  o a structured range of complexity; and
  o the assessment should take place within a defined framework, at points by which students can be effectively prepared, while allowing time for supportive remediation. (Hodgen & Wiliam, 2006)

Easy to administer:

• the assessment should provide the opportunity for rapid collation of results, error determination, diagnosis and feedback (Black & Wiliam, 1998).

(Coben, Hall, et al., 2008, pp. 96–97)

The next phase (currently underway) seeks to evaluate this tool and compare it with assessment of the same competencies in a practical setting, using task-based activities.
Progress reports on the project have been presented at national and international conferences (Coben et al., 2008; HEA, 2006; Sabin et al., 2008) and published in articles (Coben, 2007).

Numeracy for Nursing at King’s College London

Meanwhile, an exploratory investigation of aspects of teaching, learning and assessment of numeracy for nursing is underway in the Florence Nightingale School of Nursing and Midwifery (FNSNM) King’s College London undergraduate/Diploma Nursing programme. Like other university Schools of Nursing in the UK, FNSNM has developed its own numeracy teaching, learning and assessment programme. This programme is being evaluated in this interdisciplinary project; in particular, we are:

- analysing existing data from online numeracy assessment of FNSNM Nursing undergraduate/Diploma students;

- critically evaluating numeracy assessment instruments and procedures used by FNSNM and recommending improvement as appropriate, in order to establish the validity and reliability of FNSNM assessment of numeracy for nursing;

- characterising the approach to teaching, learning and assessment of numeracy for nursing in FNSNM with a view to developing future studies, including international comparative studies.

We have conducted an initial analysis of the difficulty and coverage of assessment items and we are currently reviewing formative and summative assessment processes and materials and analysing the results of summative assessments of FNSNM nursing students’ mathematical knowledge. The project will be reported on at the 9th Annual Interdisciplinary Research Conference, Transforming Healthcare through Research Education and Technology, School of Nursing and Midwifery, Trinity College Dublin: 5th-7th November, 2008.

We envisage that this project will complement the ‘benchmark’ project in Scotland since it entails an analysis of a different set of assessment items in terms of the scope and nature of numeracy for nursing implicit in them. We hope that these projects may contribute to the establishment of a sound basis for teaching learning and assessment of numeracy for nursing in the UK and elsewhere in the world.

The Scope for International Collaboration in Research and Development on Numeracy for Nursing

Following on from these projects, and building on Sabin’s (2001) review of research and the other studies outlined above, there appears to be considerable scope for international collaboration on research and development in numeracy for nursing.

Debate on the nature and scope of numeracy for nursing should be facilitated through existing national and international networks such as ALM (Adults Learning Mathematics—A Research Forum, www.alm-online.net/), FINE (European Federation of Nurse Educators, www.fine-europe.eu/Organisation.htm) and other international, national and regional healthcare and nursing and nurse education organizations and mathematics and numeracy education fora. This should raise awareness of issues in numeracy for nursing and alert practitioners and others to the current lack of agreement on what numeracy is required for nursing and the variation in standards and content likely to be found in assessments of numeracy for nursing.

If a benchmark for numeracy for nursing can be successfully established in Scotland and is accepted by the profession and by nurse educators, employers and others, the standards expected of qualified nurses in other countries and at other stages in nurses’ education and subsequent careers (newly-qualified; experienced; etc.) could be compared with the benchmark. The validity and reliability of assessments of
numeracy for nursing used in various countries and institutions could also be compared with the benchmark. Teaching, learning and assessment programmes in numeracy for nursing could be compared in terms of their fitness for purpose, fitness for practice and fitness for award. The complexity and potential difficulty of both the mathematical and nursing content could be compared.

As a first step, an international comparative study of numeracy for nursing is in preparation. This will investigate: relevant aspects of regulatory frameworks and employment contexts; the numeracy nurses need to be safe and effective; the nature and scope of numeracy education for nursing, including case studies of educational interventions in numeracy for nursing. The study will include an exploration of what adult numeracy educators, in collaboration with nurses and nurse educators, can do—and are doing—to help turn numeracy for nursing from a poorly-understood area of concern to a well-understood beacon of good practice. The time is surely ripe for collaboration on an international comparative study drawing together and carrying forward research and development in numeracy for nursing: we have much to learn from each other.

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