Counting on numbers – squaring the numeracy divide?

Adam Watts
Ruth Shiner
Liz O'Gara
Tom Warrender
School of Applied Sciences, Biomedical Science Division

Background and Rationale

Concern about levels of basic numeracy has engaged politicians, educators and employers alike. There is evidence of poor levels of numeracy in the UK school and adult populations (Dearing, 1996; NCIHE, 1997; Basic Skills Agency, 1997; Coben, 2003; Smith, 2004). Low levels of numeracy for students entering Higher Education (HE), across a range of subject disciplines are also documented in the literature (Tariq, 2002a; Tariq, 2002b; Phoenix, 1999).

Decline in the mathematical fluency of students embarking upon HE courses appears to be due to affective issues, a so called 'maths anxiety' (Mackenzie, 2002; Coben, 2003). Presage [1] (Biggs, 2003; Ramsden, 2003) is a key issue, particularly against the backdrop of the 'massification' of higher education (Coaldrake, 2001) and many HE institutions' strong commitment to widening participation and lifelong learning. Students enter university with a range of qualitatively different conceptions of, and approaches to, learning. This will be no different for numeracy and mathematics (Crawford *et al.*, 1998).

It is useful to frame a general working definition of numeracy: "To be numerate means to be competent, confident, and comfortable with one's judgements on whether to use mathematics in a particular situation and if so, what mathematics to use, how to do it, what degree of accuracy is appropriate, and what the answer means in relation to the context" (Coben, 2000). Degree programmes in the School of Applied Sciences typically involve modules with embedded numeracy as defined; and this potentially limits participation especially among those who fear mathematics. Gaining an insight into presage will help define the extent of self-efficacy in performing numeracy tasks, and inform both design of teaching and learning activities and alignment of learner support.

The aims of this study were to explore the confidence and attitudes to numeracy among Level 1 students studying at the School of Applied Sciences, University of Wolverhampton, and to investigate student and staff perceptions of numeracy and identify any consonance or dissonance that may exist.

The innovation

A questionnaire was prepared, based on the work of Mackenzie (2002) and Tariq (2004), and issued to Level 1 Applied Science students during induction week. It was produced using Surveyor by ObjectPlanet software, hosted online and distributed via a URL link from the University virtual learning environment, WOLF (Wolverhampton Online Learning Framework) and the University email system. Questions related to three themes; prior experience of numeracy, attitude to numeracy and perceived confidence in application of numeracy. This third theme was further subdivided into student and staff perceptions. A five-point Likert scale of 'Strongly agree', 'Agree', 'Neither agree nor disagree', 'Disagree' and 'Strongly disagree' was used for assessing prior experience and attitude, and a four-point scale for rating confidence C=0 (not at all confident), C=1, C=2 and C=3 (very

[1] Presage refers to two sets of factors: students factors (such as prior knowledge and motivation) and teaching factors (such as objectives, assessment, teaching climate, etc.). According to (Biggs, 2003, pp. 18-19), these presage factors exist prior to learning.

confident). Students were asked to rate their personal confidence (self-efficacy as defined by Pajares, 1996) in each of twenty eight numeracy skills (after Tariq, 2004). Staff were asked to rate their perceptions of what level of confidence would be expected of a level one undergraduate entrant in the same numeracy skills. All students completing the questionnaire were asked to indicate formal mathematical qualifications. Statistical analysis using Mann-Whitney U Test was performed in SPSS version 11.5. In addition, students in the Biomedical Science Division completed a series of self-assessment activities (example in Appendix 1) that engender autonomy in the process of identifying and reflecting upon what they can and cannot do.

The outcomes

Summary of Questionnaire Findings

160 fully completed questionnaires were returned, from across the School of Applied Sciences, which comprises four Divisions: Biomedical Sciences, Biosciences, Environmental Sciences, Analytical Sciences and Geography (EAS) and Psychology. 31 academic staff, all involved in Level 1 undergraduate teaching returned fully completed questionnaires.

Prior Experience and Attitude to Numeracy in Level 1 undergraduates

67% of the student respondents were female, and 33% male, mirroring the gender demographic of the School. A significant proportion of the students (85%) have passed GCSE maths or equivalent, with 28% of students having studied maths at AS level and 8% at A2 level. This prior learning profile is similar to that reported by Mackenzie (2002). The age profile of the students is 18-41 years; hence non-traditional entrants may well have more distant experience of maths; however 8% of students have gained a qualification in maths during an Access course, and 17% report Key Skills qualifications in maths.

The majority of students (75%) report having enjoyed maths at primary / first school. This positive view of maths is continued at secondary / high school, with 67% of respondents agreeing with the statement. 57% say that they find doing number skills (sums) easy, and 61% intimate a willingness to learn new number skills. Although fewer than half of the students (49%) report that they like working with formulae and equations (mathematical constructs), there is widespread acknowledgement and recognition that numeracy is implicit both in terms of academic study and employability. Students expect to use number skills in modules (92%) and at work (95%). Expectation of working with formulae and equations in modules (83%) and at work (71%) is also recognised.

Approximately a third of students agree with the statement "I am concerned about learning new number skills". 29% are male and 71% are female, congruent with the respondent demographic. 39% of Bioscience and EAS students express 'concern' about learning new number skills. A smaller, yet significant percentage of Biomedical Science students also report 'concern' (29%). A markedly lower percentage is noted for Psychology students (10%). 'Avoidance' as evaluated by agreement with the statement "I avoid formal number work" demonstrates a similar trend overall with 21% admitting to such avoidance, of which 22% are male and 78% are female.

Table 1. Prior learning experience and attitude to numeracy of students expressed as percentage frequency (to nearest whole number) (after Mackenzie, 2002)

	Strongly agree (%)	Agree (%)	Neither agree nor disagree (%)	Disagree (%)	Strongly disagree (%)
I enjoyed doing maths at primary/first school	36	39	13	8	4
I enjoyed doing maths at secondary/high school	27	40	12	13	8
I find doing number work (sums) easy	19	38	27	13	3
I want to learn new number skills	19	42	29	8	2
I am concerned about learning new number skills	9	23	40	23	5
I avoid formal number work	4	17	28	40	11
I use number skills in everyday life	24	59	13	4	-
I expect to use number skills in the world of work	42	53	4	1	-
I expect to use number skills in modules for my degree	46	46	5	3	-
I like working with formulae and equations	16	33	26	17	8
I expect to work with formulae and equations in my degree	34	49	12	5	-
I expect to work with formulae and equations at work	23	48	23	5	1

Table 2. Percentage frequency (to nearest whole number) of students agreeing or strongly agreeing with statements relating to maths anxiety and avoidance (Mackenzie, 2002) analysed by Division. Male (○) and Female (▲) students

	All students (%)	○	▲	Biomedical Science (%)	Bioscience (%)	EAS (%)	Psychology (%)
I am concerned about learning new number skills	32	29	71	29	39	39	10
I avoid formal number work	21	22	78	17	26	22	10

Student and Staff Perceptions of Confidence with Numeracy Skills

Students generally express high levels of confidence about basic numeracy skills (addition, subtraction, multiplication, division, fractions, using a calculator and basic statistics). Low levels and no confidence are noted for basic algebra, unit conversion, integration, differentiation, molarity and modelling, a common factor being the applied nature of the numeracy skills.

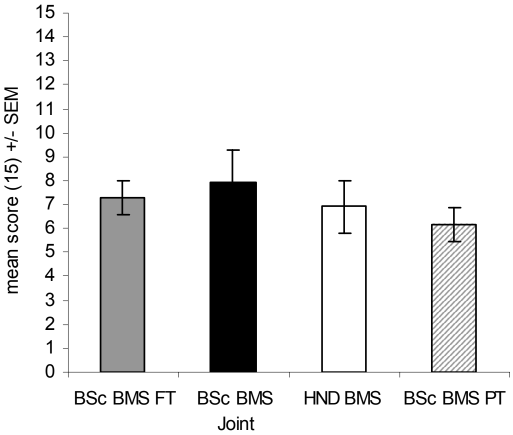
Differences in student and staff perceptions of confidence in numeracy application are evident in 9 out of the 28 numeracy skills. There is a dissonance in perception with respect to the basic numeracy skills: multiplication, division, decimals, ratios and proportions, the size of numbers and communicating data, with staff expectation of confidence in ability to apply such skills significantly higher than students' perceived confidence. Conversely, compared to staff, students report higher levels of confidence in the more advanced skills of integration, differentiation and basic statistics. Statistical analysis using a Mann-Whitney U Test indicated a significant difference in staff and student perceptions for all four Divisions of the School.

Table 3. Differences in student and staff perceptions of confidence in 28 numeracy skills analysed by cohort and Division

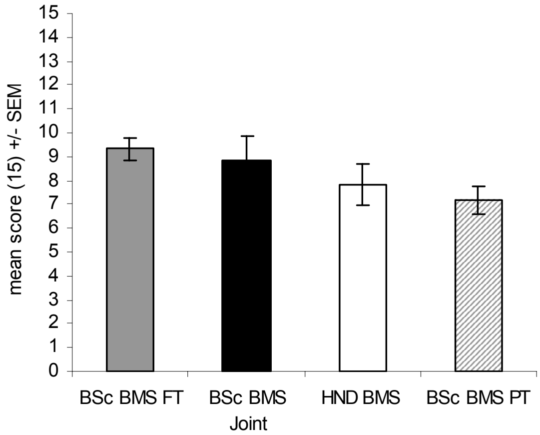
Numeracy skill	Complete Cohort $P < 0.05$ (two-tailed)	Biomed. $P < 0.05$ (two-tailed)	Biosci. $P < 0.05$ (two-tailed)	EAS $P < 0.05$ (two-tailed)	Psychology $P < 0.05$ (two-tailed)
Addition	n/s	n/s	n/s	n/s	n/s
Subtraction	n/s	n/s	n/s	n/s	n/s
Multiplication	sig.	sig.	n/s	sig.	n/s
Division	sig.	sig.	n/s	sig.	n/s
Fractions	n/s	sig.	n/s	n/s	n/s
Decimals	sig.	sig.	n/s	n/s	n/s
Percentages	n/s	sig.	n/s	n/s	n/s
Ratios/Proportions	sig.	sig.	n/s	n/s	n/s
Probabilities	n/s	n/s	n/s	n/s	n/s
Logarithms	n/s	sig.	n/s	n/s	n/s
Calculating things mentally	n/s	n/s	n/s	n/s	n/s
Judging whether your answer makes sense	n/s	n/s	n/s	n/s	n/s
Basic Algebra e.g. rearranging and solving equations, using formulae	n/s	n/s	n/s	n/s	n/s
Using a calculator	n/s	n/s	n/s	n/s	n/s
Appreciating the size of number	sig.	sig.	n/s	n/s	n/s
Exponentials and Powers	n/s	sig.	n/s	n/s	n/s
Scientific notation	n/s	sig.	n/s	n/s	n/s
Unit conversion	n/s	n/s	n/s	n/s	n/s
Reading scales (measurements)	n/s	sig.	n/s	n/s	n/s
Integration	sig.	n/s	sig.	sig.	n/s
Differentiation	sig.	n/s	n/s	sig.	n/s
Interpreting/transforming data from Graphs	n/s	n/s	n/s	n/s	n/s
Interpreting/transforming data from Spreadsheets	n/s	n/s	n/s	n/s	n/s
Interpreting/transforming data from Charts and Tables	n/s	n/s	n/s	n/s	n/s
Molarity	n/s	n/s	n/s	n/s	n/s
Basic Statistics e.g. mean, mode, median, standard deviation	sig.	n/s	sig.	n/s	sig.
Modelling e.g. understanding how variables interact, creating formulae	n/s	n/s	n/s	n/s	n/s
Communicating data	sig.	sig.	n/s	n/s	n/s

Student performance in self-assessment tests

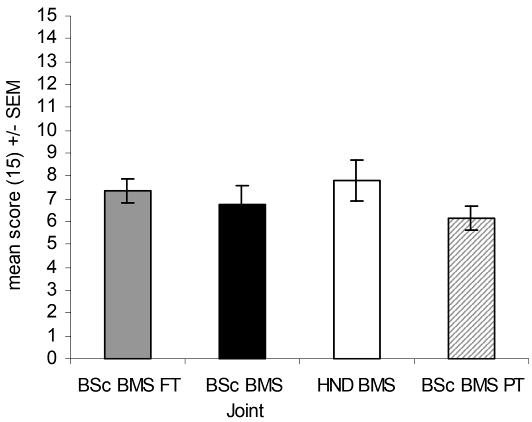
The mean score for students in the Biomedical Science Division indicate consistent levels of performance approximating to 50% correct responses for three of four self-assessment (SA) test themes. Performance in the algebra SA test is poor corresponding with low self-efficacy expressed by students. Staff and student perceptions are consonant for algebra.



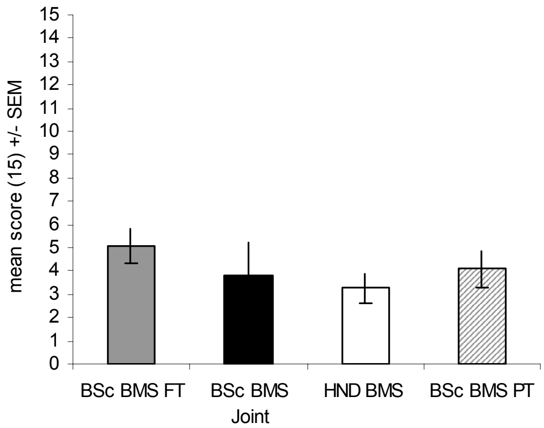
a) Size of things



b) basic numeracy skills



c) Applying numeracy skills



d) Algebra

Figure 1. Mean score (out of 15) ± SEM for Biomedical Science (BMS) cohort on each of four self-assessment tests analysed by Award (Nb FT= Full-time and PT= Part-time mode of study)

Benefits

This exploratory study contributes to the debate on attitudes and confidence in applying numeracy and the wider discourse considering declining standards of numeracy in HE entrants. Negative attitudes, low levels of confidence and dissonance in perceptions between students and staff may be incompatible with deeper approaches to learning.

This study provides a useful insight into the self efficacy and attitudes to numeracy in the context of Level 1 entry onto programmes of study in applied sciences. It also informs the development of embedded numeracy tasks within the curriculum. This situation analysis emphasises the importance of presage and should inform constructive alignment (Biggs, 2003, p. 11) of the Level 1 curriculum in the context of embedded applied numeracy tasks. Knowledge of 'affective' factors that influence performance in learning quantitative skills may help teachers change students' perceptions that numeracy is an obstacle to learning. This might reduce the need for teaching numeracy as a separate skill within the module, enabling a fuller engagement with the theoretical perspective of applied numeracy. In parallel, closer alignment of learner support in the area of numeracy may be facilitated, linking with development of more effective and flexible strategies that accommodate individual learner needs.

The study enables clear identification of those aspects of applied numeracy where dissonance in perception is noted between students and staff. This enables staff to reflect and challenge their own practice, facilitating a more strategic intervention and development of appropriate learning experiences.

Evaluation

The study revealed that a majority of students demonstrated positive attitudes to their prior learning experience in mathematics at both primary/first school and secondary/high school, 75% and 67% respectively (Table 1). This is consistent with previously reported findings for primary/first schools (Mackenzie, 2002); however the two-thirds of students claimed to have enjoyed maths at secondary/high school is in contrast to Mackenzie's findings. This may be a reflection of the cohort surveyed. In this study the students are Level 1 entrants onto a degree programme in applied sciences, consequently a more pragmatic view might be anticipated, with students viewing maths as integral to pursuing their chosen future studies. There is also widespread acknowledgement and recognition that numeracy is implicit both in terms of academic study and employability. This has positive implications for embedding appropriate quantitative tasks in teaching and learning activities and is important given the evidence that numeracy problems impact more negatively on job prospects than literacy problems (Bynner & Parsons, 1997).

Lack of confidence and negative attitudes, sometimes bordering on the irrational fear of 'all things numerical' (Tariq, 2003; Mackenzie, 2002), is reported by 32% of the students (Table 2). A greater proportion of those reporting concern were female (71%). Highest levels of concern are shared by Biosciences and EAS students (39%), a trend that is mirrored for avoidance, this may be linked to students opting to undertake academic studies in these areas with the notion that this is a way of studying science whilst avoiding the maths.

Despite the high level of confidence reported by the majority of the students, a dissonance in perception for the basic numeracy skills of multiplication, division and decimals is apparent, with staff expectation of confidence in ability to apply these skills significantly higher than students' perceived confidence (Table 3). This is of concern given the widespread infusion of such fundamental concepts in quantitative tasks both within the context of both degree and workplace and links in with the declining standards in numeracy reported by many authors. Interestingly, compared to staff, students report significantly greater levels of confidence with the more advanced mathematical skills of integration, differentiation and application of basic statistics. Dissonance in appreciating the size of numbers is also of concern, as many quantitative tasks are underpinned by this concept. Some students appear to have difficulty conceptualising and rationalising calculated values, demonstrating a greater trust in a calculator display, than their own judgement. Staff also expected a higher level of confidence to be displayed in communicating data, a key skill for scientists.

Reassuringly the majority of students report positive attitudes to maths and appreciate the academic and vocational relevance of numeracy; however evidence of concern about, and avoidance of, maths and lower levels of confidence in 'applied numeracy' are noted. Appropriate support and intervention strategies are required to empower the students.

Future developments

The relationship between students perceived levels of confidence in numeracy application, actual skills and progression need further investigation as the 'problem' of numeracy is a potential obstacle to effective learning, as self-efficacy beliefs can be predictive of subsequent capability (Bandura, 1986). It is hoped that this study will prompt wider evaluation of numeracy skills and attitudes and development of a discourse relating to numeracy issues pertinent to HE entrants. The following measures are recommended:

- Students should be given a linked self-assessment test, enabling autonomy in the process of identifying and reflecting upon what they can and can not do

- Existing numeracy support strategies will be reviewed and developed, acknowledging both students' perceptions and attitudes to numeracy and outcomes from self-assessment
- Good practice from across the University and HE sector in both face-to-face and virtual learning contexts e.g. www.mathscentre.ac.uk will be used to provide a learner support strategy that facilitates autonomy in identification of numeracy skills, enabling learners to self-assess and self-address confidence and competence via access to support resources
- Intervention will address emerging issues such as dyscalculia (Coben, 2003)

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Name: Award:

Theme: Number Skills Algebra

1. At a routine checkup, Emma Student's blood pressure is 133/86 mmHg (systolic/diastolic).
   a) calculate the Pulse Pressure (SP-DP) note: SP is systolic pressure; DP is diastolic pressure

   b) calculate the Mean Arterial Pressure (MAP = DP + 1/3(SP-DP))

2. $E_X = \frac{RT}{zF} \ln \frac{[X^+]_{ECF}}{[X^+]_{ICF}}$

Assume that RT/zF = 26.6

Table 1

Ion	Concentration mmol/l	
	ECF	ICF
Na^+	156	13
Cl^-	130	9.5
Ca^{2+}	1	0.1
K^+	5	160

Where:
E_X = equilibrium potential for the ion mV
R = Universal gas constant
T = absolute temperature (K)
Z = valence
F = electrical constant (Faraday)
$[X^+]_{ECF}$ = concentration of ion in ECF
$[X^+]_{ICF}$ = concentration of ion in ICF

Using the Nernst equation and the data in Table 1 calculate the equilibrium potential in mV for
a) sodium (Na^+) b) calcium (Ca^{2+})

3. y = mx + c is the equation for any straight line, what is the value of x, when y=2, m=3 and c=-2?

4. The volume of a spherical droplet of fat is 0.0624 cm^3, calculate its surface area?
Clue: surface area of sphere = $4\pi r^2$ and the volume = $\frac{4}{3}\pi r^3$

5. Solve (i.e. find what *m* =) for the equation $\frac{2m-3}{4} = \frac{4-5m}{3}$

6. Calculate the co-ordinates of the point where the straight line y = x – 2 intersects the curve $y = x^3 + x + 6$

How confident are you with the answers you have given? ☐ (15)

Things that went well?	Things that didn't go so well?

Useful Resources:

Counting on numbers – squaring the numeracy divide
Adam Watts