

Numeracy for Nurses: The Case for Traditional Versus Non-traditional Methods for Teaching Drug Calculation

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Two methods for teaching drug calculation were compared—one using traditional formula-based teaching methods, the other building on students' existing mathematical problem-solving skills. On the basis of quantitative measures, the formula-based approach appeared more effective. However, students' interview responses revealed that the learning experiences of the two student groups were quite different. The findings are supported by other evidence that alternative teaching methods may be more effective in increasing students' confidence, and achieving better long-term recall and transfer of skills.

The ability to calculate drug dosages is one of the most common nursing functions, but one that is potentially fraught with danger (Adams & Duffield, 1991; Rutherford, 1996). Nurses may spend up to a third of their working day involved in activities relating to medication calculation and administration (Gill & Fairhall, 1996) and are “responsible for the safe administration of medicines to patients who trust them not to make mistakes” (Dummett, 1998, pp. 58). The following problems are typical of the dosage calculations nurses must perform prior to administering medications to their patients.

An 8-year-old patient is ordered paracetamol 300 mg. On hand is Dymadon Paediatric Suspension containing paracetamol 120 mg per 5 mL. How much will you give the child?

Calculate the drip rate if 1 litre of fluid is to be administered intravenously over 12 hours. The giving set delivers 15 drops per mL.

The Problem of Calculation Error

Calculation error is a widely reported phenomenon among nurses and has been identified as a significant contributor to the overall incidence of medication error in hospitals and other health facilities. It has been linked to generally low levels of numeracy in society (Hek, 1994), particularly amongst women (Lerwill, 1999). Concern about deficits in the numeracy skills of nurses have been reported in many countries including Britain, Australia, Canada, Sweden, USA, New Zealand and New Guinea. (Cartwright, 1996; Kapborg, 1995; Reynolds & Pontious, 1986; Sullivan, 1982). Bindler and Bayne (1991) examined a number of studies and found that estimates of calculation error rates ranged from 5% to 21% of administered doses. A number of Australian studies (e.g., Gillham & Chu, 1995; Gillies, 1994; Rutherford, 1996; Santamaria, Norris, Clayton, & Scott, 1997) indicate high failure rates on dosage calculation tests amongst nursing students and registered nurses. They tested 220 high-achieving registered nurses who were short-listed for entry to a graduate nurse program at a Melbourne hospital. They found that 58% were unable to accurately calculate 11 drug dosages commonly performed in clinical practice.

Teaching and Learning Dosage Calculation in the Nursing Curriculum

Preparing nurses to become competent, confident and safe practitioners in all aspects of drug calculation and administration is seen as a priority for both educational and

employing institutions to protect patients from potentially fatal medication errors (Adams & Duffield, 1991; Miller, 1992; Sullivan, 1982). Most of the mathematical skills needed for dosage calculation are learned in the junior years of high school (Clarkson, 1990; Hutton, 1998). However some skill areas will be likely to need further development, particularly those identified by authors such as Cockcroft (1982), Hoyles, Noss, & Pozzi (2001), and Sowder and Wheeler (1989) as being problematic for many students. These include measurement concepts, units of measurement, proportional reasoning skills, and estimation skills.

Concern has been expressed by nursing educators about the apparent ineffectiveness of the methods traditionally employed in teaching drug calculation to nursing students (Worrell & Hodson, 1989), and the apparent loss of skills by students who had previously demonstrated competence (Adams & Duffield, 1991; Blais & Bath, 1992; Connor & Tillman, 1990). Rather than concluding that high error rates in dosage calculation must be due to the inadequate mathematical skills of nurses, another possible explanation may be the way in which nurses are taught to carry out calculations during their undergraduate studies (Santamaria, 1997). Widespread use of formula-based methods for teaching drug calculation skills in nursing programs is reported in Australia and many other countries (Ashby, 1997; Best & Moore, 1988; Gillies, 1994; Hoyles et al., 2001; Rutherford, 1996; Santamaria et al., 1997; Sullivan, 1982; Weinstein, 1990). An example is the ‘nursing rule’ (Hoyles et al., 2001, pp. 13):

$$\frac{\text{What you want}}{\text{What you've got}} \times \text{The amount it comes in}$$

However, just as McIntosh (1998) reports that in everyday life we use invented strategies far more frequently than written arithmetic for simple computations, experienced nurses, too, have been found to make little use of the formulae they have been taught during their undergraduate training (Cartwright, 1996; Hoyles et al., 2001). Rather, they use a range of correct proportional reasoning strategies, especially those that preserve the situational meaning of the problem (Hoyles et al., 2001). Over-emphasis on formulae and algorithms in the learning of mathematics has been identified as potentially damaging to students (Goldin, 1990), particularly if it involves rote learning which may result in them failing to memorise what appears to be meaningless information (Baroody & Ginsburg, 1990). Alternatively, according to Baroody and Ginsburg, students may memorise information incorrectly or may not be able to use their learned knowledge effectively or may not be capable of transferring it to new situations. Further, systematic calculation errors or ‘bugs’ may result from memorising incorrect or partially correct procedures. Of concern also is the likelihood that when instruction results in mathematics not making sense, students may cease to monitor their calculations thoughtfully (Baroody & Ginsburg, 1990) and may blindly accept results (Usiskin, 1998). They may abandon common sense and fail to draw on their own practical knowledge (Baroody & Ginsburg, 1990)—a phenomenon noted amongst nursing students who sometimes give clearly unreasonable answers to dosage calculations (Gillies, 1994).

Contemporary perspectives on how students learn mathematics have focussed on the view that students construct mathematics through their own experiences, as opposed to mathematics being an independent body of ‘truths’ or an abstract set of rules, learned through imitation and reliance on the rote use of algorithms (Goldin, 1990). The shift in focus in mathematics learning has been described by Schoenfeld (1992, pp. 335) as:

seeking solutions, not just memorising procedures;
exploring patterns, not just memorising formulae;
formulating conjectures, not just doing exercises.

The importance of learning mathematics with understanding is also widely accepted within the mathematics community because mathematics that is understood will be more easily remembered and more easily transferred to new situations (Hiebert & Carpenter, 1992). In the nursing literature, several authors (e.g., Best & Moore, 1988; Segatore, Edge, & Miller, 1993,) have advocated a shift away from traditional practices for teaching drug calculation skills, particularly those methods that rely on rote learning and procedural application of formulae. However, there is little evidence of research focussed on investigating how successful alternative strategies might be, or finding strategies that might result in better long-term retention and transfer of nurses' drug calculation skills.

This paper reports on aspects of a study (Gillies, 2003) that attempted to redress the paucity of research into alternative methods for teaching drug calculation. The study responded to the challenge of abandoning the use of formulae, instead focusing teaching efforts on developing students' proportional reasoning skills, as advocated by Segatore et al., (1993). While an overview of the broader study is provided, the primary focus of this paper is on those outcomes relating to the learning experiences of students. The aim of the study was to compare the effectiveness of two different methods for teaching drug calculation—the first following the traditional practice of using specialised formulae; the second based on the following objectives and principles: the goal of providing students with appropriate learning experiences, aware that they construct their own knowledge; the belief that learning is more successful when new knowledge is integrated with existing knowledge, thus strengthening connections between concepts and information; that learning mathematics with understanding is more likely to result in achievement in mathematical tasks. The following research question was formulated. Which approach is more effective in developing students' drug calculation skills:

an approach based on learning and applying specific drug calculation formulae, in accordance with traditional nursing education practices, or
an approach that emphasises the similarities between dosage calculation and everyday mathematical problems, draws on students' existing mathematical problem-solving skills, and gives students the freedom to explore different solution methods and to use their method of choice?

Methodology

Participants

A total of 69 students volunteered to participate in the program—all recently enrolled students in the first-year of the Bachelor of Nursing Program at the University of Technology, Sydney. Participants were assigned to two groups—the 'formula group' and the 'problem-solving group'—on the basis of their availability around their regular program of lectures and tutorials. Only 19 of the participants completed all requirements to qualify for inclusion in the study—twelve from the formula group and seven from the problem-solving group. All students were female except for one male in the formula group.

The Teaching Intervention

The teaching intervention comprised weekly, two-hour sessions conducted over a four-week period. The content included calculation of oral medications in solid and liquid form,

volumes for injection, and calculations relating to intravenous infusions. Some program content was common to both groups, including instruction in arithmetic processes, metric units and conversions, and estimation and checking strategies. Students were required to perform all calculations without the aid of an electronic calculator, in keeping with the policy of the University's undergraduate nursing program at the time.

The formula approach involved providing students with the relevant formula for each problem type, demonstrating its use, and then working through practice problems. The problem-solving approach sought to explore students' existing problem-solving skills through sheets of 'everyday problems'. The problems were designed to parallel typical drug calculation problems but were set in everyday contexts. Through class discussion students were encouraged to suggest different approaches that might be used for solving the problems. After working through each sheet of everyday problems in this way, students then applied their preferred techniques to the corresponding set of drug dosage problems.

Instruments

Data collection occurred at three points. Prior to the teaching intervention, demographic data were collected via a Student Survey; Aiken's (1979) Attitude to Mathematics Survey was administered; students completed a pre-test (Proportional Reasoning Test); and participants' scores on a previously administered Maths Diagnostic Test were extracted from the results for the entire cohort. At the end of the final session, students completed a Program Evaluation and a post-test (Drug Calculation Test). During several weeks following the teaching intervention, each student included in the study was interviewed by the researcher to obtain their perceptions about their learning and the effectiveness of the program they attended. The PRT (pre-test) and DCT (post-test) were designed to parallel each other, each comprising 10 items and requiring identical arithmetic operations involving identical numbers, and similar unit conversions. The PRT problems were set in everyday contexts while the DCT comprised typical dosage problems.

Results and Discussion

Analysis of students' performance on the two tests—the PRT and the DCT—indicated that the learning gains made by students in the formula group were greater than those made by the problem-solving group. This result suggested that the application of formulae was a more effective way of performing drug calculations than allowing students to employ their method of choice from the various problem-solving methods explored in class by the problem-solving group. This finding is in keeping with the assertions of Gould (1996) that methods that rely on rote learning and memorisation are appealing because of their apparent success in achieving the goals of learning—at least in the short term.

Students' responses to the Program Evaluation, indicated that students in both groups liked the method they were introduced to. On the basis of the quantitative measures, the conclusion reached was that the formula approach, as it was taught in the program, was more highly favoured by participants than the problem-solving approach. Students' responses on all but three of the twelve Likert-type items favoured the formula approach. Students' ratings indicated that the formula method was perceived to be more effective in terms of students' understanding of the steps in the calculation, and as a way for them to remember how to perform drug calculations in the future. By contrast, there were three items in the Program Evaluation that favoured the problem-solving approach. The problem-solving method was favoured in terms of: how much students felt they had

learned during the sessions; the extent to which students' confidence in their drug calculation ability had developed, and the level of confidence students felt in terms of whether their calculations would result in correct answers.

The interview data provided a different view of the effectiveness of each of the two teaching approaches. Students' responses to interview questions provided insights into their affective responses to the teaching methods that were not evident through quantitative measures. It was apparent that the two different approaches to teaching drug calculation had resulted in two quite different models of learning.

Two Different Models of Learning

Problem-solving Group: A model of Personal Growth and Confidence Building. For the problem-solving group, the pattern of learning that emerged was characterised by a cycle that commenced with freedom to select a problem-solving method of their choice. Students reported that this led to a sense of control over, and understanding of, the calculation process they engaged in. A feeling of personal satisfaction and achievement flowed from each correct answer obtained, together with a feeling of increasing expectation that their answers would be correct. Students' increasing sense of confidence in the accuracy of their answers was significant because they believed that correct answers would ensure their patients' safety—a goal of great importance to them. In short, the nature of learning that occurred among students in the problem-solving group was characterised by a cycle of personal growth and confidence building, a cycle evident in the following explanation given by Tammy (not her real name).

It was good because it was my choice, basically. And if you're doing something, you get a satisfaction out of doing it your way instead of somebody else's way. ... It's satisfying doing it the way that you understand best, ... because you know what you're doing; you have more knowledge. It makes you feel better about yourself and you feel more confident that you've got the right answer, which is very important. You have got to get it right, no matter what. Just one little stuff-up and somebody is gone.

There were also indications at the end of the teaching trial, that students in the problem-solving group displayed more positive attitudes to mathematics and to drug calculation. They reported feeling less fearful than they had earlier felt about this aspect of the nursing curriculum. Responses such as Tammy's illustrate the reciprocal effect that exists between achievement in mathematics and affective factors such as attitude, self-concept and anxiety (Relich, Way & Martin, 1994; Spielman, 1999; Wong, 1992).

Formula Group: A Deficit Model. By contrast, students in the formula group reported that the availability of formulae was a good way of overcoming their own inadequacies and deficiencies in mathematics. It was perhaps not unexpected that students should have a preference for developing procedural understanding because it is less demanding cognitively than developing conceptual understanding and offers more immediate rewards (Gould, 1996). The comfort students drew from the perception that a formula would save them from having to think very much was evident in Melika's explanation of why she was a "big fan of formulae":

It takes away a little of that thought process. ... You put the numbers in these places, turn the handle, and the answer comes out.

The mindless calculation process that may accompany formula use, which attracted Melika, has been reported by authors such as Usiskin (1998). Usiskin also notes a tendency for students to unquestioningly accept answers obtained through rote learning and formula

use. Students' explanations of why they liked the formula approach revealed many negative perceptions about their own competence and confidence in performing mathematical tasks. Students explained that they relied on formulae because they "were not very good mathematically" or "didn't have the know-how to do things without a formula" and it gave them a sense of security and comfort. Some students viewed formulae as a crutch that made the calculation easier by giving them a guaranteed "first step". Without a formula they "wouldn't have any idea where to start"; they certainly "couldn't develop (their) own formula", indicating that students may believe a formula is essential for every calculation.

There was evidence that, amongst students in the formula group, the type of learning that occurred was procedural learning—the type of learning typically associated with rote procedures and memorisation (Skemp, 1986). By contrast, for students in the problem-solving group who were exposed to a range of different problem-solving methods, their descriptions indicated that the type of understanding they developed was more closely aligned with conceptual understanding. This has important implications for the retention, recall and transfer of nurses' drug calculation skills. Long periods of time may elapse between occasions when a particular type of calculation is needed (Cartwright, 1996). Nurses also need to be able to apply their skills to varied situations in clinical practice that may not be overtly similar to what they have encountered before either during training or in clinical practice (Gillham & Chu, 1995). Wide variations in the ages of patients, medical circumstances, vulnerability of patients, and types of drugs prescribed call for a high degree of flexibility amongst nurses in applying their drug calculation skills. Conceptual understanding has been found to be more likely to lead to the development of skills that are robust and flexible, thus enabling nurses to recall their skills when needed and apply them confidently, especially in unfamiliar situations (Hiebert & Carpenter, 1992).

Conclusions and Implications for the Teaching of Drug Calculation

The limitations of the study—particularly the short duration of the teaching intervention and the small sample size—did not allow firm conclusions to be reached. The present study demonstrated how appealing formula-based methods may be to students because learning by such methods appears quicker and easier (Gould, 1996). However insights were also gained into how alternative methods for teaching drug calculation, such as those proposed by authors such as Segatore et al. (1993) and Best and Moore (1988), might lead to greater success in the long term, particularly in respect of raising nurses' confidence levels, as well as promoting better recall of skills and the ability to transfer skills to a range of different clinical situations. One of the disadvantages of using a teaching approach that focuses strongly on development of understanding is that more time is needed for students to develop this type of learning, in comparison to methods based on rote learning and memorisation and little understanding (Gould, 1996).

The findings reported highlight the need for further research focussing on the long-term effectiveness of different teaching methods. Specifically, there is a need to compare, through a longitudinal study, the effects of teaching method on: the subsequent ability of nurses to recall their drug calculation skills; nurses' ability to successfully transfer their skills to different and unfamiliar clinical situations they may encounter in professional practice; development of nurses' confidence in their drug calculation ability.

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