Similarities and differences in the nature and role of contextualization in Mathematics, Mathematical Literacy and the Science South African FET Curricula

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This paper provides a documentary analysis of the nature and role of contextualization in the FET (Grades 10-12) subjects Mathematics, Mathematical Literacy and Physical Sciences. The analysis is framed by Bernstein's notion of classification and an adaptation of Graven's orientations to Mathematics. Key arguments within our analysis are that within the Science curriculum there is substantive emphasis on scientific literacy and citizenship. On the other hand the Mathematics curriculum focuses largely on the development of abstract mathematics necessary for further studies and assumes the development of mathematical literacy on the part of the learner rather than including this as a goal or outcome. Unlike scientific literacy which is included in the subject Physical Sciences, Mathematical Literacy

is offered as a separate subject, compulsory for those not taking Mathematics. This leads to a situation where Mathematical Literacy learners may have no exposure to scientific literacy in the FET band and Science learners may have little exposure to Mathematical Literacy in the FET band. Given that in the FET Mathematics/Mathematical literacy learning area, Mathematics is structured as the subject dealing with disciplinary development, and therefore, a more academic track, we argue that differential status is accorded to contextualisation within the Mathematics/Mathematical Literacy curricula. This contrasts with the Physical Sciences curriculum in which contextualisation is drawn within the bounds of the subject and integrated with the need for disciplinary development.

- Introduction

Contextualisation has emerged as an important theme internationally in both mathematics and science education (Cooper & Dunne, 2000; Yager and Tamir, 1993). This paper provides a documentary analysis of the nature and role of contextualization in the FET (Grades 10-12) subjects Mathematics, Mathematical Literacy (ML) and Physical Sciences. In particular we conduct a comparative analysis of the curriculum statements for each of these subjects. The analysis is framed by Bernstein's (1982) notion of classification (focusing particularly on the boundary between academic and everyday knowledge) and an adaptation of Graven's (2002) orientations to Mathematics as a tool for analysis of the nature and role of contextualization embedded in these subjects' documents.

Key arguments within our analysis are that within the Physical Sciences curriculum there is substantive emphasis on scientific literacy and citizenship and that the organization of this emphasis as one of three equally important learning outcomes has maintained a focus on contextualisation throughout the curriculum and exemplar assessment documents. Thus scientific contextualisation is incorporated within the disciplinary development frame of the subject, and viewed as an important and visible feature of what students looking at a trajectory into further study related to the subject need for access. Green and Naidoo (2006) further argue that the incorporation of the context into the disciplinary frame of the subject becomes overshadowed by the need to study science for its social constructionist and utilitarian worth. Ramsuran (2005) considers that a universal notion of scientific literacy has been adhered to in the curriculum with very little attempt to localize the definition.

On the other hand the Mathematics curriculum focuses largely on the development of abstract mathematics necessary for further studies and largely assumes the development of mathematical literacy on the part of the learner rather than including this as a goal or outcome. Unlike scientific literacy which is included in the subject Physical Sciences, Mathematical Literacy is offered as a separate subject, compulsory for those not taking Mathematics.

The framework for analysis

Our analysis of the curriculum documentation is framed by Bernstein's (1982) notion of classification (and its centring on integration). In Bernstein's (1982) terms we argue that classification is overtly weakened in the Mathematical Literacy curriculum as well as in the Physical sciences curriculum through the increased emphasis on integration with environmental and/or 'everyday contexts'. We elaborate on this in the next section. Classification refers to the degree of 'boundary strength' between areas of learning. However it does not simply refer to what is classified but also to the relations between these areas of learning.

"Classification refers to the nature of differentiation between contents. Where classification is strong, contents are well insulated from each other by strong boundaries. Where classification is weak, there is reduced insulation between contents, for the boundaries between contents are weak or blurred" (Bernstein, 1982, p.159).

Earlier analysis by Graven (2002) of the introduction of Mathematical Literacy, Mathematics and Mathematical Sciences (MLMMS) in Curriculum 2005 for the GET band of schooling (Grades 1-9) identified four different mathematical orientations. The four orientations identified in MLMMS (and in supporting documents such as illustrative learning materials, teacher guides, and texts) were:

1. Mathematics for critical democratic citizenship. It empowers learners to critique mathematical applications in various social, political and economic contexts.
2. Mathematics is relevant and practical. It has utilitarian value and can be applied to many aspects of everyday life.
3. Mathematics as induction into what it means to be a mathematician, to think mathematically and to view the world through a mathematical lens.
4. Mathematics as a set of conventions, skills and algorithms that must be learnt. Many will not be used in everyday life but are important for further studies.

Adaptation of these orientations has proved useful for the analysis of the Mathematics (see Parker, 2006) and the Mathematical Literacy National Curriculum Statements in the FET band (See Graven & Venkat, 2007). The revised natural science curriculum for the GET band (DOE, 2002) which encompasses life sciences, earth sciences as well as physical sciences works with three outcomes as follows:

Learning Outcome 1: Scientific Investigations: The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific, technological and environmental contexts.

Learning Outcome 2: Constructing Science Knowledge: The learner will know and be able to interpret and apply scientific, technological and environmental knowledge.

Learning Outcome 3: Science, Society and the Environment: The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment.

These three outcomes are similar to the FET outcomes for Physical Science and they dovetail well with the four mathematical orientations outlined above and are adapted thus for the purposes of comparative analysis between Mathematics, ML and Physical sciences.

1. Math/ML/ Science for critical democratic citizenship (Mathematics orientation 1 and natural science learning outcome 3)
2. Math/ML/Science for practical relevance and application (Mathematics orientation 2 and natural science learning outcome 1 and 3)
3. Math/ML/Science for induction into mathematical and scientific working (Mathematics orientation 3 and natural science learning outcome 1 and 2)
4. Math/ML/Science for developing mathematical and scientific knowledge necessary for further mathematical and scientific studies (Mathematics orientation 4 and natural science learning outcome 2)

It is interesting to note that the focus on mathematical and scientific literacy changed in the GET band when C2005 (DOE, 1997) was reviewed and resulted in the RNCS (DOE, 2002). In Natural Science the reduction of 9 learning outcomes to 3 was an attempt to make the delivery of the curriculum more practical. But in the shift from MLMMS to Mathematics several of the contextual specific outcomes were shifted to the rationale of the document and the 9 specific outcomes were replaced with 4 content based outcomes. In the latter case revisions resulted in a more strongly classified curriculum. But in the science the trend was towards even weaker classification as evidenced by the recommendation that:

> "The other 30% of the time should be used to extend these minimum knowledge statements; alternatively, science content from contexts which are significant to the learners and local community may be used. The contexts may be economic, environmental, social, or health matters… (DOE, 2002 :61)"

On the other hand, the FET Physical sciences became more strongly classified with the appearance of a content document (DOE, 2006) which fore fronted Learning Outcome 2 at the expense of the other two learning outcomes.

Comparing Mathematics/ ML and Physical sciences in the NCS documents

Due to space constraints it is not possible to share a detailed comparative analysis across all aspects of the curriculum documents. For this reason we have chosen to focus on some key aspects of the documents which include: the Intended Audience; Definitions; Purpose; Learning Outcomes and Assessment Standards.

Below we provide a comparative table for each of these curriculum aspects for the three subjects. Each table is followed by some analytical discussion drawing on the frames discussed above.

Intended Audience

Table 1 shows the intended audience for the three curricula.

Table 1. The intended/recommended audience

Mathematics	Mathematical Literacy	Physical sciences
Learners who perceive Maths to be necessary for career path or study direction In practice: Learners who passed or performed well in GET Mathematics	Learners who might wish to proceed with learnerships that require ML or proceed in HE institutions with disciplines in the social and life sciences In practice: Primarily learners who performed poorly in Maths in Gr 9	Learners wanting access to academic study of science and science related programs In practice: Learners who take Mathematics in the FET and performed well or passed Science in Gr 9

All three subjects' curriculum documents emphasise the intention to prepare learners for further studies. In the case of both Mathematics and Physical sciences this means a focus on disciplinary concerns while in the case of ML this means the development of a much broader competence that can be applied in a range of learnerships and social studies. The overlap between learners taking Mathematics and learners taking Physical sciences is historically common as the Physical sciences curriculum requires a reasonable knowledge and competence in mathematics. For example, calculus is useful to understand kinematics and logarithms are required to work with pH. This leads to a situation where both Physical sciences and Mathematics learners have little exposure to mathematical literacy (as a competence) in the FET band. These claims will be substantiated in the analysis that follows.

Definitions

The Definitions of the three curricula are shown in table 2.

Table 2: Definitions of the Curricula

Mathematics	Mathematical Literacy	Physical Sciences
The curriculum for Mathematics is based on the following view of the nature of the discipline. Mathematics enables creative and logical reasoning *about problems in the physical and social world* in the context of Mathematics itself. It is a distinctly human activity practiced by all cultures. Knowledge in the mathematical sciences is constructed through the establishment of descriptive, numerical and symbolic relationships. Mathematics is based on observing patterns; with rigorous logical thinking, this leads to theories of abstract relations. Mathematical problem solving enables us to understand the world and make use of that understanding in our daily lives. Mathematics is contested over time through both language and symbols by social interaction and is thus open to change" (DoE, 2003, p9)	*Mathematical Literacy provides learners with an awareness and understanding of the role that mathematics plays in the modern world. Mathematical Literacy is a subject driven by life-related applications of mathematics. It enables learners to develop the ability and confidence to think numerically and spatially in order to interpret and critically analyse everyday situations and to solve problems (DoE, 2003a, p9).*	Physical Sciences focuses on investigating physical and chemical phenomena through scientific inquiry. By *applying* scientific models, theories and laws it seeks to *explain and predict events in our physical environment*. It also deals with society's desire to understand how the physical environment works, how to benefit from it and how to care for it responsibly. (DoE, 2006)

While the definitions for Mathematics, ML and Physical sciences are of course different it is interesting to note some clear similarities in the rhetoric of the definitions. For example all three definitions have similar statements about contexts which indicate that they enable understanding of the world (physical, social and modern) – see shaded parts of definitions in the table above, thus indicating the inclusion of orientation 2 (see above). Orientation 1, while not explicitly present in any of these definitions, can be inferred to some extent from the shaded parts in relation to supporting a better understanding of the world we live (which is part of citizenship). It could be argued that there is more inclusion of this orientation in the ML and Physical sciences definitions through their inclusion of the terms 'critically analyse', 'care responsibly' respectively.

While orientations 1 and 2 are thus present to an extent in all the definitions the Mathematics and Science definitions seem to foreground disciplinary concerns (see bold part of table above). In the Mathematics definition emphasis is placed on intra-disciplinary concerns which move beyond the real world. These statements indicate an emphasis on orientations 3 and 4 above. Similarly the definition in Physical Sciences highlights disciplinary concerns which are rooted in the nature of the discipline, aligning with orientations 3 and 4. It should however be noted that for both the Mathematics and Science definitions there is some attempt to connect these disciplinary statements to the physical and social world (see italicised parts of the definitions). No such disciplinary concerns exist in the definition of ML and by contrast this subject is "driven by life-related applications" and thus orientations 3 and 4 are absent in the definition. Thus while in terms of definitions the Mathematics and Physical Science definitions seem similar with respect to their foregrounding of disciplinary concerns (and in their stronger classification the ML) an analysis of the learning outcomes in these subjects shows that while Mathematics continues to foreground disciplinary concerns Physical Science shows a strong emphasis on contextualisation through the inclusion of Learning Outcome 3 as one of three equally important outcomes and thus shows weaker classification in this respect. We elaborate on this below.

Learning Outcomes (LO's) and reference to Assessment Standards

The learning outcomes for the three curricula are shown in table 3 below.

Table 3: Learning` outcomes in the three curricula

Mathematics	Mathematical Literacy	Physical sciences[10]
1. Number & number relationships 2. Functions and algebra 3. Space, Shape and Measurement 4. Data Handling & probability	1. Number & operations in context 2. Functional relationships 3. Space, Shape and Measurement 4. Data Handling	1: Practical Scientific Inquiry and Problem-solving Skills 2: Constructing and Applying Scientific Knowledge 3: The Nature of Science and its Relationships to Technology, Society and the Environment

Mathematics and ML both have four learning outcomes relating broadly to 'content areas' which are quite similar to each other except for the reference to algebra and probability in the Mathematics curriculum (see table 3 above). A superficial look at the Mathematics and ML outcomes tells us little about the nature of contextualisation intended within these outcomes (since indeed they are organised as broad 'content' areas). In contrast, the Physical sciences curriculum has three outcomes which involve problem solving and the nature of scientific inquiry (LO1 – links with orientations 2 and 3); knowledge (LO2 – links with orientation 2 and 4); nature of science and the relationship between scientific knowledge and the real world (LO3 – links with orientation 1 and 2) which are intended to be applied to all knowledge areas taught. In this respect we see a balance across the four orientations in the Science curriculum and we see that contextualisation, rather than being a separate endeavour are integrated with disciplinary concerns. Thus the Physical sciences curriculum outcomes indeed highlight the central importance of exploring the relationship with the social world and the environment.

While it is beyond the scope of this paper to do a thorough analysis of the related assessment standards in each of these outcomes, we can draw on other research that has analysed these. For example Parker's (2006) analysis (drawing on Graven's (2002) identified orientations above) confirms a clear bias in the assessment standards towards orientation 4 in Mathematics. Her analysis shows that over 90% of all the assessment standards incorporate this orientation. On the other hand Christiansen (2007, 97) using a different coding system to analyse the 18 assessment standards of the NCS for Mathematical Literacy for grade 11 notes that 7 of the 18 are 'strictly ordered by mathematics' and thus argues that 'the NCS for ML is less driven by everyday applications than implied by its stated purpose'. She cites examples

[10] While the Physical Science curriculum maintains its integrity as two cognate disciplines (physics and chemistry), there is evidence of weakened classification both in the inclusion of one of the five knowledge areas (Matter and Materials) as an integration of chemistry and physics (DOE, 2003:11) and through the provision of learning outcome 3.

of assessment standards referring to the quadratic formula and positive exponents and roots as examples of 'mathematics claiming to refer, yet being obviously self-referential in its alien-ness to the lived practices' (p98). Thus while there is an absence of orientations 3 and 4 in the definition and purpose of ML these do appear (even while they do not dominate) in the assessment standards.

In the case of physical sciences, the assessment standards are developed from thrusts as outlined below which largely stay true to the orientations as expressed in the learning outcomes and hence the orientations as outlined earlier. Table 4 shows these thrusts by learning outcome.

Table 4: Thrusts of the Assessment Standards by learning outcome

Learning Outcome 1	Learning Outcome 2	Learning Outcome 3
Conducting an investigation	Recalling and stating specified concepts	Evaluating knowledge claims and science's inability to stand in isolation from other fields
Interpreting data to draw conclusions	Indicating and explaining relationships	Evaluating the impact of science on human development
Solving problems		
Communicating and presenting information and scientific arguments	Applying scientific knowledge	Evaluating science's impact on the environment and sustainable development

Thus since each learning outcome must be applied to each content related assessment standard we see a balance between orientations 1, 2, 3 and 4

In summary

From the above analysis we argue that a general split occurs between the four orientations in the FET band between Mathematics and ML with Mathematics focusing on the more tightly bounded mathematical orientations 3 & 4 while Mathematical Literacy focuses on the less tightly bounded and more utilitarian orientations 1 & 2. On the other hand the Physical sciences curriculum seems to balance all four orientations serves both disciplinary and scientific literacy concerns. Table 5 provides a crude summary of this splitting of orientations between the three subjects.

Table 5: Focal Orientations in the FET band across the subjects

Mathematics	*Mathematical Literacy*	*Physical sciences*
Orientation 3: Math for induction into mathematical working Orientation 4: Math for learning skills, algorithms, theorems etc. necessary for further math learning	Orientation 1: ML for critical democratic citizenship Orientation 2: ML for practical relevance	Orientation 1: Science for critical democratic citizenship Orientation 2: Science for practical relevance Orientation 3: Science for induction into the nature of science Orientation 4: Science for learning skills, methods and concepts necessary for further science learning

We note in summary that there is differential status accorded to contextualisation within the Mathematics/Mathematical Literacy curricula and the Physical sciences curricula in that within the split between Mathematics and Mathematical Literacy contextualisation in Mathematical Literacy is defined outside of disciplinary development, and therefore, further related academic study pursuits while within Physical sciences contextualisation is centrally included within the academic stream. This would seem to suggest that it is not important for academically inclined learners who are studying mathematics to be able to apply their knowledge in everyday situations or perhaps that such a competence would develop on its own for Mathematics learners. This may be too much to expect of these learners only a fraction of whom carry on to study mathematics in its disciplinary form.

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