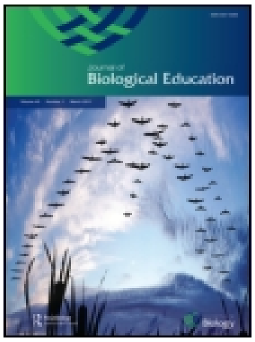

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A decline in numeracy skills among bioscience undergraduates

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This study provides evidence of a decline in basic numeracy skills among first-year bioscience undergraduate students. The results of two types of numeracy test are presented. The first, a test of conceptualised numeracy skills which forms a component of an introductory microbiology module, indicated a decline in numeracy skills between 1995 and 2000, and a significant positive correlation between students' highest mathematics qualifications and their scores for their first attempt at the test, with those possessing the highest grades at A-level attaining the highest marks. The second, a diagnostic test of basic numeracy skills revealed that bioscience students entering Stage 1 in 1999 and 2000 did not differ significantly in their ability to answer correctly the 15 questions posed, and no significant difference between males and females was apparent. However, in both years, a high proportion of students (42 – 63%) encountered difficulties with those questions that required an understanding of fractions, indices, logarithms, or units of measurement. Only 6.3% of students answered all 15 questions correctly. Once again, there was a significant positive correlation between students' scores in the diagnostic numeracy test and their GCSE or A-level grades in Mathematics. Reasons for the perceived decline in numeracy skills and the educational implications are discussed.
Key words: Numeracy, Skills, Biosciences, Undergraduates, Gender.

Introduction

In 1998, the UK government's Numeracy Task Force provided a definition of numeracy that focussed on '*a proficiency that involves a confidence and competence with numbers and measures*' (Department for Education and Skills (DfES), 1998). The Government's Numeracy Project, which resulted in its National Numeracy Strategy for primary education in England (DfES, 1998), was established following growing concerns, particularly over the past two decades, about the numeracy skills of the nation's population. A survey of basic numeracy among 2890 British adults (aged 16 years and over) in 1981 revealed that many adults did not possess the necessary skills to cope with essential everyday transactions in a modern society and that males scored more favourably than females (Webb, 1984). In 1996, the Basic Skills Agency commissioned research into the standards of numeracy among adults (aged 16 to 60 years) across seven countries (Basic Skills Agency, 1997). The participating countries were the UK, France, the Netherlands, Sweden, Denmark, Japan, and Australia. Respondents in the UK performed least well, with only 20% of individuals able to provide the correct answer to all 12 basic numeracy tasks and, once again, males scored more favourably than females. This overall result for the UK was in stark contrast to that for Japan, which demonstrated the best performance, with 43% of respondents achieving a full set of correct answers (Basic Skills Agency, 1997).

More recently, numerate disciplines within higher education and recruiters of graduates have expressed concerns about the numeracy skills of students (Brown *et al.*, 1998). In addition, Dearing *et al.* (1997) reported that only one in three graduate students felt that their numeracy skills had improved while they were in higher education, although clearly any improvements will have been dependent upon whether or not the subjects studied by the students provided opportunities for the further development of their numeracy skills. Others have reported numeracy problems within particular disciplines and professions. For example, the standard of mathematics among qualified and student nurses has caused alarm within the nursing profession (Cartwright, 1996; Hutton, 1998), while Phoenix (1999b) expressed concerns about the reduction in the core level of mathematical ability among students entering life science degree courses.

Among the reasons proposed for the perceived decline in numeracy skills are:

- changes to the General Certificate of Secondary Education (GCSE) in Mathematics and the Advanced (A-) level Mathematics syllabuses in the 1980s and 1990s (Phoenix, 1999b). A GCSE qualification is normally awarded to pupils aged 16 years after 2 years' study, while an A-level is normally awarded to pupils aged 18 years after 2 years' further study of an 'advanced' syllabus;
- individuals' lack of confidence, panic, and fear of mathematics (Green *et al.*, 1983; Lenton and Stevens, 1999; Bishop and Eley, 2001);
- difficulties which arise through not distinguishing between the teaching of facts and skills, and teaching through conceptual understanding (Lenton and Stevens, 1999);

- an over-reliance on the use of calculators and other technology (e.g., computers) for simple calculations (Cartwright, 1996; Hutton, 1998).

The Government's National Numeracy Strategy has attempted to address some of these concerns by proposing changes in the teaching of mathematics in primary, middle, and special schools (e.g. its recommendations include guidelines on the use of calculators and the inclusion of oral and mental work in every lesson), providing teacher training and support for schools (e.g. by providing 'numeracy consultants' and 'numeracy' training programmes to support teachers' continuing professional development), and creating a climate of support and encouragement with regard to numeracy skills for parents and children at home, as well as for the wider community (e.g. through the World Mathematical Year 2000 initiative which was launched in January 2000 and led by UNESCO) (DfES, 1998).

Numeracy skills of higher education entrants

The subjects that individuals go on to study in higher education vary in their requirements for numeracy skills. Some disciplines require a high level of mathematical knowledge and application (e.g. mathematics, physics, engineering), others may require an intermediate level of numeracy (e.g. chemistry, biosciences, psychology), while those at the opposite end of the spectrum (e.g. languages and drama) may require little, if any, application of students' numeracy skills. Although numeracy skills may not always appear necessary within a specific academic discipline, or may not be emphasised in some academic activities, nevertheless their application may prove essential in many subsequent work-related tasks, as well as in individuals' everyday lives.

Universities can no longer assume that all their entrants possess the skills that define a numerate individual, particularly in view of the fact that many academic disciplines do not require entrants to possess any formal mathematics qualification (e.g. at GCSE level or its equivalent). In addition, although the further development of numeracy skills is an inherent part of *some* subject specialisms in tertiary level education, they are not developed within the curricula of *all* disciplines and, therefore, some students may have had limited or no opportunity to practise and extend these skills since their compulsory (pre-16) education. Nevertheless, all students (regardless of their formal mathematical training or higher education discipline) need to be numerate if they are to succeed in the workplace and in their everyday lives. A view supported by Green *et al*. (1983) and Gillespie (1998) who highlight the importance of numeracy skills to arts and humanities students as well as to science and engineering undergraduates, since numeracy encourages critical thinking and independent reasoning, skills valued by employers (Gillespie, 1998).

In general, the numeracy skills of entrants into higher education are judged on the basis of students' mathematics qualifications at GCSE or A-level (or equivalents). However, in recent years there have been growing concerns about declining standards at GCSE (Foster, 2001) and at A-level (O'Reilly, 1998), as well as concerns about changes made to the GCSE Mathematics curriculum (Phoenix, 1999b). As a consequence, some higher education disciplines no longer rely solely on entrants' pre-university mathematics qualifications as predictors of students' competencies in basic numeracy skills, but use diagnostic testing to assess the mathematical skills of their entrants. The use of diagnostic tests, which may be paper- or computer-based, represents only one strategy in identifying a student's level of proficiency in numeracy skills, and only the first stage in supporting the further development of such skills. However, diagnostic testing of both entrants and graduates may become increasingly important as concerns grow about the deficiency of numeracy skills within some professions. For example, the UK government recently introduced a numeracy test for trainee teachers as part of its campaign to raise standards in teacher training. Between 1 May 2000 and 30 April 2001 no trainee was to be allowed to acquire Qualified Teacher Status (QTS) in the UK and begin their induction without passing the numeracy test. From 1 May 2001 trainees were required to pass tests in literacy and IT (Judd, 2000; Teacher Training Agency, 2000). However, problems arose with this strategy when a number of trainees failed to pass the numeracy test (Thornton, 2001).

Within the biosciences, which encompass a wide range of disciplines from biochemistry and biophysics to microbiology and ecology, the range and level of mathematical skills required of undergraduates vary, although all require a core of numerical ability (Phoenix, 1999b). Many bioscience students enter their degree programmes possessing only GCSE Mathematics (or equivalent) and only a minority possess a higher mathematics qualification (e.g. A-level). For example, within the School of Biology and Biochemistry, Queen's University Belfast, in 1999/2000 the percentages of students possessing grades A to E in A-level Mathematics at undergraduate Stages 0, 1, 2 and 3 (i.e. in successive years of the degree programmes, from the foundation year (0) to the honours year (3)) were 11%, 23%, 31%, and 17% respectively (unpublished data); an entrance requirement is a minimum of GCSE-level Mathematics at Grade C.

Concerns have been expressed that changes to the GCSE Mathematics curriculum, which include the removal of some topics (e.g. logarithms), have reduced the core level of mathematical ability of students entering life science degree courses (Phoenix, 1999b). In addition, the widely held view that GCSE standards have been falling over recent years was supported in 2001 by Jeffrey Robinson, a former principal mathematics examiner for the Oxford Cambridge and RSA (OCR) examining board, who disclosed how pass marks were being lowered to inflate GCSE results (Foster, 2001). Recent reports (Lake, 1999; Phoenix, 1999b) suggest that many bioscience university entrants are not adequately equipped with many of the basic numeracy skills which broadly define a numerate individual (DfES, 1998; Lenton and Stevens, 1999). These basic numeracy skills are essential if students are to develop the more advanced mathematical skills required by the subject. However, bioscience departments are concerned that many of their students:

- lack confidence in their ability to deal with basic mathematical concepts and to do basic arithmetic and algebra;
- are unable to calculate accurately and efficiently without the aid of a calculator ;
- lack an appreciation of numbers (i.e. fail to recognise why numbers are important, and exhibit a limited sense of the sizes of numbers and where they fit in the number system);
- do not possess strategies to check whether their answers are reasonable;
- lack the ability to convert between units of measurement;
- are unable to manipulate numbers and equations;
- are unable to explain data presented in graphs, charts, and tables (Lake, 1999; Phoenix, 1999b).

Of particular concern to those who teach undergraduate students is the growing deficit in basic numerical dexterity, an appreciation of numbers, and basic algebra among entrants (Phoenix, 1999b). The remainder of this paper describes a case study that illustrates the nature of this concern and describes strategies implemented by the School of Biology and Biochemistry, Queen's University Belfast in an attempt to improve the numeracy skills of its entrants.

Methods

Conceptualised numeracy skills

The School of Biology and Biochemistry, Queen's University Belfast offers a second-semester Level 1 Microorganisms module to Stage 1 undergraduate students. This module attracts approximately 140 to 170 students annually from the Schools of Biology and Biochemistry (with its nine bioscience first degree programmes), Agriculture and Food Science, and Biomedical Sciences. As with many bioscience modules there is an emphasis on the development of practical skills, some of which inevitably require the students to apply their numeracy skills.

In 1995, the practical component of this module was redesigned, in part to accommodate the increasing class size. One of the changes to the module was the introduction of a Practical Skills Test. During the first five weeks of this module, students complete a variety of practical tasks that aim to help them develop some basic microbiological skills, e.g. aseptic technique and the use of various methods to enumerate microorganisms. The level of skill the students have acquired is assessed in week 6 (March), when students attempt a five-point practical test. Two of the five elements in the test require each student to demonstrate his/her competency in some basic aseptic procedures, while the remaining three elements of the test involve some basic microbiology-related mathematical calculations (see Appendix 1). All three calculations are integrated into the previous five weeks of practical exercises upon which students receive oral and written feedback. Students are permitted the use of calculators at all times, including during the practical test. Those students who fail one or more elements of the practical test are required to attend a re-sit test in week 11 (April or May) of the module, during which they must attempt all five elements again. In recent years, records have been maintained of the students' performance in the numerical elements of the test. In addition, details of students' GCSE and A-level results were available from the University's central records for 234 students entering between September 1997 and September 1999. This enabled correlation analyses of students' highest pre-university mathematics qualifications versus their overall performance in the numerical part of the practical test.

Diagnostic test of basic numeracy skills

In response to growing concerns about the apparent decline in the students' basic numeracy skills (a conclusion partly drawn from data accumulated from the practical skills test described above), in February 2000 (for September 1999 entrants) and November 2000 (for September 2000 entrants), first-year students in the School of Biology and Biochemistry were invited to attend a lunchtime seminar that highlighted the importance of numeracy skills and directed students to a variety of useful resources (including textbooks, a computer-assisted learning programme, Internet sites, and tutor and peer support). The proportion of students attending the numeracy seminar was 71% in February 2000 and 89% in November 2000 (1 in 5 of whom had attended the February seminar). No formal mathematics tuition was provided in this session, which represented one of a programme of seminars concerned with key skills. As part of this session, the students were asked to attempt (without prior warning and *without* the use of calculators) a basic numeracy test comprising 15 elements (see Appendix 2). The 15 calculations in the 1999 and 2000 tests were the same, although the numbers were changed to minimise plagiarism. The tests were marked by the author and returned to students via their School (Personal) Tutors who provided individuals with feedback on their performance. The data collected were analysed using a Chi-squared contingency test to establish whether or not there were any significant differences between (i) the 1999 and 2000 entrants, and (ii) females and males in terms of their ability to answer correctly each of the 15 questions. The proportion of students (20%) who had attended both numeracy seminars were excluded from the November data set.

In addition, for 31 students a correlation analysis was possible of students' highest pre-university mathematics qualifications versus their overall performance in the basic numeracy skills test.

Results

Conceptualised numeracy skills

Table 1 summarises the class results for the three numerical elements of the Microorganisms practical test (see Appendix 1) for Stage 1 entrants between 1995 and 2000. The data illustrates the decline in some basic numeracy skills of students enrolled on this module, particularly between 1995 and 1998. This trend is apparent when considering both the first attempt at the test and the re-sit, although, not surprisingly, a greater number of students were successful in their second attempt at the test. Nevertheless, between 1997 and 2000 the percentage of students able to answer correctly all three questions at their second attempt in the re-sit test fell from 63% to 41%. In comparison, the percentage of students who failed to answer correctly any of the three questions at their second attempt rose from 2% to 12% over the same period. In any one year, a small number of students (0 – 6) who managed to score on the first test attained a mark of zero on the second test, although approximately 75% of these students had succeeded in scoring only 1/3 at their first attempt. Students consistently experienced greatest difficulties with the calculations involving indices (i.e. powers of 10 in the dilution series question) or volume and units of measurement (i.e. the haemocytometry question).

When the students' grades for their highest mathematics qualifications were examined for a sample of 234 students it became apparent that there was a significant positive correlation with the students' individual marks for their first attempt at the numerical elements of the practical test ($r = 0.182$, $df = 232$, $p = 0.005$), with those possessing the highest grades at A-level attaining the highest marks out of three. In contrast, there was no evidence of a correlation when the results for the re-sit test were analysed ($r = 0.105$, $df = 216$, $p = 0.123$). When the students' GCSE and A-level grades were analysed separately using the mean mark out of three for each sample group of students, significant correlations were obtained only for the A-level grades at both the first attempt and in the re-sit test (Table 2).

Table 1 Summary of students' performance in the three numerical elements of the Level 1 'Microorganisms' practical test at their first attempt in week 6 and in the re-sit test in week 11 of the second semester, for students entering Stage 1 between September 1995 and September 2000.

Questions	*Percentage of students answering correctly*									
	1995		*1997*		*1998*		*1999**		*2000**	
	Week 6 Test	*Week 11 Retest*	*Week 6 Test*	*Week 11 Retest*	*Week 6 Test*	*Week 11 Retest*	*Week 6 Test*	*Week 11 Retest*	*Week 6 Test*	*Week 11 Retest*
	N=140	*N/A*	*N=151*	*N=141*	*N=170*	*N=165*	*N=150*	*N=132*	*N=147*	*N=135*
Dilution series	41	N/A	44	82	41	81	33	64	45	66
Micrometry	76	N/A	49	85	42	82	51	65	55	70
Haemocytometry	54	N/A	40	82	34	66	42	71	43	67
3/3 questions	16	N/A	13	63	9	52	14	49	21	41
2/3 questions	48	N/A	31	26	29	28	28	33	27	32
1/3 questions	26	N/A	34	9	31	19	29	15	28	15
0/3 questions	10	N/A	22	2	31	1	29	3	24	12

N/A = data not available
Data for 1996 entrants not available
*Students had attended a seminar on numeracy skills earlier in the academic year

Diagnostic test of basic numeracy skills

Figure 1 illustrates that students entering Stage 1 in 1999 and 2000 did not differ significantly in their ability to answer correctly the 15 questions posed in the basic numeracy test. The only significant difference between the two groups arose for question 3 (a calculation involving multiplication). Similarly there was no significant difference between males and females (Figure 2), except for question 4 (a calculation involving division). However, in both years a relatively high proportion of students (42 – 63%) encountered difficulties with those questions that required an understanding of (i) fractions (no. 6), (ii) indices (nos. 10 and 11), (iii) logarithms (no. 12), and (iv) conversion between units of measurement (no. 13) (Figures 1 and 2). Although the mean mark was 11/15 (sd = 2) correct answers, the lowest score was 5/15 and only 14 students (6.3%) answered all 15 questions correctly. There was a significant positive correlation between students' scores in the numeracy test and their GCSE or A-level grades for the 31 students where the latter information was available (r = 0.586, df = 29, p = 0.001).

Discussion

The three numerical elements of the practical test (Appendix 1) evaluate some of the characteristics that define a numerate individual (DfES, 1998; Lenton and Stevens, 1999). For example, question 1 tests the students' conception of the size of numbers, through their understanding of the use of indices (in particular powers of ten), while questions 2 and 3 test the students' knowledge of the relationship between different units of measurement, as well as their ability to manipulate numbers and equations and perform basic calculations involving multiplication and division (Appendix 1). Some might find the apparent decline in the students' abilities to perform these relatively simple calculations alarming. It could be argued that the trend observed over a number of years might reflect a decline in the proportion of students possessing A-level Mathematics and/or an increase in the number of entrants possessing only grade C in GCSE Mathematics. Although the complete set of data required to test this hypothesis is unavailable, this appears an unlikely scenario, given the School's statistics for A-level Mathematics for students distributed across the four successive years of study in 1999/2000 presented in the Introduction.

The very slight improvement in overall performance in the practical test results for 1999 and 2000 compared to previous years (Table 1) may, in part, have been due to the fact that in these years all first-year students were invited to attend a seminar that highlighted the importance of numeracy skills and provided students with the opportunity to gain some insight into their individual basic mathematical skills via a diagnostic numeracy test comprising 15 elements (Appendix 2). Students were also directed towards and encouraged to use a number of self-help resources (textbooks, computer-based learning materials, and Internet sites) in order to improve their basic numeracy skills. A future study might investigate the impact, if any, of such resources on students' basic numeracy skills. Of course, many experienced teachers might argue that since students were 'invited' to attend the seminar, those weaker students who most needed to do so may well have been absent.

Table 2 Correlation between Stage 1 students' highest pre-university mathematics qualifications and their mean marks for the three numerical elements of the Level 1 'Microorganisms' practical test over three years (1997 – 1999 entrants), at their first attempt in week 6 and in the re-sit test in week 11 of the second semester.

Qualification	*Grade*	*Mean mark out of 3 (N)*	
		Week 6 Test	*Week 11 Retest*
GCSE mathematics	A*	2.75 (4)	3.00 (4)
	A	1.60 (58)	2.46 (54)
	B	1.11 (81)	2.27 (77)
	C	1.01 (18)	2.69 (16)
Pearson correlation coefficient		0.92 (p = 0.08)	0.46 (p = 0.54)
A-level mathematics	A	2.09 (11)	2.91 (11)
	B	1.75 (20)	2.53 (15)
	C	1.30 (23)	2.44 (23)
	D	1.27 (11)	2.40 (10)
	E/N	0.5 (8)	2.25 (8)
Pearson correlation coefficient		0.97 (p = 0.01)	0.93 (p = 0.02)

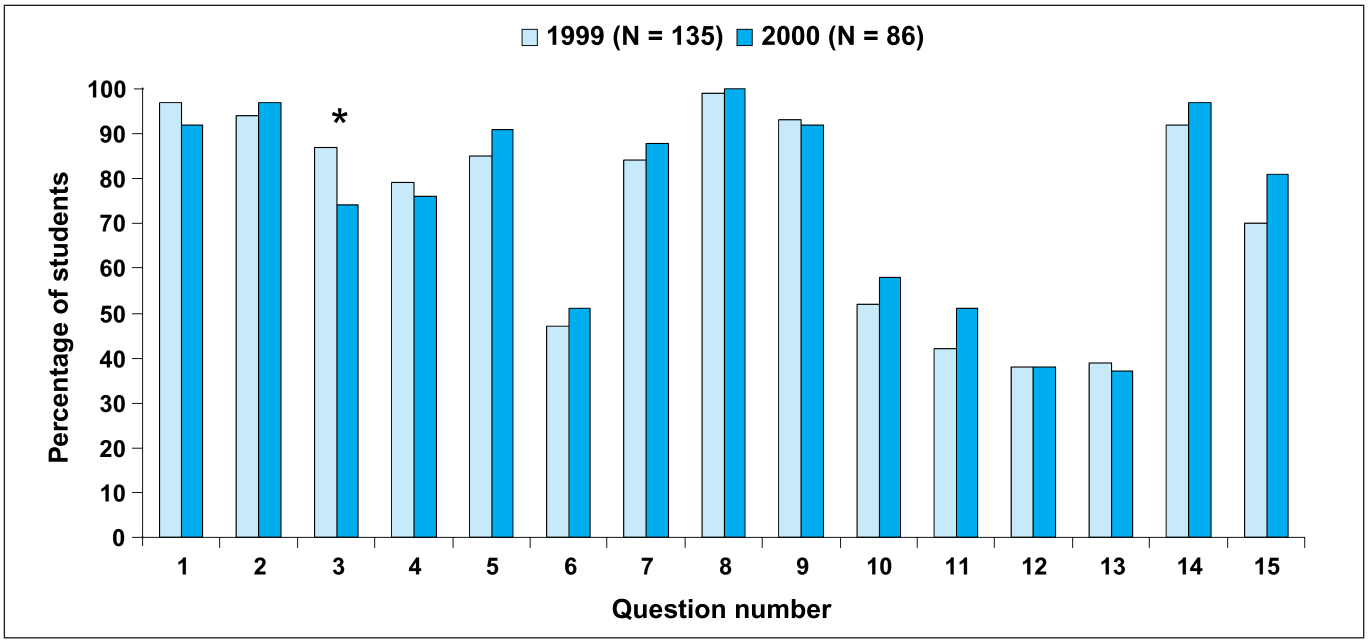

Figure 1 *Percentage of students entering Stage 1 in 1999 and 2000 who provided correct answers to the 15 basic mathematics questions illustrated in Appendix 2. * The only significant difference between 1999 and 2000 arose for question 3 (χ^2 = 5.32, df = 1, p = 0.021).*

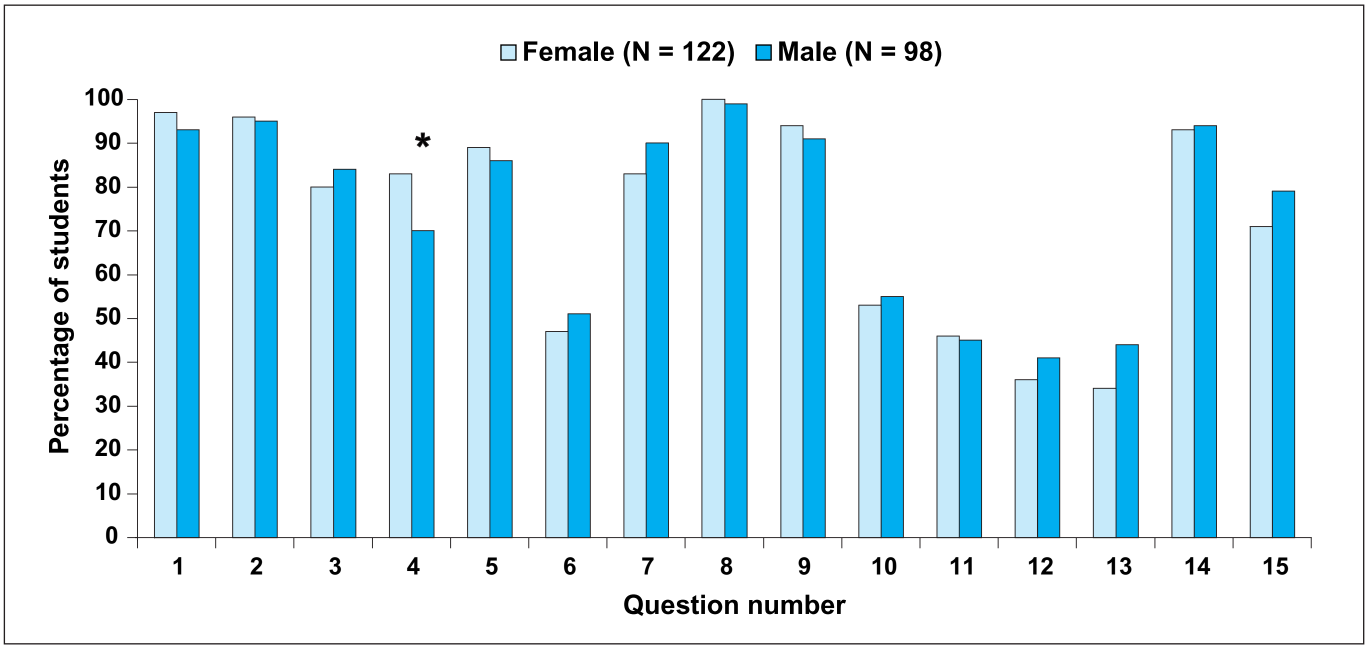

Figure 2 *Percentage of female and male students who provided correct answers to the 15 basic mathematics questions illustrated in Appendix 2 (1999 and 2000 data combined). * The only significant difference between females and males arose for question 4 (χ^2 = 4.74, df = 1, p = 0.029).*

Results obtained for the diagnostic numeracy test highlight the difficulties students have with particular calculations, specifically those involving fractions (especially multiplication and division), the number system (decimals, indices, and logarithms), and units of measurement. These findings support those from previous studies (Hutton, 1998; Lenton and Stevens, 1999). The results also revealed the positive correlation between students' GCSE or A-level mathematics grades and their scores in both the diagnostic numeracy test and their first attempt at the practical test. This finding is similar to that of Hutton (1998) who reported that the better the qualification in mathematics of nursing students, the higher the score in a diagnostic numeracy test. However, in contrast to some previous reports (Webb, 1984; Basic Skills Agency, 1997) the current study found no significant difference between males and females in their ability to provide correct answers to 14 of the 15 calculations in the diagnostic numeracy test.

Such diagnostic tests represent useful tools to help tutors identify weaknesses or deficiencies in entrants' required numeracy skills. However, the challenge is to then develop strategies aimed at addressing the former, and supporting the further development of the latter before attempting to develop in students the more advanced mathematical skills required by the subject.

Universities have developed various strategies aimed at helping students to attain acceptable levels in key skills, including numeracy. Some institutions offer students 'free-standing' skills courses, or 'add in' specific skills sessions to existing subject-specific courses. However, there are those who resent the fact that these approaches inevitably reduce the amount of subject-specific teaching time available (Phoenix, 1999a), and who would argue that students should accept greater responsibility for developing their proficiency in key skills through independent learning, as well as via subject-specific modules which have one or more key skills 'embedded' within them (personal communication). Others hope that changes to the post-16 curriculum, which came into effect in September 2000, will result in improvements in the skills of students entering higher education from 2002 onwards and that this might allow some non-subject specific teaching time to be reclaimed (Phoenix, 1999a). Time will reveal whether this is indeed the case or whether this sentiment reflects a vain hope. In the meantime, tertiary education cannot afford to wait and see if the situation improves, but must continue to be proactive in developing strategies to raise the key skills (including numeracy) competencies of their students.

Strategies aimed specifically at improving the numeracy skills of undergraduates have included:

- offering summer courses for students prior to their entry into higher education or during their undergraduate programme (Phoenix, 1999a);
- offering a one-year foundation module that covers specifically the mathematics required at degree level within a discipline (Duffin *et al.*, 1999);
- using the results of diagnostic tests to organise revision classes or tutorials as necessary (Hutton, 1998);
- encouraging the application of mental calculation and the more appropriate and effective use of calculators (Duffin *et al.*, 1999);
- providing a drop-in 'surgery' facility where staff can deal with students' acute problems of understanding. However, such facilities are usually not designed to deal with underlying deficiencies in numerical competence (Duffin *et al.*, 1999);
- providing tutorial support, either within or outside subject-specific modules;
- the use of computer-based learning (CBL) packages (Montgomery, 1998);
- the provision of additional resources for self-help and independent learning. For example, self-instructional texts (Garvin and Butcher, 1995) and web sites (e.g. *Maths Help* at www.maths-help.co.uk);
- encouraging students engaged in work experience to reflect on the skills (including numeracy) they are developing.

Many of the strategies listed above (e.g. summer schools, special courses, surgeries and tutorials) are highly demanding in terms of staff time, while others (e.g. CBL programmes, self-instructional texts, web-based resources) encourage students' independent learning. However, what many of them fail to do is provide an integrated, yet flexible programme that allows the effective and efficient delivery of skills tuition to all students, irrespective of their academic discipline and timetable constraints.

In this study, the informal lunchtime seminar programme, which ran in 1999 and 2000, proved to have limited success in addressing the perceived deficiencies in students' key skills (including their numeracy skills). This was perhaps, in part, due to the large numbers of students involved (191 in 1999/2000 and 120 in 2000/2001), combined with the fact that students were not formally assessed and, therefore, appeared reluctant to engage in independent learning, or to take advantage of the self-help resources provided. Consequently, the informal programme of study has been transformed into a more extensive and formal 12-week, first-semester module ('Skills in Biosciences'), which is currently running for all first-year students in the School of Biology and Biochemistry. With regard to the numeracy skills component of this module, students are still presented with a diagnostic numeracy test (in week 4) and directed to a variety of self-help resources. However, their numeracy skills are now formally assessed in a second basic numeracy test in week 8 (which contributes 5% towards their final module mark) and in the module examination in January (which contributes 50% of the module mark). The examination also tests the students' problem-solving skills and their knowledge and understanding of practical skills and techniques. It remains to be seen whether or not this strategy (which is highly demanding in terms of staff time and input) improves students' overall competence and confidence in a range of skills, including numeracy.

Educational implications

The results presented support the view that universities can no longer assume that their entrants (including those possessing formal mathematics qualifications) are 'numerate individuals', as defined by the government's Numeracy Task Force (DfES, 1998). Higher education institutions will need to develop strategies to assist their student populations in developing numeracy skills (as well as other key skills) to the level(s) necessary for them to be successful in their education, work, and everyday lives.

The problems facing institutions of higher education are (i) recognising the levels of numeracy skills entrants have achieved through entrance qualifications, and/or assessments through internal diagnostic tests, and (ii) developing strategies to support the further development of their numeracy skills where appropriate. However, academic staff and student attitudes toward the teaching of basic numeracy skills at the tertiary level vary, with a proportion of both groups resenting any time spent explicitly on basic numeracy skills. This is primarily because they believe that many strategies aimed at developing students' numeracy skills reduce the amount of subject-specific teaching time available, and students in particular don't appreciate the limitations that numeracy skill deficiencies place on learning in the subject area. In addition, there is always the risk of disenfranchising and alienating high achievers, while attempting to cater for the low achievers.

Supporting the development of numeracy skills can present a real challenge (Drake, 2001). On the one hand, the integration of numeracy skills within discipline and vocational training helps students appreciate their relevance and application. However, subject-specialist teachers and trainers sometimes lack confidence in their own numeracy abilities. On the other hand, using numeracy 'experts' (e.g. mathematicians) and/or free-standing mathematics courses can create artificiality from the students' perspective, and can give rise to time-tabling problems, particularly within a modular system. A combination of various teaching and learning strategies may provide a way forward.

Those teaching in higher education find themselves having to address the problem that a significant proportion of their first-year students appear deficient in some of the basic skills they would once have expected them to attain during their compulsory education, despite annual reports of improvements in the grades attained by students at GCSE and A-level. Is the secondary-level curriculum adequately addressing the skills competencies that individuals require to be successful in their future education and employment? This paper has perhaps raised more questions than it has provided definitive answers. How do students' standards of numeracy skills compare with their overall educational performance as measured by their entrance qualification grades in other subjects? Is the perceived decline in numeracy standards an isolated phenomenon, or is it paralleled in terms of other basic skills such as literacy and communication skills? What effects do intervention strategies and availability of resources (such as those outlined) have on skills development? There is certainly a great deal of scope for future investigations in this area.

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Websites

Web-based links for further reading

Basic Skills Agency, www.basic-skills.co.uk/
DfES, www.dfes.gov.uk/numeracy/
Maths Help, www.maths-help.co.uk

Appendix 1

Examples of the three numerical elements of the Level 1 'Microorganisms' practical test

1. *Dilution series: the enumeration of bacteria*
A sample of water taken from a pond near an industrial site has been investigated with regard to its content of bacteria. The water has been diluted in a 10-fold series to 10^{-6}, by diluting 0.5 ml into 4.5 ml of $^1/_4$-strength Ringers solution. 0.1 ml of each dilution has been spread-plated onto nutrient agar plates and incubated for 3 days at 25°C. The following colony counts have been obtained:

Dilution:	0	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
Count:	UC	UC	UC	UC	204	26	3

Calculate the best estimate of the number of bacteria in the pond as cfu/ml.

2. *Micrometry: measuring cellular structures*
Determine the **real size (in μm)** of the cell or structure (indicated by the arrow) illustrated in the micrograph.

3. *Haemocytometry: the enumeration of yeast cells*
Area of small counting chamber = 1/5 mm^2
Depth of small counting chamber = 0.2 mm
Mean no. of yeast cells in one small counting chamber = 11
Calculate: (a) the volume of one small counting chamber in cm^3
(b) the concentration of yeast cells in suspension in terms of cells ml^{-1}

Appendix 2

Example of the paper-based diagnostic mathematics test Stage 1 undergraduate students were asked to attempt without the aid of a calculator

1. 6.27 + 1.81 + 3.72
2. 11.32 – 2.58
3. 16 x 43
4. $\frac{3608}{11}$ *(present your answer as a number, not as a fraction)*
5. $^1/_4$ + 0.6 *(present your answer as a decimal, not as a fraction)*
6. $^4/_5$ x $^5/_8$ *(present your answer as a decimal, not as a fraction)*
7. 3% of 4000
8. In the following series of numbers, which number has the smallest value?
0.62 0.25 0.1983 0.375 0.5
9. In the following series of numbers, which number has the greatest value?
1.25×10^{-12} 2.45×10^{-9} 1.66×10^{-5} 2.97×10^{-11}

10. $(4.5 \times 10^6) - (2 \times 10^4)$ *(present your answer in standard form)*
11. $\dfrac{6 \times 10^{-9}}{2 \times 10^{-3}}$ *(present your answer in standard form)*
12. $\log_{10} 10000$
13. If the length and width of a rectangle are 9 mm and 6 mm respectively, what is the area of the rectangle in cm^2?
14. If $y = 7x + 6$, what is the value of x when $y = 69$?
15. If $y = (x^3) - 41$, what is the value of x when $y = 84$?

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