Mathematical Literacy of Students in First Year of Medical School at a South African University.

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The literature pertaining to the definition of Mathematical Literacy (particularly in the Tertiary context) is briefly reviewed. A Mathematical Literacy questionnaire, designed in accordance with this definition, was administered to students entering the MBChB Program at a South African university in 2003. In general the level of Mathematical Literacy of Medical students is higher than that of entry-level Humanities students, and comparable with that of Science students doing Earth or Biological sciences. The response to the results of this testing, in terms of curriculum interventions in the first year of MBChB, are outlined and their degree of success is evaluated. The post-testing of the MBChB students indicated a statistically significant increase in the Mathematical Literacy of these students.

Introduction

Many matriculants enter universities without the necessary mathematical literacy, language competence or computer literacy to enable them to succeed in their chosen course of study or career. It is generally assumed that a learner who has studied mathematics to a sufficiently high level in school will automatically be "mathematically literate" as well, which is not necessarily true. The results of the testing of the Mathematical Literacy of entry-level students in most Faculties at U.C.T reveal that there are many areas of weakness, the extent of which is generally surprisingly great, particularly for Medical students. The implications for University teachers is that more attention must be given to ways of integrating development of the necessary Mathematical Literacy competencies into the university curriculum.

The Quantitative Literacy Test Project at the University of Cape Town surveys the extent of the Mathematical Literacy of school-leavers who are registering for their first year of study in tertiary education. A questionnaire is administered, which is intended to measure the student's ability to interpret context-based information presented either verbally, graphically, in tabular or in symbolic form. In the first-year MBChB curriculum, this information was used to select students for extra Mathematical Literacy tutorials, and to inform the design of diagnostic testing questions, compulsory computer-based and classroom-based interventions.

What is Mathematical Literacy?

There is an ongoing debate about the meaning of the terms Mathematical Literacy, (Numeracy, or Quantitative Literacy), and its relationship to "Literacy" (and to "Mathematics"). The definition that underpins the work of the Numeracy Centre at U.C.T is as follows:

> *Mathematical Literacy is the ability to manage situations or solve problems in real contexts, and involves responding to quantitative (mathematical and statistical) information that may be presented verbally, graphically, in tabular or symbolic form. It requires the application of a range of different knowledge, behaviours and processes and it can be observed when it is expressed in the form of a communication, in written, oral or visual mode.*

This definition has evolved through the experience of working with students and designing curriculum interventions at the tertiary level, and is informed by the work of various authors. (Kemp (1995),

Chapman & Lee (1990), Baker, Clay & Fox (1996), Hughes-Hallet (2001) and The Adult Literacy and Lifeskills Survey, amongst others)

Hughes-Hallett (2001) stressed the importance of "real contexts" in a definition of Mathematical or Quantitative Literacy as follows:

> "…Mathematics focuses on climbing the ladder of abstraction, while Quantitative Literacy clings to context. Mathematics asks students to rise above context, while Quantitative Literacy asks students to stay in context. Mathematics is about general principles that can be applied in a range of contexts; Quantitative Literacy is about seeing every context through a quantitative lens."

This idea that an important component of Mathematical Literacy is the ability to operate within a real context, is mentioned throughout the literature; yet the current dominant practice (particularly in South Africa) is to teach Mathematical Literacy in the restricted context of the formal Mathematics classroom. Very often the closest learners get to context-based Mathematical Literacy is the exposure to contrived "real-life" examples masquerading as "reality" in the mathematics classroom (Usiskin, 2001). In learning Mathematical Literacy, the contexts themselves need to be understood as clearly as the mathematical "skills" that are applied within the context. This is why students often find a context-based Mathematical Literacy course quite challenging, even if the mathematical skills required are fairly elementary (Archer, Frith, Prince, 2002).

According to the definition, it is a mistake to view Mathematical Literacy as a set of identifiable arithmetic skills and it should not be seen as a set of techniques that can be taught and learnt without reference to the social contexts where they might be applied. Baker, Clay and Fox (1996) use the term "numeracy" to mean "the collection of numeracy practices that people engage in – that is the contexts, power relations and activities – when they are doing mathematics".

The definition stresses that mathematically literate behaviour can be thought of as a practice involving the exercise of several related competencies. Chapman and Lee (1990) go so far as to argue that it is not possible to make a separation between the notions of Numeracy (Mathematical Literacy) and Literacy, but rather that Numeracy should be situated within a larger notion of Literacy that involves many competencies:

> "The problem of recognising the need for and applying appropriate mathematics in non-mathematical contexts arises precisely because the skills of reading, writing and mathematics are inextricably interrelated in the ways in which they are used in communication and hence in learning."

Kemp (1995) argues that Mathematical Literacy includes the ability to communicate clearly and fluently and to think critically and logically. In dealing with quantitative or mathematical ideas in context, students should be able to interpret ideas or messages presented either verbally, graphically, in tabular or symbolic form, and be able to make transformations between any of these forms. She stresses that the tertiary curriculum makes great demands on students' Mathematical Literacy.

Initial testing of Quantitative Literacy of Medical students

Over the last four years, the Numeracy Centre has carried out extensive testing of incoming students, in Humanities, Law, Commerce, Health Sciences and Science Faculties, which has provided statistically sound evidence for the extent of the problem. These tests have shown conclusively that

many students lack quite basic quantitative literacy which school-leavers are usually assumed to possess. (Frith, Bowie, Gray & Prince, 2003)

Method.

In 2003 (as in other years) all students in the Health Sciences Faculty filled in a "Quantitative Literacy Questionnaire" (QLQ) during Orientation Week, which was administered under examination conditions. There was no time-limit imposed on the writing of the test; some students taking as little as 30 minutes to complete, others taking up to 2 hours. The questionnaire is intended to measure their knowledge of some of the mathematical literacy content that is often assumed by university first-year course curriculum designers.

The questionnaire consists of three sections, which differ in complexity:

- Section A consists of easy multiple choice questions requiring basic numerical ability, (mostly involving fractions, decimals and percentages) and a low level of interpretative skill.
- Section B consists of a theme question involving the use of diagrams, tables and graphs. The questions are organized around a particular context (provision of services and quality of life in South Africa in 2003). This is the part of the test where the mathematical literacy is tested most coherently, and the ability to interpret and reason logically about information presented verbally, graphically and in tabular form is emphasized.
- Section C has an example of the application of 'everyday' mathematical literacy, and also tests the understanding, use and construction of simple formulae in 'everyday' situations.

Each question has a score of between 1 and 3, depending on the level of difficulty of the question. This difficulty level is a reflection of the literacy, interpretative and computational skills required in order to answer the question correctly. The questionnaire has not been designed to provide a standardised score which would indicate whether a participant is "Mathematically Literate" or not, but rather to survey the competence of particular cohorts of students in a comparative way, and identify problem areas for curriculum intervention.

Results.

A summary of the results for the MBChB students on the test as a whole and for the different sections is given in Table 1. The distribution (of scores for the test as a whole) is illustrated in Figure 1.

Table 1. Results by section and overall for Medical Students on the Quantitative Literacy Questionnaire in February 2003.

	Mean	**Median**	**Min.**	**Max.**	**First Quartile**	**Third Quartile**	**Std. Dev.**
Section A	82%	85%	31%	100%	72%	92%	15%
Section B	69%	69%	37%	98%	60%	79%	14%
Section C	70%	70%	15%	96%	59%	82%	16%
Overall	73%	74%	37%	97%	64%	83%	12%

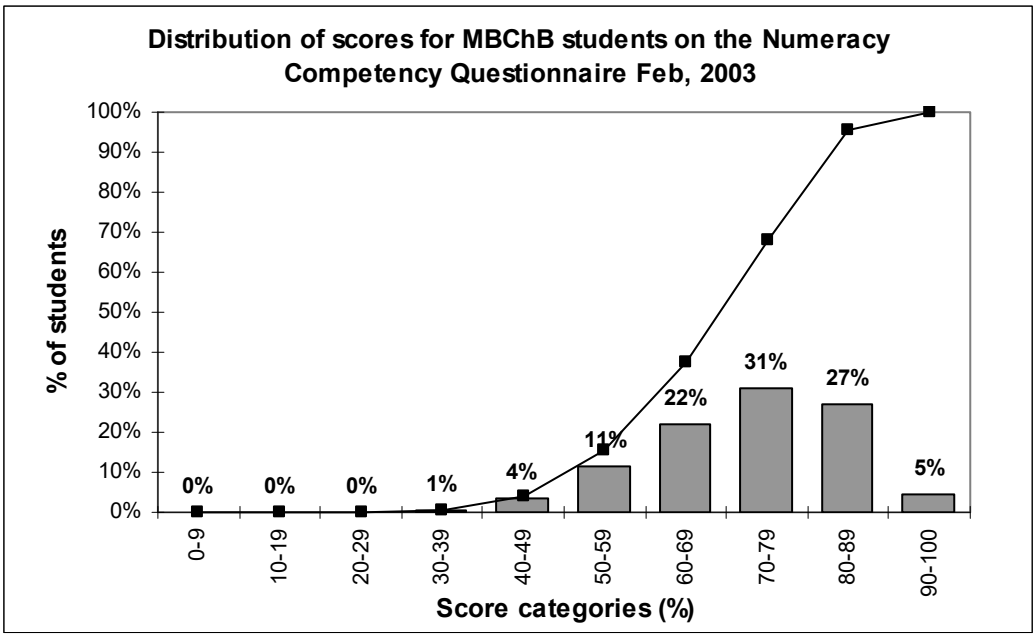

Figure 1. The distribution of scores for MBChB students on the whole Quantitative Literacy Questionnaire in February 2003 .

As one might expect, the distribution illustrated in Figure 1 (for Medical students) is somewhat better than that of Science students and considerably better than for Humanities students. However there is a tail comprising 38% of the students who scored less than 70%, and for whom their Quantitative Literacy is judged to be inadequate for the demands of their particular course of study. Considering that all these students have matriculated with Mathematics as a subject, this supports the statement that passing mathematics at school does not necessarily ensure that one is Mathematically Literate.

In order to determine particular areas of weakness, it is instructive to examine the percentage of students who answered correctly on individual questions (the facility values for the questions). Table 2 contains a brief description of each question for which the facility value was 70% or below. From this table it can be seen that some of the concepts that presented a high level of difficulty to entry-level Medical students were: ratios, calculation of percentage increase, the understanding that percentage change is not the same as change in absolute magnitude, graphical representation of growth rate and basic statistics. Since these are all competencies that are essential for the understanding of many of the contexts (and even some of the most basic texts) that Medical students encounter in first year, the results summarized in Table 2 are cause for concern. This led to an initiative where the staff of the Numeracy Centre became involved in providing interventions and curriculum advice in the Medical Faculty.

Table 2. Facility values (percentage correct) for selected question for all MBChB students on the Quantitative Literacy Questionnaire in February 2003. All questions for which facility was less than 70%.

Question.	Description of content.	Facility value %.	Comment.
Section A			
9	%, compound interest, 2 years	63	29% incorrectly calculated using simple interest
13	Approximation	63	37% could not find the best approximation
16	Ratio (given as a to b)	70	26% incorrectly interpreted as having total a, not (a+b)
Section B			
25	Comparing number of passes to pass rate	59	41% did not understand increase in number does not imply increase in rate (proportion)
29	Integrating information from a	11	87% incorrectly equated largest proportion with largest

	stacked bar and a pie chart		number
36	Interpretation of chart (total >100%)	68	32% did not see that totals on vertical axis >100% (text dense)
37	Comparing multiple bar charts	52	48% could not compare readings of 2 bars in one category
39	Using bars to compare change	33	67% equated increase in number with increase in proportion (text dense)
41	% increase	18	79% gave difference in percentage points, not % increase
43	Growth graphs - rate	63	37% could not select graph with highest rate
Section C			
48	Calculating cost for cell phone call	69	31% could not use table and text to calculate cost
50	Statistics - range	15	77% did not know statistical definition. of range
52	Understanding of median	49	51% could not find median of 5 unordered numbers
53	Mean, median and mode	42	58% did not understand these terms
56	Use of variable to express % increase	47	53% could not express a given% larger than N as a decimal fraction of N
60	Construct a formula (three variables)	51	49% could not construct a formula given an everyday problem using variables.

Interventions undertaken in first year curriculum.

In response to these results, various interventions in the first-year MBChB curriculum were carried out. The Quantitative Literacy Questionnaire results were used in two ways, first to identify students in need of extra tutorials to assist them with the Mathematical Literacy demands of their curriculum, and secondly to identify the concepts which where most in need of attention.

In the first semester, students who had achieved below 70% on the original Quantitative Literacy Questionnaire were obliged to attend two workshops which addressed the topics: ratio, percentage, percentage increase, frequency distributions, percentiles, and rate of change on graphs. The quantitative literacy concepts dealt with in the workshops, were embedded within the contexts of the integrated health sciences curriculum (for example birth and mortality rates, growth charts and distributions of birth weights) and were assessed in the class tests.

In the second semester, Workshops were held for the entire MBChB cohort roughly every two weeks, and the same principle of integration within the contexts of the health sciences curriculum was applied. In this case the quantitative literacy intervention was closely associated with the Public Health component of the curriculum. Some of the content topics covered were: interpretation of tables and charts, the normal distribution and basic statistics. In addition, all the students were obliged to complete a course of six 2-hour Excel-based interactive tutorials intended to develop their competence with and understanding of data representation and analysis, and with basic use of Excel for these purposes. Six of the questions asked in the student evaluation were of a general nature, asking student's opinions about the value of the learning experience, the appropriateness of learning to use Excel, the appropriateness of the contexts used and the effect on their confidence. The aggregate of the responses to these six questions were as follows. Of those who answered the questions, 62% percent were positive or strongly positive, 26% were neutral and only12% percent were negative (or strongly negative).

Post-testing of the Quantitative Literacy of Medical students

Towards the end of the second semester of the first year of MBChB, a post-test was administered in the same manner as the original Quantitative Literacy Questionnaire, to assist with the process of evaluating the effectiveness of the curriculum in developing students' Mathematical Literacy.

Method.

The post-test consisted of a subset of the questions from Sections A and C of the original Quantitative Literacy Questionnaire (QLQ) and some questions which matched those in Section B, but did not deal with the same context. It was designed to be completed within one hour. The questions selected for the post test included most of the ones that had proved to be most difficult in the original test. For the purposes of comparison between performance at the beginning and at the end of the year, the corresponding questions from the original Quantitative Literacy Questionnaire were defined as the pre-test. Correlations between the scores on the pre-test and post test were all significant at the 5% level, indicating a satisfactory degree of test-retest reliability. The Cronbach alpha coefficient for the pre-test and post test were 0.76 and 0.79 respectively, indicating satisfactory internal reliability for research purposes. (Finchilescu, 2002)

The number of students for whom there were both pre- and post-test results was 125. The results presented in the next section all refer to this cohort of 125 students (approximately 60% of the whole class, whose results on the original QLQ were reported above)

Results.

It can be seen from Figure 2 that for all sections, and for the test as a whole, there was an improvement in the scores, when the students are considered as a whole. Except for in Section A, the minimum score increased from the pre- to the post-test. In all cases there was an increase in the first quartile, median and in the third quartile, indicating a shift of the distribution upwards in all cases.

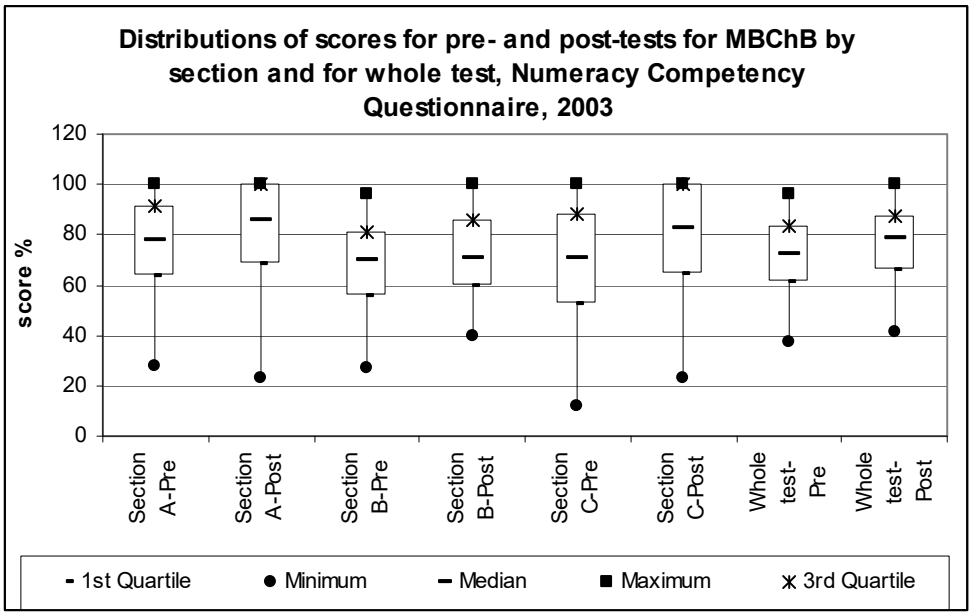

Figure 2. The distributions of scores for MBChB students on the QLQ pre- and post-tests in 2003. The distributions for the three different sections are presented separately, as well as the distribution for the whole test.

The changes in the values of the means for Sections A to C and for the test as a whole are shown in Table 3, together with the values for the Student's t-test statistic and the significance value (p-value) for the result of the test.

Table 3. Difference in mean results by section and overall for MBChB between the pre- and post tests in 2003.

	Mean	Std Dev.	Difference in Mean (Post - Pre)	t statistic	p-value
Section A (Pre-test)	77.27	18.71	3.27	2.02	0.046
Section A (Post-test)	80.54	19.83			
Section B (Pre-test)	68.19	15.12	4.51	3.39	0.001
Section B (Post-test)	72.71	16.01			
Section C (Pre-test)	70.54	23.81	7.53	4.41	0.000
Section C (Post-test)	78.07	19.15			
Overall (Pre-test)	71.19	14.41	5.08	5.28	0.000
Overall (Post-test)	76.27	15.15			

The differences in the mean values for Section B, Section C and the whole test are 4.5, 7.5 and 5.1 percentage points respectively, in all cases having an extremely high level of statistical significance. For Section A, the difference is 3.3 percentage points, with a confidence level of just over 95%.

Considering changes in the mean score for the whole cohort for the whole test, does not yield information about changes in performance on individual questions or changes in the performance of particular sub-groups of students. Figure 3 shows the change in facility values between the pre- and post-test for five of the (more difficult) questions highlighted above (in Table 2), for both the whole cohort and for the students who scored below the 25% percentile on the pre-test.

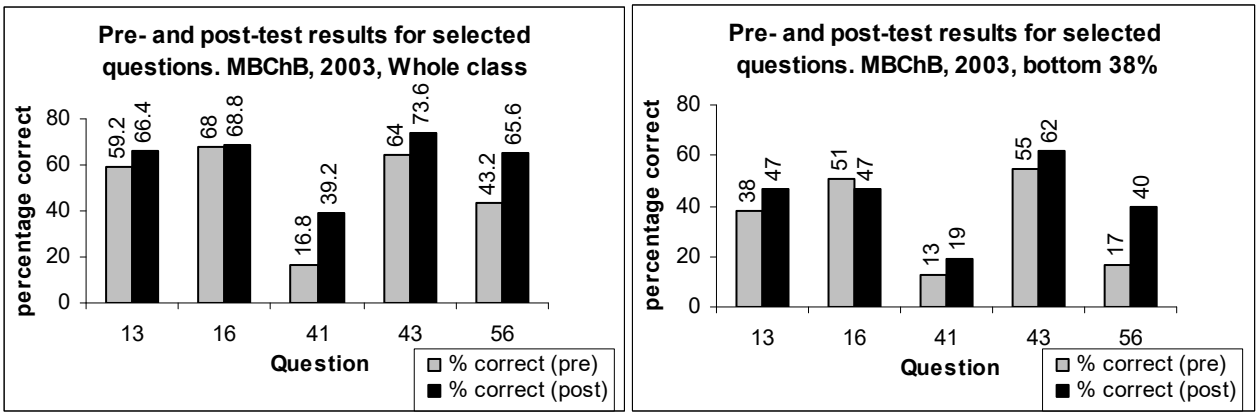

Figure 3. Scores on selected questions for MBChB students on the QLQ pre- and post-tests in 2003. Whole class (left) and students who scored below 70% on Pre-test (right).
(Questions: 13 - approximation; 16 - ratio; 41 - concept of % increase; 43 - rate on graph; 56 - calculation of % increase)

Although there is an improvement in the scores in all cases illustrated (except question 16), they are not as large as might have been hoped. The topic that appears to have been learned most successfully is the calculation of percentage increase, while the problems with working with ratios appear to have

persisted. Ideally one would like to see at least 70% of all students answering correctly on all items in the test. This presumably indicates that limited interventions in the form of irregular workshops are not sufficient, particularly for the weaker students. This supports the introduction of weekly workshops, which are planned for MBChB first-years in 2004

Conclusions

The Quantitative Literacy Questionnaire is a useful diagnostic tool for identifying students in need of extra Mathematical Literacy interventions in the MBChB program. These were judged to constitute 38% of the MBChB cohort. The questionnaire is also useful for curriculum design, in terms of identifying concepts and contexts with which the students have the most difficulty. Interventions carried out in the MBChB program with the intention of addressing the identified deficits in Mathematical Literacy, were evaluated using a Quantitative Literacy post-test. This revealed moderate statistically significant improvements in scores for the test as a whole, and for the different sections of the test considered separately. There was also a moderate improvement in the percentage of students answering correctly for specific individual questions (on topics that students found most difficult in the pre-test) both for the class as a whole, and for the students who scored below 70% on the pre-test.

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