Diagnosis of Mathematical Skills Among Bioscience Entrants

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Abstract

A paper-based diagnostic test of mathematical skills, presented to Stage 1 undergraduates, revealed that entrants encounter difficulties with some of the basic mathematical concepts that are essential if students are to successfully complete a programme of study within the biosciences. Students reacted favourably towards a number of computer-based learning materials aimed at supporting development of their basic mathematical skills through self-directed learning. However, the availability of such resources made no significant difference to the students' overall performance in a subsequent test. Some issues and applications are discussed.

The Execution

In the autumn of 2001 the School of Biology and Biochemistry introduced a *'Skills in Biosciences'* module for all its Stage 1 undergraduate students (approximately 125). The introduction of this module was in part to facilitate implementation of Queen's University's Student Skills Policy, but more importantly it was an attempt to ensure that all first-year entrants, who increasingly exhibit a wide diversity of entrance qualifications, had a common foundation in a range of key skills (including communication, numerical, ICT, problem-solving and team-working), as well as practical bioscience and career management skills.

Entrants possess a wide diversity of mathematics qualifications, ranging from grade C at GCSE level to grade A at A2-Level. Within the 'numerical skills' component of this 'skills' module, two 1-hour lectures and a 3-hour practical class are devoted to highlighting the importance of numerical skills within a bioscience context, explaining some of the more basic mathematical concepts and providing students with an opportunity to further develop and practise their numerical skills. In the first of two lectures, following a brief introduction on why numerical skills are important and an explanation of the characteristics that define a numerate individual [1], students are asked to complete a 30-minute paper-based practice test of their basic mathematical skills and knowledge (see Example of Paper-Based Diagnostic Test, p15), *without* the aid of a calculator. This test is marked and returned to students at the start of their practical class in the following week, but marks do not contribute towards their final module mark. In the second lecture, contextual examples are provided of some of the mathematical concepts students must understand, but with which many often experience difficulties, e.g. using measuring scales and SI units, manipulating equations, logarithms, power expressions and scientific notation.

The following week, students have a 3-hour practical class, during which they are asked to access, use and evaluate four computer-based learning (CBL) resources that can provide them with help in diagnosing, further developing and/or practising their numerical skills. Students are able to use the results of the practice test to help them identify their personal strengths and address their weaknesses. The resources include: (i) the 'Working with Numbers' section of *Key Skills Online* (intranet support for students available from Gower Publishing), (ii) *Maths for Microbiology* (a Question Mark CBL tutorial developed by

Fiona McGartland in collaboration with the author and accessible via Queen's intranet), (iii) *Numbers Count* (a prototype web site currently under development by the author and specifically aimed at supporting the basic mathematical skills covered in Stage 1). The fourth resource is selected from a list of additional, 'maths' web sites.

One week after the practical class, students sit a second, assessed test, which is similar in structure to the practice test and which once again does not allow the use of calculators; marks from this test contribute 4% towards a student's final module mark. In addition, students face ten similar questions in the module examination in January (where the use of calculators is permitted).

Results

The purpose of the tests is two-fold. Firstly, to collect data on the basic mathematical skills and skills deficits of entrants, and secondly to inform students about their mathematical abilities at the start of their undergraduate experience and provide them with the opportunity to address any weaknesses early in their course of study. Figure 1 summarises the results of the practice and assessed tests held in 2002. It illustrates that a relatively high proportion (i.e.>50%) of students encountered difficulties with those questions requiring an understanding of (i) fractions (nos.3 and 4), (ii) logarithms (nos.11 and 12), problems involving conversions between units of measurement (nos.13 and 14), and (iv) SI units (nos.17-20).

Although there was no significant difference between the mean marks out of twenty (10.4 and 10.9 correct answers respectively) for the two tests ($t = -0.85$, $df = 219$, $p = 0.4$), the lowest scores were 2/20 and 3/20 and only 2 (2%) and 1 (1%) student respectively answered all twenty questions correctly. The percentages of students exhibiting an increase, decrease or no change in marks following the second test were 49% (mean increase in marks = 17%), 37% (mean decrease in marks = 12%) and 14% respectively. There was a significant positive correlation between students' mean scores in the two tests and their GCSE, AS-, or A2-Level grades in mathematics ($r = 0.679$, $df = 116$, $p < 0.001$). The percentages of students possessing GCSE, AS-Level or A2-Level as their highest qualification in mathematics were 66%, 8% and 26% respectively. The results presented support those of an earlier study, which used a similar diagnostic test [2].
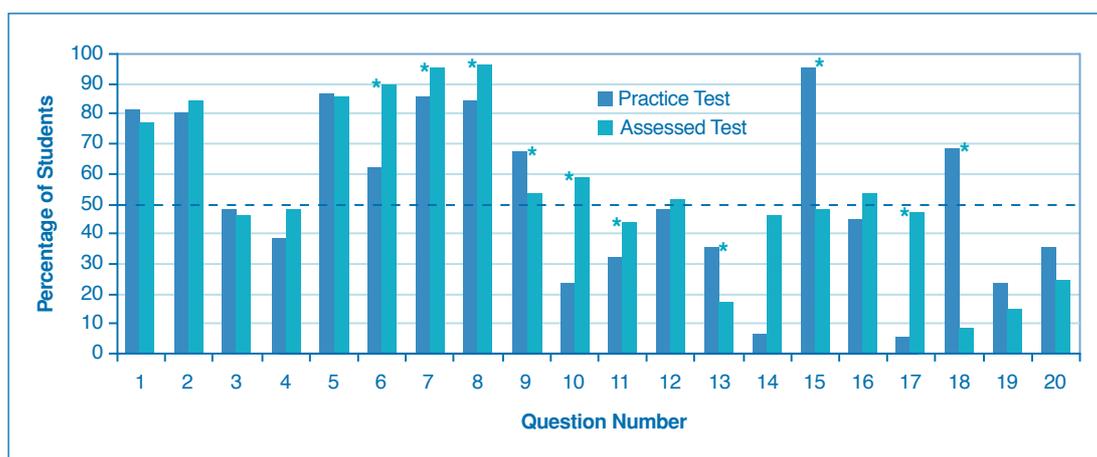
Figure 1: *Percentage of students in 2002 who provided correct answers to the 20 basic mathematics questions illustrated in the Appendix. * Significant differences between the practice (n = 109) and assessed (n = 118) tests ($\chi^2 \geq 4.0$, df = 1, $p < 0.05$).*

Issues

Among the main issues to emerge from the use of this and similar diagnostic tests is the students' lack of confidence and, in some cases, almost fear of anything numerical. Many fail to appreciate the importance of numerical skills, not only within their elected academic discipline, but also in selection procedures used by employers, their future profession, as well as in their everyday lives, and their reliance on calculators for even the simplest procedure is alarming. The introduction to and availability of CBL resources appeared to have little effect in improving the students' mathematical skills. There are several possible reasons for this, including insufficient time prior to the second test, as well as students' reluctance to assume responsibility for their own learning. A number of alternative strategies may be directed towards improving entrants' numerical skills [3]. In future years it may prove necessary to 'stream' students on the basis of results from the practice test and offer staff-led, small-group tutorial/workshop sessions at which the specific concerns and skills deficits of individual students may be addressed more directly.

Applications Across Academic Disciplines

Such paper-based diagnostic tests are relatively easy to prepare and assess, even when dealing with relatively large numbers of students, and the calculations included can be tailored to the specific requirements of an academic discipline. Alternatively, if there is little opportunity or requirement for the development of basic numerical skills within a particular discipline (e.g. English), and the primary purpose of such tests is to prepare graduates for the employer selection procedures they may encounter, a variety of numerical tests are commercially available (e.g. from Saville and Holdsworth Limited).

The experiences described are informing the development of teaching and learning strategies, not only in the School of Biology and Biochemistry, but also across Queen's University. For example, work is in progress to develop a model for the diagnosis and support of basic numerical skills among arts and humanities students, with a view to better preparing them for the numerical skills tests employers are increasingly using as part of their graduate recruitment procedures.

Example of the Paper-Based Diagnostic Test

Stage 1 undergraduate students were asked to attempt (without the aid of a calculator) in Autumn 2002.

1. $45.92 + 32.76 + 3.33 - 9.76$
2. $(2.8 + 9.2 - 3.1) \times (12 + 38)$
3. $4267/9$ *(present your answer as a decimal to 3 places)*
4. $5/6 \times 4/5$ *(present your answer as a decimal to 3 places)*
5. 12% of 4000
6. Decrease 63 by 20%
7. In the following series which number has the smallest value?
   $0.1298 \quad 1.298 \times 10^{-3} \quad 12.98 \times 10^{-1} \quad 1.298 \times 10^{-2} \quad 129.8 \times 10^{-4}$
8. In the following series which number has the largest value?
   $3.539 \times 10^{6} \quad 3539 \quad 0.3539 \times 10^{7} \quad 353.9 \times 10^{4} \quad 35390 \times 10^{3}$
9. $(5.5 \times 10^{2}) + (3.5 \times 10^{-2})$ *(present your answer in standard form)*
10. $(0.5 \times 10^{5}) \times (5 \times 10^{3})$ *(present your answer in standard form)*
11. $\log_3 81$
12. $\log_{10} (10^{5} \times 0.001)$
13. The mean weight of a mouse is 25g. If there are 100 mice per hectare calculate the biomass of mice in a square kilometre. Present your answer in $kgkm^{-2}$.
14. A good hay crop will yield 100 bales per hectare, weighing an average of 200 kg each. What area of land (in km^{2}) would yield 4×10^{6} kg of hay?
15. If $y = \log_{10} (x + 1) - 0.25^{-1}$ what is the value of y when x is 9999
16. Transpose and simplify the following equation to make x the subject: $y = (x - 6) - 2$
17. What is the SI base unit for amount of substance?
18. What is the definition of a pascal in SI base units?
19. What is the prefix for 10^{9} in SI units?
20. What is the prefix for 10^{15} in SI units?

References

[1] *The Implementation of the National Numeracy Strategy*, DfES (1998). The final report of the Numeracy Task Force [online]. Available from http://www.dfes.gov.uk/numeracy/ [accessed: 23 December 2002]. (Also available from Department for Education and Skills, London.)

[2] A decline in numeracy skills among bioscience undergraduates. *Journal of Biological Education* 36(2), p76-83, Tariq, V. N. (2002a).

[3] Numeracy skills deficit among bioscience entrants. *LTSN Bioscience Bulletin* Autumn 2002, no. 7, p.8, Tariq, V. N. (2002b).