A framework for understanding the quantitative literacy demands of higher education

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Abstract
For many students entering higher education in South Africa there is an articulation gap between the demands of the curriculum and their competencies. This mismatch is particularly critical in the area of quantitative literacy (mathematical literacy, numeracy) and if not addressed, has negative consequences for equity of outcomes for higher education. There is a need to make explicit the quantitative literacy demands of the curriculum so that they can be examined critically and addressed by educational interventions and other curriculum changes. We describe our approach to characterizing the quantitative literacy demands in curricula in disciplines, by presenting a framework for analysing aspects of quantitative literacy events in the curriculum. This is useful for helping educators to recognize the demands on students' quantitative literacy (and assumptions about students' competencies) that are often implicit in their curricula, for the purpose of informing the design of education interventions and for developing test constructs.

INTRODUCTION

The practice of quantitative literacy (numeracy) in people's work, education and daily lives has assumed increasing importance in the last few decades, as most areas of society have become imbued with numbers and quantitative approaches to problems (Steen 1999). 'Indeed, what the printing press did to increase people's need for literacy, so the computer has done for numeracy' (Steen 2001, 10). Due to the powerful and dominant role played by quantitative methods in many areas of society, citizens need to understand and practice these methods effectively and critically in various contexts.

The importance of the role of quantitative literacy (or mathematical literacy) in higher education curricula is increasingly being recognized (Kemp 1995; Chapman 1998; Schneider 2004; Yasukawa 2007; Frith and Prince 2006a). Quantitative literacy (also known as numeracy) is not the same as mathematics and the distinctions have been well described (Hughes-Hallet 2001; Madison 2004; Johnston 2007; Frith and Prince 2006b). Many academic disciplines make significant demands on students' quantitative literacy, even in disciplines such as in Law and Humanities, which may not appear to be quantitative in nature. Quantitative disciplines, such as in Engineering and Sciences, make complex demands in terms of quantitative literacy, for which traditional mathematics courses do not necessarily prepare students adequately (Hughes-Hallet 2003).

In South African universities, many students entering higher education are unprepared to meet the quantitative literacy demands inherent in university curricula (Prince, Frith and Jaftha 2004). For example, in a quantitative literacy test administered to entering medical students in 2008, 50 per cent could not read a ratio (expressed per 100 000) off a table and convert the value to a percentage (Prince, Frith and Jaftha 2008). The level of unpreparedness illustrated by this example is largely as a result of educational disadvantage, attributable to the structure and history of the education system in our country (Scott et al. 2005; Scott et al. 2007). The consequences are often most starkly evidenced in the quantitative competencies of the students. For example Scott et al. (2007) report that in 2003 only 27 per cent of the students who passed Higher Grade mathematics were black, even though blacks comprise 78 per cent of the population. (In South Africa it is common to use race-based criteria when discussing the effects of past inequalities). These inequities in the outcomes of schooling, lead to inequity of access, but also if they are not addressed explicitly by the university curriculum, to inequities of outcomes of higher education, which are both economically and socially unacceptable. Scott et al. (2007) report, for example, that the completion rates after five years in South African universities in a variety of disciplines are approximately twice as high for white students as for black students. Thus paying attention to the quantitative literacy demands of the higher education curriculum is an important element of a strategy to address inequity and to improve educational outcomes.

There is a need for systematic approaches to curriculum changes which will reduce the 'articulation gap' (Scott et al. 2005, 273) which exists in many cases, between the quantitative literacy demands of curricula and the quantitative literacies of the students. For university lecturers, who are competent practitioners in their discipline, including its quantitative aspects, it is difficult to see explicitly what the quantitative demands of the discipline are. Their own quantitative literacy practice in their discipline is so fluent, that the quantitative literacy embedded in it can be quite transparent to them. This often makes it difficult for a lecturer to recognize (without assistance) the assumptions they are making about students' quantitative literacy and when it is these assumptions that are setting up barriers to learning. There is a

need to make the implicit demands of the curriculum explicit, both for lecturers and students.

Part of our role in the Numeracy Centre at the University of Cape Town, is to engage in discussion with lecturers to help them to recognise and respond to the quantitative literacy requirements embedded in their curricula. A framework for systematically describing quantitative literacy events embedded in the curricula of disciplines, for example in Health Sciences, Humanities or Law, makes this kind of work more productive, as it provides a structure for making explicit the quantitative demands of the curriculum and identifying barriers that these demands may be presenting to students. A framework of this kind can also be used to assist in the design of quantitative literacy interventions run by the Numeracy Centre, either in the form of dedicated quantitative literacy courses (Archer, Frith and Prince 2002) or in the form of quantitative literacy interventions (workshops or tutorials) provided within other courses (Frith, Jaftha and Prince 2005). A similar framework has been used for defining a test construct for quantitative literacy as a test domain (Frith and Prince, 2006a).

In this article we will present our framework for identifying and describing elements of the quantitative literacy competencies demanded by the curriculum of a discipline. We will demonstrate its application in the area of first year medical studies. We foresee that its application need not be restricted to Higher Education curricula. We will begin with a brief outline of the theory underlying the framework.

PERSPECTIVES ON QUANTITATIVE LITERACY

The term 'quantitative literacy' is preferred in the USA, while the term 'numeracy' is most often used in the UK and Australia. In South Africa the term 'mathematical literacy' refers to the same concept and is also used as the name for the school subject. In this article we will use the term 'quantitative literacy' and would think of it as being interchangeable with 'numeracy' and/or 'mathematical literacy' (but not the school subject).

We conceptualise quantitative literacy as a social practice in which people manage situations or solve problems involving quantitative information. We prefer to think of quantitative literacy as social practice, in the same way that the New Literacies Studies see literacy as a social practice. Street and Baker have written a number of articles (Street 2005; Street and Baker 2006) developing the idea of quantitative literacy as social practice. Lave (1988) is also an important originator of this conceptualisation of numeracy. In higher education there are different quantitative literacy practices associated with different academic disciplines, to which the curriculum introduces students and in which students in those disciplines need to become competent practitioners.

Johnston (2007) and Yasukawa (2007), while also conceptualising numeracy as social practice, focus on the individual's critical awareness, defining numeracy as 'a critical awareness that builds bridges between mathematics and the real world'

(Johnston 2007, 54). This definition they derive from their work with basic adult education as well as with students in higher education. It is desirable for students to develop the ability to ask critical questions about the use of data and mathematics, 'in whose interest' type questions, and also questions about the appropriateness and limits of the maths model in the real situation' (Johnston 2007, 53).

In South Africa for the Further Education and Training curriculum (the last three years of formal schooling), the definition of 'Mathematical Literacy' is as 'a subject driven by life-related applications of mathematics' (Department of Education 2003, 9). If we think about quantitative literacy in Higher Education from this perspective, we focus on those 'life-related' applications that occur within the 'life' of academic disciplines. What is clear, regardless of one's preferred definition, is that quantitative literacy must not be seen as merely a set of generic mathematical skills and techniques. To use a very simple example, there is very little use in knowing how to calculate the mean of a collection of numbers without the ability to recognise when it is appropriate to do so, or to be able to recognise when it has been done inappropriately.

In Higher Education, students have to practice quantitative literacy in different curricular contexts and within different disciplinary practices. The quantitative literacy demands of the curriculum are often not recognised explicitly. This means that sometimes unrealistic assumptions are made about the students' preparedness for dealing with quantitative elements in the curriculum.

A common error is to assume that students who have done mathematics will necessarily be quantitatively literate. Quantitative literacy as defined above can be seen to require the exercise of competencies which it cannot be assumed that exposure to the study of the discipline of mathematics will have developed. For example, students study little statistics in the school Mathematics curriculum, but many of the quantitative literacy demands of many disciplines are in this area (Hughes-Hallett 2001). Furthermore, the mathematics curriculum includes very little practice within life-related (or other) contexts and does not focus on 'critical engagement' (Johnston 2007, 53).

QUANTITATIVE LITERACY EVENTS (NUMERACY EVENTS)

The concept of a 'quantitative literacy event' provides a useful unit of study for analysing the quantitative literacy needs of students and when analysing or designing curricula. The idea of a 'numeracy event' has been expanded in various articles by Street and Baker (for example Street and Baker 2006). They define numeracy events as 'occasions in which a numeracy activity is integral to the nature of the participant's interactions and their interpretative processes' (Street and Baker 2006, 221).

The framework described in this article attempts to generalise the description of the various competencies that are brought to bear by an individual (or groups of individuals) when they engage with a quantitative literacy event within the higher education environment. The intention is to develop a perspective on quantitative

literacy events that will make the different quantitative literacy demands of the curriculum more explicit.

In this article we illustrate the application of the framework by demonstrating its application to a particular event, selectively observed through the analysis of the learning materials made available to students for a tutorial discussion. This approach allows us to describe in detail the competencies required by a student in order to successfully engage with the materials in the manner intended, but can provide only a limited picture of the overall social and curricular context of the real quantitative literacy event. This context is determined by a multitude of factors, such as the composition of the student groups, their mood, the manner in which the material is presented, their perception of how it will be assessed, the tutors' modes of interaction, the placing of the tutorial in the overall curriculum, how much relevant background material they have been exposed to, the time of day, and so on. All these contextual factors have an influence on the nature and educational effectiveness of the event, which is not revealed by studying only the learning materials provided. Nevertheless, analysing the aspect of the event concerned with students' behaviour when they engage with the material provides a rich source of information useful in making explicit the implicit quantitative literacy demands of the event.

THE ROLE OF MATHEMATICS AND STATISTICS IN QUANTITATIVE

LITERACY

There are close parallels between quantitative literacy (numeracy) and literacy, if both are construed as social practices. However one can also argue that '… there are levels at which literacy and numeracy as conceptual entities are not parallel' (Kelly, Johnston and Baynham 2007, 45). Quantitative literacy events cannot be successfully engaged with, without also engaging in some of the practices of the disciplines of mathematics and statistics themselves: '. . . the analogy with literacy is not uniform; there are distinctive features of maths that cannot simply be reduced to those of literacy' (Street 2005, 91). The level of the mathematical or statistical knowledge and competence required obviously depends on the context of the numeracy event – a quantitatively literate lawyer would need a high level of competence in probabilistic reasoning and a quantitatively literate engineer would require significant technical competence with mathematical techniques (Conversely, an engineer who is competent at all the mathematical techniques is not necessarily quantitatively literate).

For some purposes, especially when using a framework to define a test construct, we have found it useful to include a dimension that specifies the mathematical and statistical 'big ideas' that are involved in a particular quantitative literacy event. We find the following six categories useful to describe the mathematical and statistical dimension:
• Quantity, number and operations
• Relationships, pattern, permutation

- Change and rates
- Shape, dimension and space
- Data representation and analysis
- Chance and uncertainty.

These categories are similar to the ones elaborated in the IALS framework (Gal et al. 2005) and are akin to the four 'learning outcomes' of the curriculum for the subject 'Mathematical Literacy' for the National Senior Certificate (NSC) (Department of Education 2003). We would choose to separate the learning outcome 'Functional relationships' from the NSC into two categories, because of the importance of understanding change and the description of change in many areas of higher education curricula. For a similar reason, we consider chance (probability) as a separate category from data analysis and representation.

A FRAMEWORK FOR DESCRIBING QUANTITATIVE LITERACY

EVENTS

Both the assessment of quantitative literacy and the study of quantitative literacy in the curriculum call for a descriptive and analytical framework. Our framework (Frith and Prince 2006a) has its roots in two other frameworks, one developed for the International Adult Lifeskills Survey (Tout 2007; Gal et al. 2005) and the other developed by Chapman (1998) for describing elements of the curriculum. It also draws on other frameworks such as PISA (OECD 2003) and TIMSS (Mullis et al. 2003).

The International Adult Lifeskills Survey (IALS) framework describes five facets of 'Numerate behaviour', namely: (1) managing a situation or solving a problem in a real context (2) by responding (3) to information about mathematical ideas (4) that is represented in a range of ways and (5) requires activation of a range of enabling knowledge, factors, and processes. What Chapman's framework adds, is an emphasis on the aspects of quantitative literacy that involve recognition, making connections, responding to signals, making judgements about what mathematics is appropriate, reflecting on the appropriateness of representations and so forth. These are steps that come between, say, reading a problem statement and starting to calculate. This framework also stresses the higher order thinking involved in aspects like reflecting on the effect of the use of mathematics and interpreting the reasonableness of results.

In our framework (Table 1) we concentrate on and attempt to expand the second IALS facet of 'responding'. We also elaborate the different kinds of representation (in the facet 'represented in a range of ways') and the different kinds of thinking that are required. In addition we extend the framework to include the ability to communicate quantitative ideas using different modes of communication.

We consider roughly in order the things that we expect a person would have to do in order to engage with a quantitative literacy event. The first category 'Knowing' refers to simple knowledge of the conventions of representation and vocabulary. We then consider the work of recognising what to do and where to direct one's

attention (as in the Chapman framework). The third category deals with making sense of representations, words and inscriptions. 'Doing the mathematics' refers to the application of mathematical or statistical techniques. In describing a quantitative literacy event, we want to guard against simply producing a list of mathematical skills required, so an important category in the framework is the kinds of reasoning and other higher order thinking that must be brought to bear. It is also important for the framework to describe the nature of the communication of quantitative ideas and information that the event requires.

Table 1: Framework for analyzing the quantitative demands in a quantitative literacy event

1. Knowing	• Knowing the meanings of quantitative terms and phrases (verbal representations). • Knowing the conventions for the symbolic representation of numbers, measurements, variables and operations • Knowing the conventions for the representation of quantitative information in tables, charts, graphs, diagrams and objects (visual representations).
2. Identifying and distinguishing	• Identifying connections and distinction between different representations of quantitative concepts • Identifying the mathematics to be done and strategies to do it • Identifying relevant and irrelevant information in representations.
3. Deriving meaning	• Understanding a verbal description of a quantitative concept/ situation/process • Deriving meaning from representations of data in context • Deriving meaning from graphical representations of relationships • Deriving meaning from diagrammatic representations of spatial entities • Translating between different representations.
4. Applying mathematical techniques	• Using mathematical techniques to solve a problem or clarify understanding -- for example: calculating, estimating, measuring, ordering, modeling, applying algebraic techniques etc.
5. Higher order thinking	• Synthesising information or ideas from more than one source • Logical reasoning • Conjecturing • Interpreting, reflecting and evaluating.
6. Expressing quantitative concepts	• Representing quantitative information using appropriate representational conventions and language • Describing quantitative ideas and relationships using appropriate language.

EXAMPLE OF AN APPLICATION OF THE FRAMEWORK

We will illustrate the framework by showing how it is used to gain insight into a particular quantitative literacy event which comprises part of a tutorial session for

students in a first year health sciences course. The framework is used to structure the analysis of the quantitative literacy competencies required for adequate performance in a task, through focussing on the 'text' (which consists of written explanation of theory, diagrams, a graph and questions) that demands the activation of the students' quantitative literacy practices. The 'text' comprises a part of the material provided to students as a basis for group discussions in a structured tutorial session. In the tutorial, students work in groups to study key concepts by attempting to answer questions provided. The whole quantitative literacy 'event' then is the engagement of particular students with their prior knowledge, with this particular text, with each other and with their tutors, in the context of the tutorial session in this particular course. We apply the framework to the text alone in order to gain insight into the aspects of the event concerned with the quantitative literacy competencies students would need to display in order to perform the task which is the core of this event in the manner intended by their lecturer.

The Haemoglobin-myoglobin event

The specific event we will use as an example of the application of the framework we will call the 'Haemoglobin-myoglobin event'. We will show how we apply the framework to study the 'text' provided to the students. This 'event' is one part of a biochemistry tutorial session for first year medical students at the beginning of their first course in biochemistry. The part of the tutorial we describe as an event is a set of questions that hinge upon understanding a text which describes and contrasts the 'oxygen-uptake' curves for haemoglobin and myoglobin. This text is typical of the kind of material students in the Sciences, Health Sciences and other technical fields must be able to comprehend and interpret. It consists of a graphical representation of the model of a relationship between variables in a real system (in this case, the human body) and a verbal explanation that uses considerable quantitative terminology.

The following extract contains the essential parts of one of the texts provided:

The haemoglobin of the erythrocytes in arterial blood passing from the lungs to the peripheral tissues is about 96% saturated with oxygen. In the venous blood returning to the heart, the haemoglobin is only about 64% saturated. The special properties of the haemoglobin molecule that make it such an effective oxygen carrier are best understood by comparing the O_2-binding or O_2-saturation curves of myoglobin and haemoglobin (see Fig 1).

From its saturation curve, it is clear that myoglobin has a very high affinity for oxygen. Furthermore the O_2-saturation curve of myoglobin is a simple hyperbolic curve …

… In contrast, the oxygen affinity of each of the four O_2-binding sites of deoxyhaemoglobin is much lower, and the O_2-saturation curve of haemoglobin is sigmoid. This shape indicates that whereas the affinity of haemoglobin for binding the first O_2 molecule is relatively low, the second, third and fourth O_2 molecules are bound with a very much higher affinity. This accounts for the steeply-rising portion

of the sigmoid curve. The increase in the affinity of haemoglobin for oxygen after the first O_2 molecule is bound is almost 500-fold.
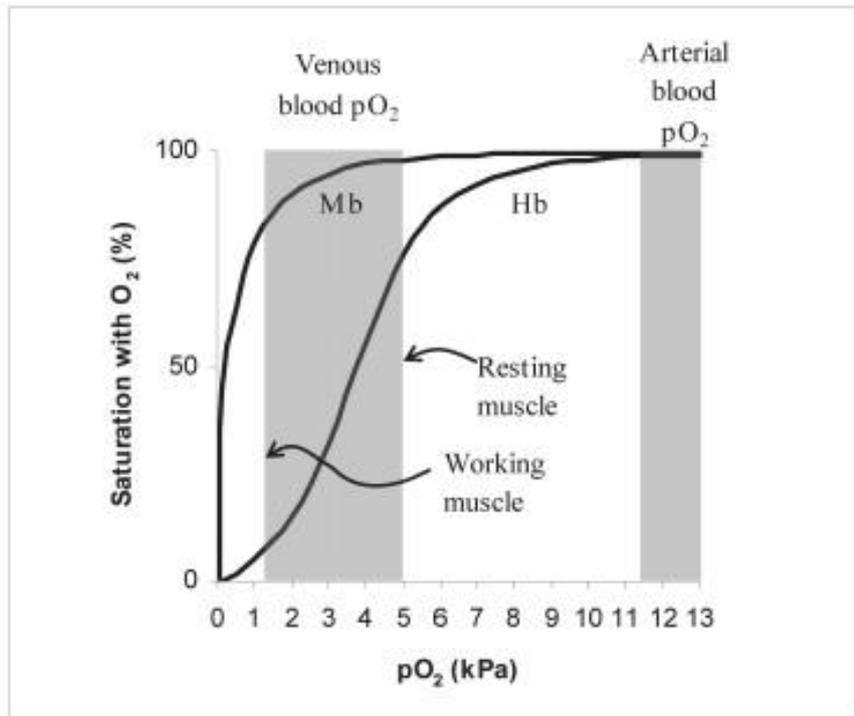

Figure 1: The oxygen-binding curves of myoglobin and haemoglobin

As part of the materials provided , students were also given diagrams of the molecular structure of haemoglobin before and after oxygen uptake. These are complex 2D representations of 3D molecular models and the relationships between the elements in the molecular structure.

The tutorial included the following tasks and questions for students to discuss, which refer to the material described above:
• Describe how the type of oxygen saturation curve for haemoglobin can be explained by the quaternary structure of haemoglobin …
• Explain why the oxygen saturation curve for myoglobin is not sigmoid
• Considering the oxygen saturation curves for myoglobin and haemoglobin, explain why haemoglobin is better suited than myoglobin for oxygen transport from lungs to peripheral tissues.

The mathematical and statistical 'big ideas' addressed by the Haemoglobin-myoglobin event

As an illustration, the Haemoglobin-myoglobin event could be analysed in terms of mathematical ideas as follows. This event primarily draws upon the mathematics in the categories 'Relationships, pattern, permutation' and 'Change and rates'. Understanding of the graphical representation mainly depends on recognising the

functional relationship between oxygen partial pressure and oxygen saturation of the molecules. Much of the understanding of the processes described depends on understanding the rate of change of saturation with respect to pressure. Other mathematical ideas used are 'Quantity, number and operations' (for example, understanding '5-fold increase', 96%); 'Shape, dimension and space' (describing the processes with reference to the quaternary structure of the molecules using the 2D diagrams of 3D molecular structures) and 'data representation and analysis' (the graphical use of the coordinate plane).

Application of the framework to the Haemoglobin-myoglobin event

(Throughout this section it may be necessary for the reader to refer to the text and Figure 1 under the heading 'The Haemoglobin-myoglobin event' above).

Knowing

This refers to simply knowing the quantitative terms and phrases, the symbols and the visual conventions, so that the student can access the meaning. (For second-language students this can be the stumbling block, even if they are quite mathematically competent).

Examples from the Haemoglobin-myoglobin event

Knowing the meanings of quantitative terms and phrases (verbal representations)
Examples of quantitative terminology used in the text are: "… The steeply-rising portion of the sigmoid curve …"; "The increase in affinity … is almost 500-fold".

Knowing the conventions for the symbolic representation of numbers, measurements, variables and operations
To understand the statement "The haemoglobin is about 96% saturated with oxygen" the student must know the convention for representing percentages.

Knowing the conventions for the representation of quantitative information in tables, charts, graphs, diagrams and objects (visual representations)
Accessing the information in the oxygen saturation curves for haemoglobin and myoglobin requires firstly an understanding of the conventions for graphical representation on a coordinate plane.

Identifying and distinguishing

This refers to the kinds of thinking that give access to understanding. It is about knowing what to pay attention to and when to pay attention. It also refers to the link between being able to understand a problem statement and being able to do the necessary mathematics or identifying the appropriate mathematics to do.

Examples from the Haemoglobin-myoglobin event

Identifying connections and distinction between different representations of quantitative concepts

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The student needs to:
- recognise and respond to the trigger to pay attention to the graph when reading the first paragraph.
- recognise the reference to diagrams in the third paragraph.
- recognise that the third paragraph goes on to link the diagrams with the graph.

Identifying relevant and irrelevant information in representations
The student needs to recognise that the vertical bands in the graph itself are not relevant to the understanding of this text.

Deriving meaning

This refers to all aspects of understanding, drawing needed information out of representations, making connections, interpreting between different representations and so on.

Examples from the Haemoglobin-myoglobin event

In order to understand the second paragraph, the student needs to interpret the phrase "high affinity for oxygen" with reference to the graphical representation.
Understanding the second sentence in this paragraph requires the student to apply mathematical knowledge about hyperbolic curves and the kinds of functions they represent and relate this to knowledge about reaction kinetics.
Understanding the beginning of the third paragraph requires associating the progression of binding the first, second, third and fourth molecules with the increasing oxygen partial pressure represented on the horizontal axis.
The reference to the "steeply rising portion" of the curve needs to be interpreted as a situation where there will be large increases in the amount of oxygen bound given only small increases in pressure, not as a dynamic rate with respect to time.

Applying mathematical techniques

This refers to applying purely mathematical or statistical techniques, such as calculating, plotting graphs or carrying out algebraic manipulations.

In the Haemoglobin-myoglobin event, although students apply an understanding of fairly advanced mathematical representations and concepts in order to understand the process of oxygen uptake, there is no requirement for them to carry out mechanical mathematical techniques, such as calculation or algebraic manipulation. This is typical of much of the quantitative literacy embedded in the curricula of disciplines such as biochemistry, physiology and many other disciplines in science and humanities. This relative absence of overt 'mathematical activities' often leads to the lack of recognition of the significant quantitative demands in many curricula, as people often naively equate quantitative literacy with 'doing calculations'.

Higher order thinking

It is hard to see how a person could be regarded as quantitatively literate, without the ability to synthesise information, reason logically, make conjectures and interpret, reflect and evaluate, at least at an appropriate level for their context. This kind of thinking seems to be fundamental for the idea of 'critical awareness' (Johnston 2007, 53).

Examples from the Haemoglobin-myoglobin event

Synthesising information or ideas from more than one source
To understand the overall process of oxygen transport from the lungs to the tissues, the student must be able to synthesise information derived from the diagrams of the molecules, from the text provided and from the representation of the oxygen-binding curve provided.

Logical reasoning
To "explain why haemoglobin is better suited than myoglobin for oxygen transport from lungs to peripheral tissues", the student must follow and recreate the logical argument contained in the text, (which is not presented in logical order in the text, but is scaffolded by the ordering of the questions).

Interpreting, reflecting and evaluating
In the process of discussing these questions to arrive at a situation where all members of the group understand the concepts, various students formulate arguments to address this task, while the other students in the group evaluate these arguments. They reflect on the explanation they have created in the light of the guiding questions and whether all steps of the argument have been adequately motivated.

Expressing quantitative concepts
The only evidence there is of quantitatively literate behaviour is in the form of some kind of expression or communication. This can be verbal (spoken, gestures, written) visual (graphs charts diagrams models or actual objects) or actions (giving the correct change in a transaction). In the academic setting it is more likely to be a written or spoken text with or without visual representations.

Examples from the Haemoglobin-myoglobin event

In answering the tutorial questions, the students communicate ideas, both verbally in discussion within groups, and on paper. Students sketch graphs and create verbal explanations, often using appropriate gestures. They also formulate written answers using formal language, such as would be acceptable in an assessment. To answer these questions students need to be able to use the appropriate terminology to describe the shapes of different graphs. This includes being able to express ideas about relative magnitudes and rate of change with respect to the values on the horizontal axis.

DISCUSSION AND CONCLUSION

We have proposed a framework for analyzing curriculum materials associated with academic quantitative literacy events, which makes the implicit quantitative literacy demands of the events more explicit, without reducing the description to a list of decontextualised mathematical skills.

We have used one example from a specific curriculum in the Health Sciences to illustrate how our framework can be used to analyse the quantitative demands of a quantitative literacy event embedded within a curriculum. The analysis focuses on the kind of thinking and behaviour that students are intended to practice when they engage with learning materials in a specified way in a collaborative learning environment. This kind of analysis makes explicit the expectations for, and assumptions about, students' quantitative literacy which are inherent in this curriculum event. This approach is similar to the one used by Chapman (1999) for analysing tasks in teacher education curricula.

Making explicit the implicit quantitative literacy in a curriculum is necessary and useful for all aspects of our engagement with quantitative literacy in the higher education curriculum. For example, to design interventions to address students' difficulties with quantitative literacy within specific disciplines, we need tools to analyse the demands of the discipline and make them explicit. This kind of explication is also useful to assist lectures in disciplines and Numeracy Centre staff to recognize and address the quantitative literacy requirements embedded in tasks they assign students. Being experts in their discipline, lecturers often find the quantitative demands of their discipline transparent, so that this kind of explication is necessary. We also use this kind of framework to develop constructs for diagnostic and other testing of students' quantitative literacy.

These various activities aimed at addressing the articulation gap between students' competencies and the demands of the curriculum are particularly important in the context of a higher education institution aiming to provide equity of outcomes in an educational landscape where so many students with potential to succeed are severely disadvantaged by poor schooling, linguistic and socio-cultural factors. This disadvantage almost invariably results in students' being inadequately prepared for the quantitative literacy demands of the curriculum in an age where quantitative capabilities are increasingly critical to success.

REFERENCES

Archer, A., V. Frith and R. N. Prince. 2002. A Project-based approach to numeracy practices at university focusing on HIV/AIDS. Literacy and Numeracy Studies 11(2): 123–131.

Chapman, A. 1998. Academic numeracy: Developing a framework. Literacy and Numeracy Studies 8 (1): 99–121.

———. 1999. Theoretical and practical integration of literacy and numeracy in a university academic programme. Teaching in Higher Education 4 (3): 363–383.

Department of Education, South Africa. 2003. National Curriculum Statement Grades 10–12 (General). Mathematical Literacy. Pretoria: Department of Education.

Frith, V., J. J. Jaftha and R. N. Prince. 2005. Interactive Excel tutorials in a Quantitative Literacy course for humanities students. In Integrating technology in higher education, eds. M. O. Thirunarayanan and A. Pérez-Prado, 247–258. Maryland: University Press of America.

Frith, V. and R. Prince. 2006a. Quantitative literacy. In Access and Entry Level Benchmarks, the National Benchmark Tests Project, ed. H. Griesel, 28–34; 47–54. Pretoria: Higher Education South Africa.

———. 2006b. Reflections on the role of a research task for teacher education in data handling in a Mathematical Literacy education course. Pythagoras 64:52–61.

Gal, I., M. van Groenestijn, M. Manly, M. J. Schmitt and D. Tout. 2005. Adult numeracy and its assessment in the ALL Survey: A conceptual framework and pilot results. In International adult literacy survey. Measuring adult literacy and life skills: New frameworks for assessment, ed. T. Scott Murray, Y. Clermont and M. Binkley. Ottawa: Statistics Canada. Available at: http://www nald.ca/fulltext/measlit/measlit.pdf. Accessed on 20 August 2008.

Hughes-Hallett, D. 2001. Achieving numeracy: The challenge of implementation. In Mathematics and democracy: The case for quantitative literacy, ed. L. A. Steen, 93–98. USA: The National Council on Education and the Disciplines.

———. 2003. The role of mathematics courses in the development of quantitative literacy. In Quantitative literacy: Why numeracy matters for schools and colleges, eds. B. L. Madison and L. A. Steen, 91–98. Princeton: National Council on Education and Disciplines.

Johnston, B. 2007. Critical numeracy? In The adult numeracy handbook. Reframing adult numeracy in Australia, eds. S. Kelly, B. Johnston and K. Yasukawa, 50–56. Sydney, NSW: Adult Literacy and Numeracy Australian Research Consortium.

Kelly, S., B. Johnston and M. Baynham. 2007. The concept of numeracy as social practice. In The adult numeracy handbook. Reframing adult numeracy in Australia, eds. S. Kelly, B. Johnston and K. Yasukawa, 35–49. Sydney, NSW: Adult Literacy and Numeracy Australian Research Consortium.

Kemp, M. 1995. Numeracy across the tertiary curriculum. In International Commission on Mathematics Instruction Conference on Regional Collaboration, eds. R. P. Hunting, G. E. FitzSimons, P. C. Clarkson and A. J. Bishop, 375–382. Melbourne: Monash University.

Lave, J. 1988. Cognition in practice. Mind, mathematics and culture in everyday life. Cambridge: Cambridge University Press.

Madison, B. L. 2004. Two mathematics. Ever the twain shall meet? Peer Review 6 (4): 9–12.

Mullis, I. V. S., M. O. Martin, T. A. Smith, R. A. Garden, K. D. Gregory, E. J. Gonzalez, S. J. Chrostowski and K. M. O'Connor. 2003. Trends in International Mathematics and Science Study (TIMMS). Assessment frameworks and specifications 2003. Second edition. Boston: International Association for the Evaluation of Educational Achievement and

International Study Center, Lynch School of Education, Boston College, US. Available at: http//timss.bc.edu/timss2003i/PDF/t03_af_book.pdf. Accessed 4 April 2008.

OECD, see Organisation for Economic Cooperation and Development.

Organisation for Economic Cooperation and Development. 2003. The PISA 2003 assessment framework – Mathematics, reading, science and problem solving knowledge and skills. Available at: http://www.pisa.oecd.org/dataoecd/46/14/33694881.pdf. Accessed on 20 August 2008.

Prince, R. N., V. Frith and J. J. Jaftha. 2004. Mathematical Literacy of students in first year of medical school at a South African university. In: Proceedings of the 12th Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education, eds. A. Buffler and R. C. Laugksch, 791–798. Durban: SAARMSTE.

———. 2008. Quantitative Literacy of students in the Medicine and Surgery (MBChB) programme at University of Cape Town in 2008. Internal Report. Numeracy Centre, University of Cape Town.

Schneider, C. G. 2004. Setting greater expectations for quantitative learning. Peer Review 6 (4): 4–8.

Scott, I., N. Yeld, J. McMillan and M. Hall. 2005. Equity and excellence in higher education. The case of the University of Cape Town. In Equity and excellence in American higher education, eds. W. G. Bowen, M. A. Kurzweil and E. M Tobin, 261–284. Charlottesville and London: University of Virginia Press.

Scott, I., N. Yeld and J. Hendry. 2007. Higher Education Monitor No. 6: A case for improving teaching and learning in South African higher education. Pretoria: The Council on Higher Education. Available at: http://download.che.ac.za/documents/d000155/HE_Monitor_6_ITLS_Oct2007.pdf. Last accessed on 2 June 2008.

Steen, L. A. 1999. Numeracy: The new literacy for a data-drenched society. Educational Leadership 57 (2): 8–13.

———. 2001. Mathematics and numeracy: Two literacies, one language. The Mathematics Educator 6 (1): 10–16.

Street, B. 2005. Applying new literacy studies to numeracy as social practice. In Urban literacy. Communication, identity and learning in development contexts, ed. A. Rogers, 87–96. Hamburg: UNESCO Institute for Education.

Street, B. and D. Baker. 2006. So, what about multimodal numeracies? In Travel notes from the New Literacy Studies, eds. K. Pahl and J. Rowsell, 219–233. Clevedon, England: Multilingual Matters Ltd.

Tout, D. 2007. Numeracy up front: behind the International Life Skills Survey. In The adult numeracy handbook. Reframing adult numeracy in Australia, eds. S. Kelly, B. Johnston and K. Yasukawa, 99–107. Sydney, NSW: Adult Literacy and Numeracy Australian Research Consortium.

Yasukawa, K. 2007. Teaching critical mathematics: some reflections from a teacher. In The adult numeracy handbook. Reframing adult numeracy in Australia, eds. S. Kelly, B. Johnston and K. Yasukawa, 228–232. Sydney, NSW: Adult Literacy and Numeracy Australian Research Consortium.