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NUMERACY IN THE WORKPLACE: THE CASE OF NURSING AND IMPLICATIONS FOR LANGUAGE ASSISTANCE

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Nursing is a relatively recent arrival in the university sector and as such, represents the increasing diversification of knowledge as traditionally vocational disciplines become academic. The problem of standards in a field like nursing is compounded by several factors including literacy and numeracy. There seems to be a consequent misalignment between the demands of the workplace and levels of preparedness. The issues of literacy are particularly critical in the healthcare environment in which life and death issues abound. The most widely documented consequence of a lack of

nursing competence is in drug administration errors. While nurse educators carry the major responsibility for training nurses, academic advisors play a significant role. Students, overwhelmed by the linguistic and mathematical demands of their subjects, become anxious about the real possibility of failure. Academic advisors need to be more multi-skilled than ever in meeting the demands placed on them to support these students. They have to identify the knowledge gaps, bridge theory and practice and support both linguistic and mathematical problem solving. This study investigates the nature of the knowledge gaps these nursing students present with when attempting to solve drug calculation problems. The results indicate an inability to conceptualize the problem both mathematically and linguistically. Some recommendations are made for the continuing language development of these students such that they might graduate, well equipped to meet the demands of the future health-care work-place.

Keywords: *language use, numeracy, academic advisors, nursing, mathematics, problem solving*

Introduction and background to the study

"Changing identities" as a conference theme aptly applies to domains of knowledge undergoing not only ideological shifts but shifts on a number of levels, especially those traditionally seen as practical, vocational and essentially non-academic such as nursing. In the push for a 'knowledge economy' standards have to be raised in these traditionally non-academic fields. The changing identity of nursing schools into the academic mainstream requires that they provide researchers as well as practitioners. They have the responsibility of ensuring their nurse graduates have levels of numeracy and literacy which equip them not only for an increasingly sophisticated, technological and demanding work environment but also for statistically complex research. The changing identity of the society being served by the nursing profession has to be articulated as does the changing identity of the nursing and student nursing body, in addition to the changing nature of learning itself. In response to these changing identities, academic advisers have to be a step ahead in their repertoire of skill and this requires increasing diversification of their operational knowledge.

Nursing educators and university support services today are particularly challenged by the diverse learning needs of nursing students, given changing demographics, the advent of the age of electronic communication (Teikmanis & Armstrong, 2001) and signs of "disengagement" (McInnis, 2001). While McInnis is referring to young undergraduates, what he says may apply to nursing students who are female, ESL, older and have the competing demands of paid work and family responsibilities. Unlike their young counterparts, they may not be computer-literate or computer-confident nor be able to easily access material on-line. There is ample American research which documents the multi-faceted challenges confronting nursing schools today and the little local research there is, suggests similar trends. Enrollments in bachelor's-degree nursing programs have declined consistently over the past 5 years, dropping 4.6% in 1999 alone, according to the American Association of Colleges of Nursing (Jannetti, 2000). As our communities become more culturally diverse, so do our classrooms and the need for representation of minorities in schools of nursing has yet to change sufficiently to meet society's needs given the increased health care needs of minority populations.(Griffiths & Tagliareni, 1999).

The increase in the number of English as a second language students coupled with increasing nursing shortages, an ageing population, an ageing nursing population, declining nursing enrolments among young students with older nursing students returning to study (Zimmermann, 2000; Jannetti, 2000), has resulted in a high risk of attrition among nursing students generally (Callister, Khalaf & Keller, 2000), and ESL students in particular (Jalili-Grenier & Chase, 1997). The problem of standards in a field like nursing is attested to by documented literacy deficits (Benjamin, 1997; Hess, 1998); language deficits among English as a second language immigrant and international nursing students (Jalili-Grenier & Chase, 1997; Malu & Figlear, 1998; Arthur, 1999; Marrone, 1999; Parks & Macguire, 1999; Gaffney, 2000), and numeracy deficits (Keill & Johnson, 1993; Ferner, 1995; Hutton, 1997; Fuqua & Stevens, 1998; O'Shea, 1999; Thomas, 2000).

Given the complex profile of learning needs, there would appear to be a misalignment between students' levels of literacy and numeracy and the increasingly sophisticated demands of the nursing workplace, the escalating demand for graduate-prepared nurses and the prediction that employment for nurses will outstrip all other occupations (Jannetti, 2000). The most widely documented consequence of a lack of nursing competence is in drug administration errors. Nursing mistakes can injure thousands, even kill (Hess, 1998; Berens, 2000).

While nurse educators have the ultimate responsibility to assist nursing students overcome gaps in literacy and numeracy for competence in the workplace, academic advisers become involved when students and lecturers turn to them to assist them achieve their educational goals. Nursing students may pose a particular challenge for the adviser who must diagnose the numeracy gap and then provide mathematical problem explanations. This is part of the changing identity of those advisers who have a language-rich background but who are called on to assist students across a range of discourses. Students in general, come from increasingly complex and diverse knowledge areas which place greater demands on the domain knowledge of the advisers. For nursing students seeking assistance with mathematical problem solving, while the mathematics underlying the solution could be elementary, the context and language in which the problems are embedded make the task of understanding the problem and explaining the solution far more difficult. Both phases of the solution process necessarily draw on the mathematical and language competencies of students and advisors alike.

The particular focus of this study is to explore the extent to which nursing students have the mathematical and language skills that are necessary to solve problems in the workplace. Because the most widely documented problem is the need for competency in mathematics for the prevention of drug administration errors, particularly drug calculation errors in the work-place, (Keill & Johnson, 1993; Ferner, 1995; Hutton, 1997; Hess, 1998; Fuqua & Stevens, 1998; O'Shea, 1999; Berens, 2000; Thomas, 2000), this study revolves around the solving of drug calculation problems. The aim of the study is to explore how advisers might help these students by understanding the nature of the difficulty they are experiencing in tackling workplace problems. Sample problems were analysed and the language issues that impede problem solving for both native and ESL students consulting with the advisor were drawn out.

Literature review

Drug administration is an integral part of the nurse's role and responsibility and with changes in legal liability, nurses are directly accountable for correct administration of medication (Ethics lecture, ACU, 2001). Many nurses report being anxious when faced with drug calculations, and while patients expect to receive the correct medication at each drug round, several studies suggest that this does not always occur (O'Shea, 1999; Ferner, 1995; Keill & Johnson, 1993; Raju, Kecskes, Thornton, Perry, & Feldman, 1989; Fuqua & Stevens, 1998). They report calculation problems, problems in the preparing, checking and administering of medications, in monitoring their effectiveness and in teaching patients how to take their drugs. A study of 40 hospitals revealed medication errors as the second most reported incident in hospitals today, attributable to a lack of nurses' mathematical skill (Gillies, 1994). Thomas (2000) reports more errors in calculations occurring particularly in high technology areas and in neonatal nursing where the mathematics involved are a little more complex (Thomas, 2000). This is by no means a new issue for nurse educators. Research carried out on second year nursing students in Australia found that a large number of students had limited understanding of basic arithmetic, and '...made errors large in magnitude, which implies potentially dangerous drug doses...[not solvable] by the use of calculators' (Gillham & Chu, 1995). Most drug calculations involve the skills of multiplication and division and while much has been written on drug calculation error, research has generally not focused on examining methods of dealing with poor calculation skills and how to test for those skills. Commenting on the situation in Australia, Cartwright (1996) called for 'creative' approaches in dealing with the problem of 'serious numeracy skills deficits' which account for errors in drug administration with an older study reporting very little published information aimed at facilitating mathematics calculations for drug and solution calculations (Weinstein, 1990).

While nursing does not require tertiary level mathematics, nurses do need to demonstrate a range of mathematical understandings and their applications (Hutton, 1997). For example, applying mathematics to practical nursing sometimes means giving answers that are nearly accurate while other calculations may require a higher degree of accuracy. Calculations involving tablets usually give simple and small answers (except some doses of major tranquilizers) while those associated with fluid doses can be more complex. Most drugs work in wide therapeutic ranges so manufacturers usually produce 'standard doses' which do not vary for adult calculations, but child doses are more difficult to compute as they are often related to body weight or surface area, and greater care and accuracy are needed. Nurses also need to make calculations of the electrolyte contents of infusions and other drugs which are expressed in percentages and ratios describing the dilution strength. They need to be able to carry out intravenous regulation and input and make output or fluid balance calculations (Hutton, 1997).

The conceptualizations in handling the administration of common and vital drugs can be problematic to nurses as they involve both linguistic analyses and mathematical computations (Miller, 1993). An example of the type of reasoning required of nurses is given in calculations involving adrenaline which has two standard strengths: 1ml ampoules of 1 in 1,000 (1:1,000) and 10ml ampoules (1:10,000). The first number represents weight in grams and the second represents volume in millilitres. 1:1,000 represents 1 gram adrenaline in every 1,000ml solution (1g/1,000ml). There are 1,000mg in 1g, so 1,000mg/1,000ml = 1/1 or 1mg per 1ml, therefore a 1ml ampoule, contains 1mg of the drug. Some drugs are expressed as percentages (grams per 100ml) so 0.9% saline has 0.9g of sodium chloride in every 100ml or 9g/litre (0.9 x 10 per litre = 9g/litre).

Weaknesses in reasoning the solutions to problems may come about because of a lack of being able to handle basic mathematical principles represented by the above calculations. Other weaknesses occur in representing calculations as equations; knowing that anything done to the numerator of a fraction must also be done to the denominator; translating both sides of equations into the same unit of measurement; checking answers if in doubt by working backwards; and being aware that equations can be modified, provided both sides are balanced before isolating the unknown (Woodrow, 1998). Some calculations may involve the integration of division and multiplication with addition and subtraction. Graphs and charts easily convey complex information and nurses are expected to be able to read such representations of information about patients (eg. one measure on the vertical axis may be temperature, and another on its horizontal axis may be time). As well as showing the last recorded temperature, an observation chart could show trends which may help with diagnosis and help save time looking through written notes. Nurses are expected to be able to read various other graphs, charts and tables for example charts showing average and normal ranges for height and weight (Woodrow, 1998).

The definition and categories of medication errors vary throughout the literature but the American Society of Hospital Pharmacists (ASHP, 1982; p. 321 cited in O'Shea, 1999) identified nine categories of medication error: omission, unauthorized drug error, wrong dose error, wrong route error, wrong rate error, wrong dosage form error, wrong time error, wrong preparation of a dose and incorrect administration technique. In a study conducted by Blais and Bath (1992) three areas of medication calculation deficiencies among nurses were identified. These were mathematical, conceptual and measurement inabilities with the most frequent type of mistake being conceptual errors (difficulty in setting up the problem), followed by mathematical errors and then measurement errors. Segatore, Edge and Miller (1993) identified 91% of all errors as conceptual errors. Other researchers (Cohen, 1994; Calliari, 1995; Gladstone 1995) also attribute most medication errors to language-based factors and not merely the result of wrong calculations. It may indeed not be possible to separate mathematics and language if all conceptualizations including mathematical ones involve language (Anderson, 2000). Hence errors may not simply be due to a lack of numeracy but to a *complex interplay of mathematical and linguistic factors.* Researchers (Blais & Bath, 1992; Segatore, Edge & Miller, 1993) have suggested that we need to examine those linguistic factors that play a key role in helping the problem solver understand the structure of a given problem.

It is a common practice for nursing schools to use a mathematics test to ascertain mathematical competency for nursing even if its effectiveness is questionable. Such tests may measure basic mathematical knowledge with little attention to the contexts in which such knowledge could be used thus not reflecting the reality of the workplace. Tests largely bear no relationship to real-life nursing calculations and according to the literature, have no real benefit in terms of learning (Rutherford, 1996). One reason is that the language associated with real-life problems is very much richer than that reflected in basic skills tests. In any case, nurses come to know the common dosage of particular drugs or the usual amount of feed for a baby of a particular size on the job. Recognising erroneous amounts becomes common sense. If an answer does not look reasonable, nurses are expected to check calculations. In fact, research on what these tests can predict is inconsistent. Some research suggests that poor performance in a written mathematics test does not necessarily predict a lack of later competence in the nursing mathematics required in the workplace. A study by Hutton (1998b) found that nursing students were particularly poor at applying mathematical concepts to problems written in words but this poor test performance was not reflected in clinical practice. On the other hand, research also shows that nurses who fail a written medication test are more likely than those who pass the test to make medication errors in practice (Calliari, 1995).

Purpose of the study

This study set out to examine the medication calculation skills of nursing students attending the academic skills support unit. The initial task was to find out if these students had poor calculation skills. The next task was to find out if these poor skills were due to low competence in mathematics or poor language proficiency or both and finally, to consider the reasons for the identified lack of skills. The results of the study would guide the researcher into preparing viable academic support programmes to assist such students and to advise the nursing faculty of strategies to deal with students experiencing difficulties.

The study was undertaken in response to the increase in the number of visits to the academic support unit at an Australian university by nursing students who were either failing the mathematics test or were failing the communications component of the practical placement in hospitals. Conversations with nursing lecturers (Australian Catholic University, 2001), suggested that some students failed the practical placement because of a 'dangerous' lack of understanding of medication instructions and not because of an inability to do the mathematics. These lecturers also suggested that those students who did have problems with the mathematics failed tests for several reasons including an over-reliance on calculators, an inability to do basic mental arithmetic, and an inability to do conversions and ratios. They recounted anecdotal evidence of students who were unable to convert milligrams to micrograms; who calculated 1:4 as a quarter and not a fifth; who rang a doctor for advice at 3am because a patient required 500mg of an antibiotic but there were no 500mg tablets left, only 250mg tablets; and of another student involved in a diet survey who said she consumed '40 ton' of sugar a year, with no idea why the answer was incorrect. Needless to say, such accounts are cause for concern and indicate the need for effective support which targets the root cause of the problem.

Method

Participants

The participants consisted of four female native speakers (NS) and four non-native speaker (NNS) nursing students at various stages of completing a nursing degree. They were randomly selected to take part in what was intended to be a pilot study for a more extensive investigation. They happened to be representative of the female , resident and international, school leaver and mature age students who comprise the nursing student body at the university. The students had either completed or were about to sit a mathematics competency test covering basic multiplication, division, knowledge of fractions, conversion of decimals and percentages to fractions, conversion of ratios to percentages, and conversion of grams to milligrams and micro grams. The mathematical knowledge base for the competency test was equivalent to Stage 4 of the New South Wales mathematics curriculum (Years 8 and 9 of high school), covered in the first year with formal drug calculations covered in the second and third years.

Materials and procedure

Two tasks (Figure 1) which are representative of the real-life problems that could be encountered by nursing students were randomly selected from a range of practice problems found in Woodrow (1998) and given to students coming to the academic adviser in the normal course of their seeking assistance in the second half of the year. The participants were asked to think aloud as they attempted to solve the problems. If they could not solve the problems, they were asked to talk about the reasons why they could not make a start or complete the tasks.

Problem 1

Neat frusemide (Lasix) is prescribed at 4mg/min for one hour. Frusemide ampoules contain 10mg/ml. The total volume for one hour will be:

a) 15ml
b) 40ml
c) 24ml
d) 60ml
e) 6ml

Problem 2

A drug infusion runs at 30ml/hr throughout 24 hours. Oral inputs are recorded as: 180, 150, 180, 90, 75, 180, 100. The overall fluid input for the whole day is:

a) 965ml
b) 995ml
c) 1855ml
d) 1275ml
e) 1675ml

Figure 1

Results

Problem 1

Only two of the eight students could produce the correct solution to Problem 1. Several students made no attempt at all to solve the problem.

Two of the NNS said the answer was 40ml.

NNS1 made the following observation:

> *I saw 10mg/ml and 4mg/min and simply multiplied.*

> NNS2 proceeded to divide 4 by 10. She then decided to change her mind and divided 40 by 10. In neither of these instances could she provide a reason.

These students obtained the answer by multiplying 4 and 10 without realising that these figures related to the mass and not volume.

NS1 commented that

> This problem was hard - we had to convert mg into mls and we had to times 60.
> I saw it as one problem and I couldn't break the problem down and may not be able to do it again even with the explanation

Problem 2

Only two of the participants could solve Problem 2. There were two incorrect responses of 1275ml. NNS2, as in Problem 1, produced a series of computations without explanation. This student multiplied 150 and 180 by 30, but could not make further progress. Here, again, the students appeared to be performing meaningless computations without any links to the solution goal. One of the NS students commented that she could not understand and that she just guessed an answer. The other two NSs did not even hazard a guess.

Discussion

The results indicate that the participants had not understood the relationships between the various elements of the problem. There was evidence of meaningless computations being performed with little concern as to the goal of the solution. The solution of Problem 1 requires that students had to work out the volume of ampoules that would contain the mass of Frusemide prescribed for one hour (240mg). It was given that 1ml of ampoule contains 10mg of the drug. Hence, the required volume of ampoule for 240mg would be 24ml. The solution is dependent on chains of proportional reasoning which students could not verbalise. The problem had to be broken down to two stages before the relevant parts could be linked. NS1 could not 'see' this part of the solution.

The key to understanding to Problem 2 was to make a clear distinction between the two modes by which the drug was being administered to the patient. That is, students needed to make sense of three notions that appear in the problem statement: 'infusions', 'oral input', 'overall fluid input'. The overall fluid input referred to the total volume. Hence the solution involves summing up the individual oral inputs (955ml), adding this to the volume given via infusion over a 24 hour period (30 x 24 = 720ml). This reasoning should produce 1675ml as the overall fluid given to the patient.

The difficulties experienced by the participants here could be attributed to several factors. Firstly, students could not articulate or even raise questions about some of the terms that appeared in the problem. Secondly, there is little evidence that students understood the context of the problem. Thirdly, there was a tendency to attempt some form of calculation with little attempt at analysing and understanding what was being asked in the problem. This pattern of results suggests firstly that nursing students who participated in the study have gaps in their knowledge of basic mathematics and secondly but equally significantly, that NS and NNS alike experienced considerable difficulty in reading and understanding elements in the problems. Malu and Figlear (1998) corroborate these latter findings in saying that word problems cause confusion for NS and NNS students alike as both groups share a lack of understanding of the words themselves and their contexts. What seems possible is that there is both a general lack of numeracy and mathematics skills (Gillies, 1994), and an inability to interpret the language of mathematics and problems with literacy in general (Rutherford, 1996).

Mature age students feel they have been 'out of the system' too long and are not confident about mathematics calculations while school leavers entering nursing often did not 'do' much mathematics in school or were not good at mathematics (Hutton, 1998a). Given that these students are all female reporting problems with mathematics, there is the added problem of mathematics being perceived as a subject girls are not good at and as a subject nurses did not need (Marr & Helme, 1990). School leavers report not being able to do calculations without calculators which are not permitted in tests because they are deemed to be '...deleterious to students' ability to estimate or approximate values of calculations' with disastrous consequences as in the case of a newborn given a dose of .09mg ICL instead of .009mg because of a calculator error (Rutherford, 1996, p.15). Errors are ascribed to nurses not being able to conceptualize the problem or conceptualizing the problem incorrectly and this applies to both NS and NNS, the latter having the added complications of a poor grasp of the socio-cultural contexts of language use (Malu & Figlear, 1998).

Malu and Figlear (1998) report that a review of the literature revealed 'scant' research on the nursing education of ESL nursing students. Their study revealed four problems that impede success for these students- language development, differing expectations of nursing education, a fear of failure and an unfamiliarity with a participatory learning model. Factual information is copied or memorized at the expense of understanding concepts and abstractions because these require more time and are harder to grasp; basic interpersonal language skills for use in daily routines are adequate but cognitive academic language proficiency needed for University is not adequate. This may account for the fact that students who come to the academic adviser for assistance and are at risk academically, may also be successfully engaged in paid employment as practicing nurses. Malu and Figlear (1998) cite examples of students who appear fluent and cope in their workplace but fail the communications component of the practical placement which forms part of their academic studies. The students reported that they suddenly forgot all their language when put under pressure of assessment in unfamiliar work environments and different social contexts. They said they often could not verbalise understanding of concepts or abstractions because they simply do not have the language to do so or they have failed to understand them in the first place.

Implications for academic skills advisors

The results of this study provide tentative support for the argument that academic skills advisors need to devise programmes and strategies to improve the linguistic competence of their nursing students with a view to building conceptual understanding of workplace problems including mathematical problem-solving. In doing so, an advisor's focus is on disentangling the various components of the concept(s) that are in question. Future research needs to provide more fine-grained analysis of mathematical representations and their linguistic contexts and of how links among the concepts and across representations are formed with a larger sample of participants. In spite of being bound to the mathematics test as used in this university, academic advisers working with nursing students, need to be aware that competency in nursing mathematics is a clinically-based skill in which practice in context is essential (Donovan 1990). Competency in nursing requires not only arithmetic but also a common sense knowledge of what is a reasonable answer for a particular patient (Coben & Thumpston 1996; Hutton 1997). Theories of learning support the need for experience and repeated exposure and nursing mathematics is no exception (Benner, 1984; Eraut, 1985; Schon, 1987). Learning opportunities in the clinical areas should be encouraged. Student nurses, especially those who have found classroom mathematics difficult, should have maximum opportunities in clinical areas to practise work-related mathematics and gain confidence and competence in its use through application.

Improving the academic success of these students is a collaborative process. Nurse educators and academic advisers working with nursing students, need to help their students explore and build language that will help in remediation of their mathematical knowledge (Flynn & Moore, 1990; Hek, 1994). While nurse educators carry the major responsibility for training nurses, academic advisors play a significant role in assessing and supporting communication skills, and devising appropriate support programs to influence the rates of success and attrition. The literature strongly suggests that support programs can greatly increase the retention of ESL students (Callister, Khalaf & Keller, 2000). Malu and Figlear (1998) propose remedial action by way of continued language development for all nursing students at risk especially because of the problems of nursing language viz. – words used interchangeably eg. 'nursing measure, intervention, order, approach'; words with dual meanings eg. 'tablet'.; words that do not always translate literally eg. 'pouring'; words that may look similar but have very different meanings eg. 'internal, interval'. While native speakers have no trouble extracting the meaning 'tablet' from the context, both groups can be confused with words like 'nursing measure', 'intervention' and 'approach'. Support programmes could provide examples of problem words and categories of these words; students could keep lists and update them; they could be encouraged to keep a vocabulary notebook or vocabulary cards that can be used to build concept maps which categorise words and connect interrelated concepts and abstractions that they find troublesome. NNS need to be given more time in exams and allowed to use bilingual dictionaries. They need to be encouraged into immersion groups for study and discussion and be involved in native speaker settings outside study.

Academic advisers may also work in other ways. They can inform lecturers on appropriate cultural orientations to enhance mutual understanding; advise on training styles that address literacy deficits and language diversity; trial and recommend software programs that enhance learning such as lecture presentation software (Gaffney, 2000) and NCLEX-RN Review software (Ross, Nice, May & Billings, 1996); assist lecturers with competency statements and performance criteria (Marrone, 1999); support students with self-directed and computer-assisted learning and electronic communication activities (Teikmanis & Armstrong, 2001); advise students on coping mechanisms, communication, effective learning strategies and tailor support programs to individual needs (Hess, 1998); mediate on matters of time extensions and exam assistance and help establish learning networks. Ultimately, the adviser seeks to help the "faculty …create a climate of caring that fosters a positive learning environment and empowers both faculty and students" (Callister, Khalaf & Keller, 2000, p.269).

Conclusion

Universities need to take up the challenge to promote traditionally vocational areas like nursing such that its graduates are capable of taking up the challenges of an increasingly complex and demanding workplace. Mathematical skill will become even more important for nurses given predicted changes in the role of nurses. Rogers (1995) proposed nurses be involved in prescribing drugs because research has shown that it results in patients receiving the drugs they need more promptly and also it greatly reduces nurses' reliance on verbal prescriptions from medical staff – a common source of error. In order to function effectively, nurses and nursing students need to develop skills in solving a range of problems. Invariably, the solution of such problems in the workplace requires that nurses are adept at applying not only elementary mathematical concepts and procedures but also applying their linguistic competence in understanding the problems. Further in-depth research is needed in order to analyse more fully the nature of the nexus between mathematical and linguistic skills in facilitating nursing students' ability at solving workplace-based problems. Recommendations are that continuing instruction in mathematics and language needs to be part of the changing nature of nursing curriculum. Faculty-based development of numeracy and literacy promotes learning as process not only as product – a necessary part of any university's overall drive towards tertiary literacy.

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