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A NOVEL VISUALLY-DISPLAYED TEST FOR ASSESSING NUMERICAL SKILLS IN PHARMACY UNDERGRADUATES

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Abstract

Diagnostic tests for students entering pharmacy degree programmes are usually written tests; however, these may not always give an accurate reflection of students' ability to deal with simple problems that test basic numerical skills in a defined period of time. An MS PowerPoint-based test comprising 30 questions presented in a timed sequence was developed. The questions ranged from simple multiplication to more complex problems involving calculations of concentration and were presented to first year pharmacy undergraduates at two institutions. The results showed that although the majority of the students from both institutions were able to answer simple arithmetic questions correctly, they performed less well on questions involving fractions, powers of ten, multistep calculations and calculations of concentration from text-based problems. This test highlights the types of problems students find difficult to solve and, serves as a useful diagnostic tool enabling a more targeted approach to teaching.

Keywords: *diagnostic assessment, numerical skills, pharmacy undergraduates.*

Introduction

It is essential that healthcare professionals who are involved in the administration of medicines to patients are both competent and confident in performing calculations. It is widely accepted that medication errors often arise from a miscalculation of drug dosage, that the problem is worldwide and is not confined to one particular group of healthcare professional.

In the UK, the death of a baby following the administration of peppermint water that was 20 times too concentrated (The Pharmaceutical Journal, 1998; 2000) called into question the standard of numeracy amongst pharmacy students. The Royal Pharmaceutical Society of Great Britain subsequently introduced the requirement that students must pass a calculations element of the registration examination with a minimum score of 70% and that the examination must be undertaken without the aid of a calculator. In the intervening years studies have been undertaken to examine numeracy in pharmacy undergraduates and the approaches that might be taken to increase their proficiency in this core skill. In a seven year study carried out by Malcolm and McCoy (2007), students were tested on entry and again after a basic numeracy course in the first term. They showed that initial mean scores decreased year on year (54% in 1999 to 40% in 2005) despite increased entry qualifications but that a more acceptable score (~ 70%) could be achieved in all years following numeracy support in the form of workshops and on -line directed study. Very similar findings were reported by Batchelor (2004) in a single cohort at another school. Interestingly, Sharif et al. (2007) found a relatively consistent level of performance (~60%) on entry at another school over the period 1999–2005. Regardless of this difference, all stressed the importance of diagnostic testing in numeracy in order to identify weaknesses and to support student learning.

With the increase in student numbers and those entering pharmacy degree programmes with non-standard qualifications, the major issues for those involved in teaching calculations is what knowledge and/or understanding can be taken for granted and at what level should teaching begin. The quotation by Ausubel (1968) cited by Batchelor (2004) "If I had to reduce all of educational psychology to just one principle, I would say this: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" exemplifies this precisely. Current entrance requirements for pharmacy

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include a minimum of a C grade pass in General Certificate of Secondary Education (GCSE) mathematics or equivalent. Few schools of pharmacy specify the need for A level mathematics but all require A level (or equivalent) chemistry, usually at grade A or B. It is assumed that these requirements are sufficient to ensure that students are proficient in basic concepts in numeracy and will be able to apply them appropriately. However, in the experience of the authors, and one expects the many of those in pharmacy education, this is not the case for all students.

Aims of the study

Our aim was to devise a simple diagnostic test that focused on basic numerical skills in order to separate fundamental arithmetic processes from other issues, such as the use of units and solving text-based problems, so that specific difficulties could be identified. We also wished to develop a test that was not paper-based, included the element of time limitation in solving problems and could be presented easily to an entire cohort of students.

Method

A test was developed using MS-PowerPoint that consisted of 30 questions which were displayed for a specific length of time for students to calculate an answer. The questions included simple multiplication, conversions between decimals and fractions, powers of ten, and calculation of concentration. The test was piloted amongst members of the faculty at one institution. This allowed adjustment in the length of time the questions were displayed so that most completed the test with all of the questions answered correctly. The final timings ranged from 3 seconds for the multiplication of two numbers to 20 seconds for text based problems. The test was presented to an entire cohort of first year MPharm undergraduates in two institutions n=118 and n=133, respectively. In the student trials, the displayed questions were followed by a blank screen for 4 seconds. Students were given a sheet with 30 numbered spaces and instructed to write an answer. Calculators were not permitted. Answers were scored as follows: correct (3), incorrect (-1), no answer (0). The questions used are shown in Table 1 as are the broad categories into which the questions were grouped.

Question	**Problem**	**Category**
1	6x5 =?	Simple multiplication (numerical)
2	A tablet dose is twice daily. How many tablets should be given for 7 days?	Simple multiplication (text)
3	$\frac{45}{9}$	Simple division (numerical)
4	5+6+8=?	Simple addition (numerical)
5	$\frac{3}{6} = \frac{?}{10}$	Simple fraction (numerical)
7	If a solution contains 1 µg / mL. How many grams are contained in 1 L?	Concentration (text)
8	Express final answer as a decimal $\frac{3}{6} + \frac{1}{4} = \frac{?}{?} = ?$	Conversion of fractions to decimal
9	Express this fraction as a decimal. $\frac{5}{15}$ =?	Conversion of fractions to decimal
10	What is the value of y when x is 8?	Interpretation of graphs
11	Answer as a decimal. $\frac{7}{(6+8)}$ =?	Conversion of fractions to decimal
12	$2 \times 10^2 \times 2 \times 10^4$ = ?	Powers of 10 multiplication
13	You have a 50% w/v solution. You need a 5% w/v solution. How many ml do you take to make 20ml?	Concentration dilution (text)
14	9x8=?	Simple multiplication
15	Round this number to 2 decimal places: 8.637854	Decimals.
16	How many grams are contained in 50ml of a 5% w/v solution?	Concentration (text)
17	Answer as a decimal: $\frac{3}{(8+2)}$ = ?	Multi-step decimal
18	The atomic weight of Ca is 40. The atomic weight of Cl is 35.3. What is the molecular weight of $CaCl_2$?	Addition (text)
19	What is the approximate value of: $\frac{(16,276 + 3,907)}{4.1}$ = ?	Multi-step arithmetic estimation
20	The molecular weight of drug x is 397.5 How many grams do you need to make 100ml of 0.1 mol solution?	Concentration (text)
21	Express as a power of 10 ($a \times 10^b$) 0.005=?	Powers of 10

23	Express result as a decimal $\frac{4.8}{3}$ =?	Decimal Division
24	$\frac{(4.8 \times 10^8)}{2}$ = ?	Power of 10 division
25	Which is the largest volume? 4740ml 4.0L 4.2×10^3 ml	Conversion of units
26	$\frac{\sqrt{36}}{2}$ =?	Multi-step division
27	$\frac{2x}{4} = 2$ What is x?	Simple algebra
28	2.1 + 1.9 =?	Simple decimal addition
29	$(2^4 \div 4) + 4$ =?	Multistep indices
30	A patient requires 5 ml of linctus a day. How much should be dispensed for a supply of 4 weeks?	Multiplication (text)

Table I. Diagnostic test. Each question has been assigned to a category of the numeracy skill tested.

Results and Discussion

The diagnostic test was presented to the first year cohorts in two schools of pharmacy. Students at one school performed significantly better (59% answered all questions correctly compared to 31% at the other) than those at the other, however, for the purposes of this study the mean scores for each question were taken. Figure 1 shows that students were able to give the correct answer to questions that involve simple addition, multiplication and division.

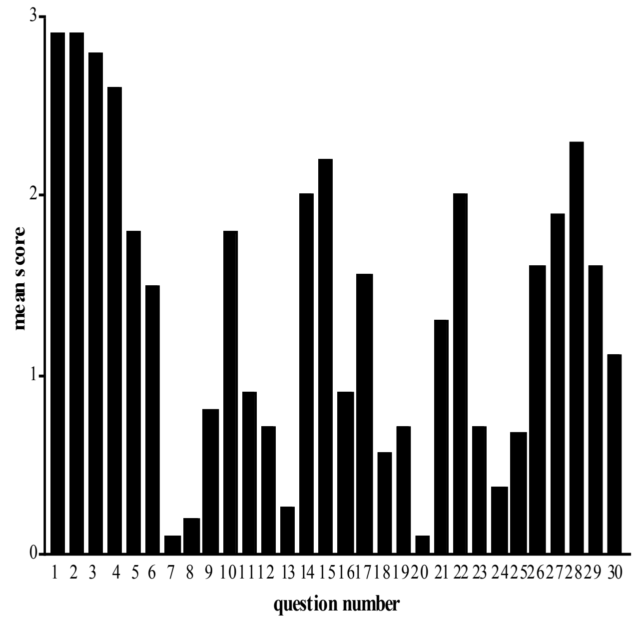

Figure 1. Mean scores for all diagnostic test questions from two institutions.

Given that the majority of questions in the test are based upon basic concepts, we were interested to see if there was a correlation between performance and where students undertook their primary school education. We found that many students had initially studied overseas before completing their secondary education in the UK. There was, however, little difference between those educated at primary school in the UK and those overseas, with 48% and 42% of each group answering all questions correctly. We further subdivided these groups into broad geographic areas: European Union, Indian Subcontinent (India, Pakistan, Bangladesh and Afghanistan), Africa, Middle East (Iran, Iraq, Saudi Arabia, Arab Emirates, Gulf States and Turkey), North America (USA, Canada and the Caribbean) and the Far East (China, Hong Kong, Macau, Malaysia, Singapore and Korea). Figure 2 shows that there was little difference in performance between the EU, UK, Africa and Middle East groups with approximately 45-55% of students answering all questions correctly.

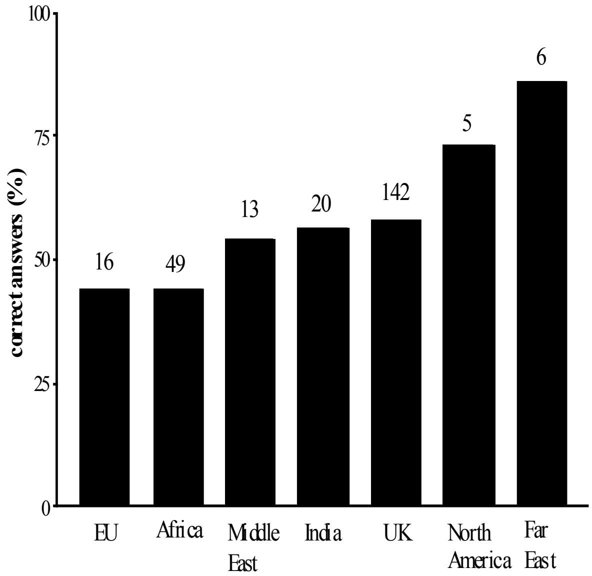

Figure 2. Percent correct answers scored by students educated at primary school level in the broad geographic areas indicated. The number of students in each group is shown above the bar.

The best performance was from students educated in North America and the Far East who scored over 70% and 80%, respectively. Whether this is reflective of a more traditional approach to teaching numeracy at primary school level in some areas, particularly the Far East remains to be established.

It is evident that many students had difficulty in answering questions involving concentrations and dilutions, powers of ten, fractions and decimals, conversion of units and multi-step arithmetic. In order to investigate this further, we determined the proportion of students who answered a question but failed to answer it correctly and those who did not attempt to give an answer (Figure 3).

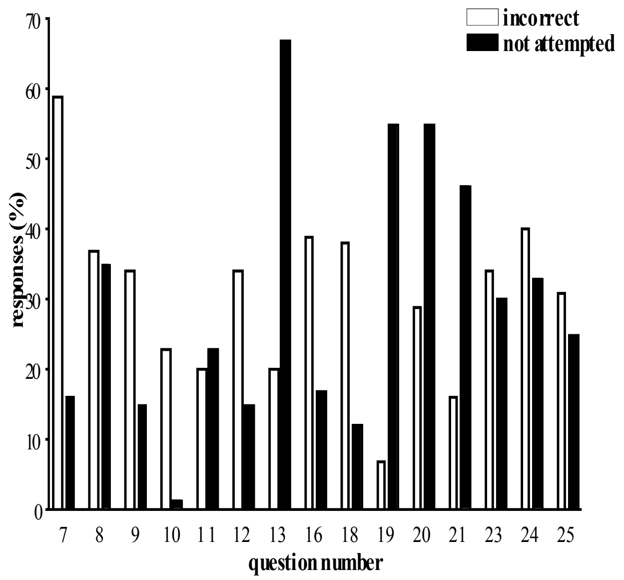

Figure 3. Percent of students giving incorrect answers or failing to answer particular questions in the test.

In some cases (questions 8, 11, 23, 24 and 25), the proportion of students who answered incorrectly or failed to give an answer were essentially the same. Interestingly, all but one of these questions involved fractions and the conversion of fractions to decimals. We found that there was a marked difference in the way students responded to other questions. For questions 7, 9, 12, 16 and 18, 40-60% of students attempted to give an answer but answered incorrectly. In this case, there was no clear trend in the type of question involved. In contrast, the 50-70% of students failed to attempt questions 13, 19, 20 and 21. Looking at these questions in more detail revealed some worrying trends. Question 7 requires an understanding of units. It is clear from the results in Figure 3 that almost 60% of students answered this question incorrectly but only 16% failed to give an answer. This suggests that the majority of students had sufficient confidence to calculate an answer, presumably because they understood what was required to solve the problem even if they were unsuccessful in doing so. Invariably, the answers were incorrect by a factor of ten, a problem that was identified amongst pharmacy students a decade ago (Nathan, 2000) and clearly remains an issue. In response to questions 19, 20 and 21 over half failed to give an answer, this increased to almost 70% for question 13. This might be expected in the case of question 13 due to many being unfamiliar with the units (% w/v) used, indeed previous studies have identified this as being the case amongst pharmacy students (Malcolm and McCoy, 2007) and even practising doctors (Wheeler et al., 2007). Question 19 is a simple estimation and perhaps suggests an over reliance on the use of calculators. The result for question 20 was somewhat disappointing given that it is a relatively simple calculation of molar concentration that relies on knowledge that should have been gained in GCSE chemistry. Our experience of teaching in classroom and laboratory settings indicates that many students prefer to use formula to solve such problems without understanding the basic principles of a molar concentration and thus being unable to recognize that this question can be solved simply by dividing the molecular weight by 100. Question 21 required an understanding of index notation and integer powers, an area others have reported students to have difficulty with (Malcolm and McCoy, 2007).

A recent survey by one of us (G. Hitch, unpublished) has shown that the teaching of pharmaceutical calculations is now firmly embedded in the curriculum at the majority of UK schools of pharmacy. Increasingly, diagnostic testing on entry is becoming the norm, but the question of the level at which the test should be pitched remains unresolved. The published diagnostic tests are based largely on material covered at GCSE and above, yet it was recognised some years ago that students taking GCSE mathematics will not necessarily have achieved the skills necessary to undertake degree programmes in which numeracy is of vital importance (Engineering Council, 2000; Haigh, 2002; Tariq, 2002). Our results suggest that testing on entry to pharmacy may need to focus more on numerical concepts and skills covered at key stage 3 and below.

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