Quantitative Literacy as situated social practice in Higher Education

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Abstract: 'Mathematical literacy' is soon to be introduced as a subject in South African schools. This has generated numerous debates in various educational arenas, such as tertiary institutions and professional bodies. This paper looks at the differences between mathematics and Quantitative Literacy (QL) and examines the implicit QL demands and conventionalized QL practices in Higher Education curricula. Although certain practices are highly valued, they are not necessarily explicitly taught to students, especially those from non-dominant or disadvantaged positions in the power structures of the university and the society. This paper explores ways in which the implicit Quantitative Literacy demands can be made explicit and can be used to provide a rich environment to facilitate mathematical and statistical concept acquisition. We look at conventionalized practices in academic disciplines (focusing our analysis on the use of charts) and propose a number of principles of curriculum design.

Keywords: Quantitative literacy, Mathematical practices, Numeracy, Access to Higher Education

IN SOUTH AFRICA at the moment 'numeracy', 'mathematical literacy' or 'quantitative literacy' is a topical issue. 'Mathematical literacy' is soon to be introduced as a subject in South African schools and this has led to vigorous debates in various educational arenas regarding what this new subject should entail, who should teach it, how teachers should be trained or retrained. Programme committees in tertiary institutions are looking at the quantitative literacy (QL) demands made by the curriculum on students and how to respond to these. Professional bodies are also looking at what the QL demands of their professions are and how to improve the QL of their members, as well as their prospective members. However, Jablonka argues that "it is not possible to promote a conception of mathematical literacy without at the same time – implicitly or explicitly – promoting a particular social practice" (2003: 75). We are interested in identifying the implicit QL demands and conventionalized QL practices in Higher Education curricula, and the particular social practices that underlie these. Although certain QL practices are highly valued, they are not necessarily explicitly taught to students, especially those from non-dominant or disadvantaged positions in the power structures of the university and the society in which the university is embedded. In this paper, we look at implicit practices in academic disciplines, focusing on the use of charts and how these can be used to facilitate the acquisition of QL. We conclude by suggesting some principles for curriculum design.

The South African Context

In a new political dispensation in South Africa, we still have people who cannot aspire to mathematically demanding arenas of work, although mathematics is a highly valued practice. There is often an assumption that mathematics is neutral in its abstraction. However, all knowledge involves questions of power, as does mathematical knowledge and it is clear that mathematics was used in particular ways for particular purposes in the Apartheid era in South Africa. Just over 50 years ago the then Minister of Native Affairs, Dr H. F. Verwoerd, had the following to say about education: "When I have control over native education I will reform it so that the Natives will be taught from childhood to realise that equality with Europeans is not for them". He went on to say the following about teachers: "People who believe in equality are not desirable teachers for Natives". But his most telling remark in terms of mathematics was: "What is the use of teaching the Bantu mathematics when he cannot use it in practice? The idea is quite absurd" (Quoted in Vithal and Volmink 2005: 3). At about the same time as Verwoerd's statements, the Freedom Charter was adopted by the Congress of the People in Kliptown, South Africa and the slogan "The Doors of Learning and Culture Shall be Opened!" was on the lips of the South African youth in the 70's and 80's.

The situation is somewhat changed in the current context. South Africa has twelve years of schooling which currently culminates in a Matriculation Certificate (to be called a Further Education and Training Certificate (FETC) from 2008 onwards). The first nine years of schooling has mathematics as a compulsory subject for all students. Until the beginning of 2005, students entering the tenth year had three options. Those wishing to go on to mathematics, science and technology could choose to do mathematics on the 'higher grade'. Those wishing to follow less mathematically demanding careers could choose mathematics on the 'standard grade' or no mathematics at all. The vast majority of students have been opting for no mathematics for various reasons, both practical and affective, such as the subject not being offered at their particular school or anxiety around mathematics.

From 2006, students entering the tenth year of schooling have to choose between mathematics and mathematical literacy (See South African Department of Education National Curriculum Statement Grades 10-12, 2002). Thus, just more than 50 years after Verwoerd's utterances, all students will now do some form of 'mathematics' in their final three years of schooling. This prospect poses huge challenges, which include teacher training and producing appropriate textbooks. In terms of Higher Education at the moment, the South African government is steering this sector through funding graduates rather than funding entering students. At the same time, institutions are faced with the need to address equity. Professional bodies are also requiring their prospective members to be equipped for the challenges of their professions. In this climate, upfronting Quantitative Literacy at Higher Education level becomes imperative. Quantitative Literacy is not the same, however, as mathematics, and it is worth exploring some of the differences between them.

Differences between Mathematics and QL

Hughes-Hallet (2001) in *Mathematics and Democracy: The Case for Quantitative Literacy* suggests that there are three main differences between mathematical knowledge and QL. Firstly, she characterizes mathematics as requiring students to climb the ladder of abstraction which rises above context and contrasts this with QL which requires students to stay in context. Secondly, she argues that mathematics is about general principles that can be applied to a range of contexts, while QL is about seeing every context through a quantitative lens. Lastly, she maintains that statistics is the quantitative tool that is most likely to be encountered in all aspects of life and thus statistics is closer to QL than is traditional school mathematics. From the above characterization of QL it is clear that more mathematics does not necessarily lead to an improvement in quantitative literacy. We use the following definition of QL for Higher Education from Prince and Frith (2005): Quantitative Literacy is the ability to manage situations or solve problems in a real context, and involves responding to quantitative (mathematical and statistical) information that may be presented verbally, graphically, in tabular or symbolic form. It requires the activation of a range of enabling knowledge, behaviours and processes and can be observed when it is expressed in the form of a communication, in written, oral or visual mode.

Implicit QL Demands in Higher Education

In Higher Education in South Africa, mathematics is strongly linked with the subject 'mathematics' itself, science and technology, engineering and, to a lesser extent, commerce, where students have to take mathematics courses relevant to their programme of study. However, Higher Education curricula often also make quantitative demands on students that are not explicitly stated or understood. According to Gee (1996), valued practices are not taught to those who do not already know them, with the result that formal institutions continue to privilege the already privileged in society. Lillis argues that confusion is such an all-pervasive experience for non-traditional students in Higher Education that it signals an "institutional practice of mystery" (2001: 53). For some students also signal an "institutional practice of misery" which works against those least familiar with the conventions surrounding academic practices.

Particular practices become part of the everyday, implicit life routines of the individual and of social institutions. These institutional practices include knowledge-making practices within disciplines. Thinking of particular mathematical practices as socio-historically situated can draw attention to the contested nature of dominant conventions. For instance, in facilitating the acquisition of QL, one needs to be aware of and critical of the uses made of the representational mode. Arguments made with symbols and charts tend to be more highly valued than those made with words in certain disciplines, but also in popular discourses where they are used to legitimize information. For instance, a text may refer to 75% of people, where the percentage in fact only represents 3 out of 4 people. We will now look at graphs as an instance of situated social practice.

Charts as Situated Social QL Practice

Graphical representations are employed as a rhetorical means in publications to both construct phenomena as well as to provide proof of phenomena. Graphs can communicate information well in particular situations, but can also "leave the viewers as uninformed as they were before seeing the display or, worse, … induce confusion" (Wainer 1984: 137).

In Archer, Frith and Prince (2002) we argue that graphs are socially situated practices and do not emphasize, for example, judgement of the quality of the graphical representation as Wainer (1984) does in his twelve rules for displaying data badly or Tufte (2001) does in his nine points of graphical excellence. We argue that although a particular graph may not be mathematically or statistically accurate, it could effectively communicate a message to a given audience. In figure 1, a poster showing HIV/AIDS infection rates, the students chose from a range of semiotic resources to produce a message deemed appropriate for a particular audience. Although the chart entitled “Female HIV Infection Rate” may not be statistically accurate, the visual representation of the data has a specific impact. It manages to put a human face to the statistics, which is important in a discussion about HIV/AIDS where numbers can easily become a distancing mechanism. The accompanying written language also situates the audience strongly in relation to the numbers: “Stats show that 52% of newly infected females are between 20 and 24. This number is said to rise. How old are u?” Here mathematics is used to persuade as well as to inform.

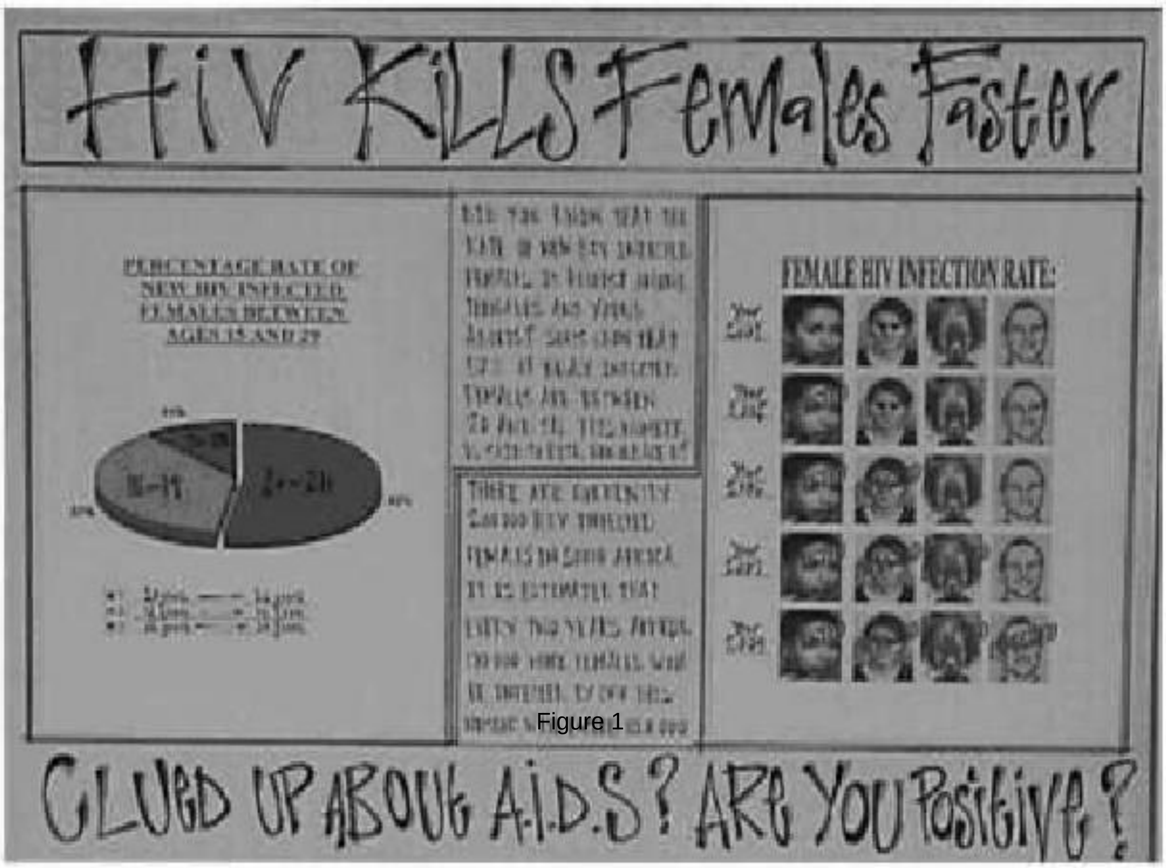


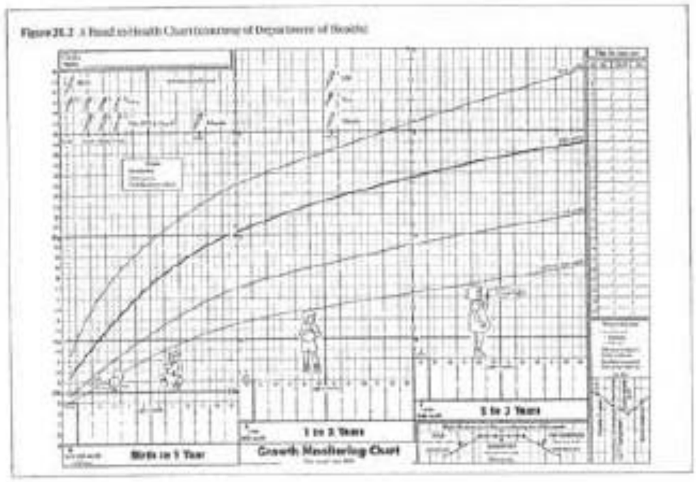
Figure 1

Roth and Bowen (2001) have conducted research based on the premise that graphs (and their written or spoken subtexts) are multimodal texts that are read by individuals of varying backgrounds. With their semiotic framework, they account for individual aspects of reading graphs and for the social matrix within which each individual operates. They identify two difficulties that students have in reading graphs. The first is difficulty with the structuring process (identifying aspects that signify) and the second, difficulties with the process of grounding signs in the world (2001: 185). We concur with Roth and Bowen that graphs contain little circumstantial information to ground signs in the world. Because graphs, like other signs, have arbitrary but conventional relations to the things they represent, one cannot elaborate their content without knowing these conventions.

Since we wish to exploit graphical representations for developing QL and graphical representations are only one aspect of larger disciplinary practices, we make a distinction between QL events and QL practice. Drawing on Street’s descriptions of numeracy events and numeracy practices, we describe QL events as “occasions in which a QL activity is integral to the nature of the participants’ interactions and their interpretative processes” and QL practices as the “discourse, the values and beliefs and the social relations that surround QL events as well as their context” (2005: 88).

We explore the extent to which growth charts (see figure 2 below) as a QL event in the first semester of the Health Sciences curriculum can be used to develop QL practices with Bachelor of Medicine and Bachelor of Surgery (MBChB) students.

Figure 2



Data from the measurement and study of the human body and its capacities are valuable objective indicators of attained size and physical growth in children. In looking at growth charts as situated social practice, it is interesting to look at the history of these charts. A variety of growth references developed and used in the United States have been used in South Africa since the early 1900s. However, according to Kuczmarski, Ogden, Guo most of these earlier references have considerable limitations, including “lack of coverage for infants and preschool children and limited representation of ethnic, genetic, socioeconomic, environmental, and geographic variability” (2002: 1-2). For instance, the Stuart/Meredith Growth Charts which were widely used were derived from data collected from 1930 to 1945 using white children living near Iowa City or in Boston, Massachusetts. However, the sample sizes were relatively small and the data did not represent the diversity of children residing in the United States. Also, the smoothed percentile lines were reportedly based on mathematical approximations of curves smoothed by hand instead of using statistical curve-fitting procedures. Having recognized the limitations of previous growth charts, a revised version of these were made available in 2000, namely the Centres for Disease Control and Prevention (CDC) Growth Charts.

In 2002, South Africa had an estimated infant mortality rate of 59 per 1000. Infant Mortality rate refers to the number of children less than one year old who die in a year, per 1000 live births during the year. We also had an estimated under five mortality rate of 100 per 1000. Under five mortality rate refers to the percentage of children born who die before the age of 5, per 1000 live births during the year. Even though HIV/AIDS was the leading cause of death among young children, accounting for 40.3% of the deaths in 2000, low birth weight, diarrhoeal diseases, lower respiratory infections and protein energy malnutrition accounted for a further 31.5% of the childhood deaths (Bradshaw and Nannan 2004). It is clear that in this context, the understanding and the use of growth charts is an important tool to screen and monitor growth in individuals and populations and is thus vital knowledge for prospective Health Science professionals.

QL Curriculum Development Opportunities Afforded by Growth Charts

Charts, in the same way as calculators and computers, are often treated as black boxes. They are reified (abstract, but considered to be real) and their construction is often rarefied (reserved for an elite group or reserved to be constructed using a software package). They are largely treated as a line chart or a time-series chart and a fair amount of misconceptions exist around what the lines mean. Growth charts are constructed, arbitrary conventionalized representational forms. In this section we explore how growth charts, as an example of a QL event, can be used to explore aspects relating to QL practice, in the Health Sciences in particular. See table 1 for an explanation of how growth charts, like so many other charts, enable us to explore with students the QL practices of the discipline. In sum, growth charts allow consideration of which statistics can be used to make sense of data, which tables and graphical representations can be used, how to go about creating these, how to use these in different circumstances. In addition, they can be used to focus attention on the influences on representational choices and the purpose to which the information is to be put.

Table 1: Curriculum affordances of growth charts

Awareness of audience	Growth charts allow the exploring of the notions of audience and context since they are used by a range of audiences (such as medical practitioners, doctors, nurses, parents from differing educational and socio-economic backgrounds) in diverse contexts (such as clinics and homes).
Communicating quantitative information	Growth charts allow for developing the ability to communicate about quantitative information for a range of purposes (such as to communities or parents about the growth of their children).
Representational choices	Growth charts allow for considering which tables and charts can be used to represent data, and in so doing, represent the situation. The representational choices are influenced by the intentions of the producers and the purpose to which the information is to be put.
Interpreting graphical representations	Growth charts allow for interpreting quantitative information in different representations (such as tables, charts, graphs and visuals) and to translate between these different representations of the same data.
Reading / using graphical representations. .	Growth charts allow for developing critical reading of graphical representations. They allow for developing an understanding of the context in which the graphical representation is situated and how graphical representations can be used a) to interpolate, b) to extrapolate, c) as a reference (describing what is) and d) as a standard (describing what should be).
Rhetorical uses of graphical representations	- Growth charts allow for developing knowledge about how graphical representations can be used in argument, as an explanatory tool, as evidence or as decoration.
Conventions of graphical representations	Growth charts allow for developing an understanding of the conventions for the representation of data in tables and graphical representations, as well as diagrams and other visual representations.
Process of quantification	Growth charts allow for quantifying aspects of humans (such as age, sex, weight, length, head circumference, stature), using and creating ratios and indices, such as Body Mass Index (BMI), that relates to physical growth.
Aspects of dimension and measurement	- Growth charts allow for developing aspects of dimension and measurement (such as age, sex, weight, length, head circumference and stature) that relate to human physical growth.
Turning data into information	Growth charts allow for developing an understanding that data on its own is not very useful until it has been used to create information. Statistics can be used to make sense of data (including mean, median, mode, range, percentiles, quartiles, inter quartile range, standard deviation). Also, which tables (including frequency and cumulative frequency tables) and graphical representations (including bar charts, scatter plots, line graphs) can be used and how to go about creating them.
Statistical concepts and techniques	Growth charts allow consideration of the statistical techniques (including sampling procedures, sample sizes and representative samples) as well as statistics (including mean, median, mode, range, percentiles, uartiles, inter quartile range, standard deviation) that are used to summarise data.
Use of technology	Growth charts allow consideration of the use of technologies such as calculators and software packages (statistical packages and spreadsheets at a basic level) to calculate and explore statistical concepts.
Uncertainty	Growth charts allow for developing the ability to appreciate that many phenomena (such as growth patterns and the diagnosis of certain illnesses) are uncertain and that the chance of uncertain events can be quantified using empirical data.

Principles for Curriculum Design

A typical teaching and learning intervention response to address both the explicit and implicit QL demands in growth charts for MBChB students would firstly entail assessing the levels of QL preparedness of the students (Prince, Frith and Jaftha 2004). Based on this knowledge, one could develop worksheets which introduce the underlying mathematics and statistics in growth charts and provide workshops to those students who have demonstrated low levels of QL where students will be given the space and opportunities to leverage resources to develop their own QL competencies.

We discuss general principles for curriculum design in Archer, Frith and Prince (2002). Some of these principles include:

- Framing QL as a particular practice in a particular context rather than a collection of discrete ‘skills’.
- Choosing the contexts for study carefully, as relevant and interesting to the people for whom the intervention is being designed.
- Incorporating a multi-faceted approach, where different knowledges and competencies can be utilized.
- Encouraging the production of multimodal texts as an outcome of QL practice, and not only the understanding and interpretation of existing texts.
- Building in scaffolding throughout the curriculum. This includes pre-tasks to develop the context, writing and computer competence.

Teaching and learning interventions are crucial to the development of QL in Higher Education. In preparing students for QL practice and the QL events of the discipline, it is important to assess students’ level of quantitative literacy in order to identify what students know well. Having done this, we can leverage resources more astutely toward the improvement of students’ opportunities to engage in QL practices and events.

Conclusion

The curriculum at Higher Education level makes both explicit and implicit cognitive demands on students. We need to guard against seeing QL as a set of definable skills. We need to understand both the QL practices of the discipline and the QL events that occur in the discipline and use these events, as a means for leveraging the existing knowledge of students towards those disciplinary practices.

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