INCOMPLETE OR INCORRECT UNDERSTANDING OF DECIMALS: AN IMPORTANT DEFICIT FOR STUDENT NURSES

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In this study more than 40% of the 355 student nurses who completed a pre-test, involving comparisons of decimal numbers, made errors that indicate an incomplete or incorrect conceptual understanding. This includes students who are sometimes able to achieve 100% on drug calculations tests. Seven test items with error rates of between 10% and 26% form the focus of our discussion. A sub-group of the students attended a one-hour remedial intervention using various physical materials to give conceptual meaning to decimal numbers. A matched post-test three months after the intervention, detected a statistically significant improvement for the intervention students but not for those who only practiced drug calculation procedures. Conceptual teaching for number sense is needed to underpin procedures.

INTRODUCTION

“Baby died after ‘decimal’ error.” This sensational BBC headline (BBC, 2005) serves to remind us of the everyday importance of competency in decimal calculations. In many occupations ‘getting it right’ most of the time is not good enough. As will be illustrated below, nurse educators are well aware of the responsibility that their students have to correctly interpret data and perform error-free calculations. In recognition of this, student nurses are commonly expected to achieve high scores, even 100%, on drug calculations tests (Sabin, 2001). However, a search of the literature strongly suggests both teaching and testing of drug calculations to nursing students assume conceptual understanding of decimals and consequently focus on calculation procedures.

In this paper we report the results of testing a cohort of Australian undergraduate nursing students for their conceptual understanding of decimal numbers, providing remedial teaching for some and then post-testing all of the available students. We contend that a significant percentage of these adult students have either incomplete or incorrect understandings about the decimal number system which will make it difficult for them to acquire procedural skills (such as drug calculations) with any understanding. They must then rely on memorizing a series of routines, which seem meaningless to them and which under the ‘wrong’ circumstances will result in error. Teaching interventions for these students need to address their fundamental understanding of decimals. In the next section of this paper we will consider the background literature both in terms of previous studies of nurses’ numeric skills as well as the diagnosis of misunderstandings of decimal notation in general. This will be followed by an outline of this study and intervention, an analysis of some of the key results and finally some recommendations.

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BACKGROUND

Studies of drug errors made by nurses have shown that one of the main sources of error is mathematical incompetence when determining the dose of a drug to be administered. Deficiencies have been identified in graduate and student nurses' basic computational ability with decimals, fractions, percentages, and ratios; see for example, Grandel-Niemi, Hulpi & Leino-Kilpi (2001), Hughes & Edgerton (2005), Sabin, (2001). This problem has been attributed to limited preparation of, or support for, nursing students who need to develop their numeracy skills (Sander & Cleary, 2004). Many studies focus on drug calculation skills and have identified common errors such as misplacing the decimal point (Hughes & Edgerton, 2005, Lesar, 2002). Lesar detected 200 cases of tenfold prescribing errors in hospitals over an 18-month period, with over-dosing cases (61%) outnumbering under-dosing cases. In reviewing the cause of tenfold medication errors, misplacement of the decimal point dominated other reasons (43%) followed by the practice of adding an extra zero (for example 5.0 rather than 5) or omitting a zero (for example .5 rather than 0.5). In both of these cases a faint decimal point may be overlooked. In addition, Hughes and Edgerton (2005) noted that the problems with miscalculations are due to "the inability to conceptualize the right mathematical calculations to be performed and understand the mathematical process leading to the solution", (pp. 81-2). Despite extensive literature demonstrating problems in nursing students' mathematical skills, we found few studies that even refer to the issues of students' *understanding* of the underlying mathematical principles and concepts behind the required calculations.

The task of comparing decimal numbers has been demonstrated to be a powerful tool to identify students with an incomplete or erroneous *conceptual* understanding of decimal numbers. Over the last two decades, researchers in various countries have used this task with students of varying ages to diagnose such misunderstandings. In Australia, for example, Steinle (2004) reported on the results of a longitudinal study involving several thousand students aged 10 to 16 years with such a diagnostic test. Stacey, Helme, Steinle, Baturo, Irwin and Bana (2001) used a similar test with over 500 pre-service teachers in four universities from Australia and New Zealand. Steinle and Stacey (2001) reported on a similar test with school students in Japan. Peled (2003) also used the task of decimal comparison as a diagnostic tool with 7th and 8th grade students in Israel.

We wish to use this well-established decimal comparison task to determine the extent of such problems within a sample of student nurses, both before and after a brief intervention designed to improve their conceptual understanding of decimal numbers.

METHODOLOGY

This study was conducted with nursing students at an Australian university where the student nurses must attain 100% on a drug calculation test by the middle of their second year and maintain this skill level through to graduation. In March 2005, we pre-tested 355 of these undergraduate nurses using a Decimal Comparison Test (DCT3a) based on the test reported by Steinle and Stacey (2001). The pre-test consisted of 30 items (pairs of decimal numbers) with the instruction *"For each pair of numbers, EITHER circle the larger number OR write = between them"*. The test was administered in the first ten minutes of a core subject lecture for each of years one to three and their results were posted on year level notice boards. Rather than a score being recorded next to student identification numbers, a diagnostic code was provided which classified any error patterns. Next to the results was an explanation of these codes and details regarding a free remedial session open to any nursing student.

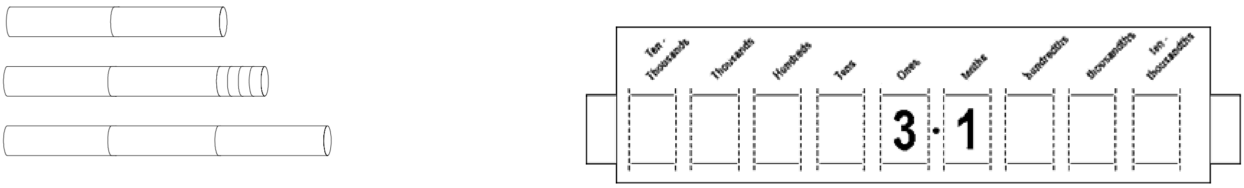
Errors were identified for 109 students but only 13 students chose to attend a one-hour remedial intervention workshop in April. As a consequence of this low uptake, the decision was made to repeat the intervention in the first lecture of 'Statistics for Nursing Research', a course taken by some first and most second year students.

The remedial intervention, conducted by members of the research team, was constrained to a one-hour interactive lecture because, if adopted, such teaching would be an addition to an already crowded nursing curriculum. After illustrating the importance of decimals for nurses and providing reassurance that such problems are reasonably common, we explained that the tests revealed their difficulties with various items: items containing zero as a digit as well as zero as a number, decimals with repeated digits and decimals which are the same in the first two places. The teaching intervention therefore focussed on these items.

We began by demonstrating and then having the students join in the construction of physical representations of each number using Linear Arithmetic Blocks (LAB). As illustrated in Figure 1a, LAB allows the representation of decimals by length and encompasses measuring with different degrees of accuracy.

This was followed by more abstract representations such as the number slide shown in Figure 1b. A number slide is a powerful visual reminder of how the digits in a number move into the next largest place value column when a number is multiplied by 10, and move into the next smallest place value column when a number is divided by 10. Note that the intervention was designed to increase students' conceptual understanding of decimal numbers and did not promote any specific procedures for comparing decimal numbers (such as examining digits from left to right).

A post-test containing 30 matched (and reordered) items was created; see Stacey and Steinle (submitted) for full details. A total of 256 students from the three year levels completed this post-test administered 12 weeks after the remedial intervention. A survey was included with the post-test, which asked students to indicate whether they had participated in our remedial intervention or spent any other time specifically working on decimals. Those who attended the intervention were also asked to give written feedback.



a) Comparing 2 tenths (0.2) with 2 tenths and 4 hundredths (0.24) and 3 tenths (0.3)

b) Number Slide

Figure 1: Representations of decimal numbers with LAB and Number Slide

Of the 355 students who sat the pre-test, 199 also sat the post-test. About half of the students who completed both tests achieved full marks on both occasions, and hence contribute no further data to this study. The key group of students of interest for this paper are the 96 students who sat both tests; made some errors; and furthermore completed a survey that indicated whether or not they took part in the intervention.

RESULTS AND DISCUSSION

Table 1 indicates that 56% of the 355 students overall made no errors on their pre-test. There is some variation by year level, but, despite their prior achievement of 100% on at least one (if not two) drug calculation test(s), only 70% of the year 3 (final year) students completed the decimal comparison test without any errors.

Year	Total number of students	Number (percentage) of students with no errors	
1	127	65	(51.2%)
2	110	52	(47.3%)
3	118	83	(70.3%)
Overall	355	200	(56.3%)

Table 1: Number and percentage of students with no errors on pre-test by year level.

A full analysis of the difficulty of individual items on the pre-test is provided by Stacey and Steinle (submitted) but for the purposes of this paper, a brief analysis follows. Of the 30 test items, 23 items had error rates of less than 5%. In fact, the mean score for the students on these 23 items was 22.6, so these items presented almost no difficulty for these students. The remaining seven items, however, had error rates from 10% to 26%; see Table 2 for details. (Note that on the test paper, the number pairs are presented horizontally, but for reasons of space, they are listed here vertically.) The subsequent sections of this paper focus on these seven items.

Item #	Q9	Q10	Q19	Q20	Q26	Q29	Q30
Number Pair	17.35 17.353	4.666 4.66	4.4502 4.45	3.7 3.77777	0.8 0.80000	0 0.6	0.7 0.00
Error Rate (n=355)	18%	26%	19%	25%	10%	15%	10%

Table 2: Error rates on seven items on pre-test.

Research had previously identified such items as causing difficulty for adult students. As mentioned earlier, these can be described as items that contain:

- zero as a digit (Q26);
- the number zero (Q29 & Q30);
- decimals with repeated digits (Q10 & Q20); and
- decimals which are the same in the first two places (Q9 & Q19).

The error rates on Q29 and Q30 are consistent with those found by Stacey et al (2001); here 16% of nursing students made an error on at least one of these two items compared with 13% of the pre-service teachers on three similar items. Furthermore, the high error rates on Q9, Q19, Q19 and Q20 are consistent with findings by Steinle and Stacey (2001).

As mentioned earlier, the students of interest in this study were those who completed both tests; made at least one error; and provided information in the survey that allowed us to identify students who had taken part in the intervention. Table 3 contains the mean pre- and post-test scores on the seven difficult items (listed in Table 2) for the 40 students who were involved in the intervention, as well as the 56 students who were not.

	Pre-test Mean (SD)		Post-test Mean (SD)		Improvement	t-test
Intervention (n=40)	4.5	(1.9)	5.6	(1.7)	1.1	p=0.008
No intervention (n=56)	4.9	(2.0)	4.8	(1.8)	-0.2	p=0.561

Table 3: Mean pre- and post-test scores on 7 items for 2 groups of students.

So, while the mean scores of the students in the intervention increased by 1.1, (statistically significant at the 0.05 level using a 2-tailed t-test), the mean scores for the non-intervention group decreased slightly (although not significantly).

An alternative analysis also provides evidence of improvement due to the intervention. Consider only the students who made some errors on the pre-test. Table 4 indicates that while 46% of such students in the intervention group made no errors on the post-test, only 23% of the non-intervention group did so. Furthermore, for the

19 intervention students who did make errors on the post-test, the average improvement was 1.5, compared with -0.2 for the 31 non-intervention students. Hence, the one-hour intervention resulted in increased test performance 3 months later.

	Pre-test: Number of students with errors	Post-test: Number (%) without errors		Post-test: Number (%) with errors	
Intervention	35	16	(46%)	19	(54%)
No intervention	40	9	(23%)	31	(78%)

Table 4: Proportion of students with and without errors on post-test.

We acknowledge, however, that factors other than the intervention may have impacted on the students' understanding of decimals between the pre- and post-tests. For example, 45 students indicated on their survey that they had used the procedurally-focussed Nursing Calculations CD-ROM recommended by their teachers. The authors of this resource claim: "This nursing calculations CD-ROM comes with a very comprehensive set of notes that are built into the program that will teach you how to carry out all the relevant mathematical procedures with many worked full examples." The mean improvement for these 45 students on the 7 difficult items was 0.7 (SD 2.4). An Analysis of Variance test was performed on the change in score for the 7 difficult items, in order to distinguish between the effects of the two factors: intervention and use of CD-ROM. The results suggest that the intervention was a significant factor (p=0.017) while use of the CD-ROM was not (p=0.324). The interaction between the intervention and use of CD-ROM was also not statistically significant (p=0.334).

Ideally the remedial intervention would be conducted as a workshop for those students who have been identified as having any difficulties, but constraints on this study meant that for many students it was conducted in a large group lecture. However, 40% of all students who attended an intervention and completed a survey (in fact, all 7 students who attended the workshop intervention and who completed a survey) reported that this teaching had changed their understanding of decimals.

The researchers observed a powerful and often verbalised 'ahha' response from students. During the workshop session students discussed their previous thinking and made the following comments:

- Student A mentioned thinking of decimals as being like negative numbers: 'when using a number line, decimals, are going the other way'.
- Student B said that her problems were with the repeating decimals. After the first digit after the decimal point she just 'cut' the rest of the digits, hence thinking 3.77777 as being the same as 3.7.
- Student C said she had difficulty deciding whether a blood alcohol reading of 0.12 was over the legal limit of 0.05 for driving

Students were positive about each of the learning materials used but especially the physical representation provided by LAB (see Figure 1a). All of the workshop group and some students from the lecture group were so pleased and excited by their new understanding that they made the unusual gesture of thanking the teachers at the conclusion of the session.

CONCLUSION

Nurse educators recognise the importance of correct computation and interpretation in nursing calculations and fortunately most nursing students deal competently with decimals. Nurse educators report, however, that some students resit their drug calculation tests many times before they achieve 100% and then cannot repeat this score in subsequent tests. This study indicates that a significant number of students harbour fundamental misunderstandings of decimal numbers which are not identified by procedurally-focussed competence tests on drug calculations. These misunderstandings may lead to calculation and interpretation errors even when students follow correct procedural routines for nursing calculations. The lack of improvement on the post-test for students who used the Nursing Calculations CD-ROM suggests that such lack of conceptual knowledge is not remedied by procedural practice. The conceptual teaching in the one hour remedial intervention conducted in this study did produce both practically and statistically significant improvement.

The diagnostic results of this study, consistent with Stacey et al's (2001) earlier work, suggest that, for vocations where numeric accuracy has public importance, testing of adults should include conceptual items. Those students who have problems in this area should be required to participate in suitable conceptual remediation in addition to the procedurally-focussed teaching currently recommended in the literature. The use of concrete materials such as LAB and number slides is intended to increase conceptual understanding and not merely provide students with another routine procedure to follow. This should result in the long-term gain of increasing students' number sense, enabling them to make sense of the calculations, estimations and comparisons they will be faced with on a daily basis.

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