VALUES IN MATHEMATICS AND SCIENCE EDUCATION: RESEARCHERS' AND TEACHERS' VIEWS ON THE SIMILARITIES AND DIFFERENCES

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Values are an inherent part of the educational process at all levels, from the systemic, institutional macro-level, through the meso-level of curriculum development and management, to the micro-level of classroom interactions (Le Métais, 1997) where they play a major role in establishing a sense of personal and social identity for the student. The notion of 'values' is not new in anthropology (*e.g.*, Kluckholm, 1962), in psychology (*e.g.*, Kohlberg, 1981; Krathwohl, Bloom and Masia, 1964; Rokeach, 1973), or in general education (*e.g.*, Halstead, 1996; Nixon, 1995; Raths, Harmin and Simon, 1987). However, the notion of studying values in mathematics education is a relatively recent phenomenon (Bishop, 1999) and even in science education the study of values in classrooms is not a major focus of research.

In the modern knowledge economy, societies are demanding greater mathematical and scientific literacy and expertise from their citizens than ever before. At the heart of such demands is the need for greater engagement by students with school mathematics and science. As the OECD/PISA definition of numeracy puts it:

> Mathematical literacy is an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgements and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned and reflective citizen. (OECD, 2003)

Clearly values are a fundamental part of that definition and in mathematics and science education they are crucial components of classrooms' affective environments, with a potentially crucial influence on the ways students choose to engage (or not engage) with mathematics and science. The extent and direction of this influence will depend on the teachers' awareness of values ascribed to the particular discipline, the values carried by their selection from the available pedagogical repertoire, and their consciousness or otherwise of imposing their own personal values (Pritchard and Buckland, 1986).

Data from a previous research project, *Values and Mathematics Project* (VAMP) has shown that teachers of mathematics are rarely aware of the values associated with teaching mathematics (FitzSimons, Seah, Bishop and Clarkson, 2000). Furthermore, any values 'teaching' which does occur during mathematics classes, happens implicitly rather than explicitly (Bishop, 2002). [1] In this article, we will report on ideas developed during a more recent research project concerned with values in both mathematics and science education. This project uses a conceptualisation of values that has not been 'tested' in any empirical research before.

Values in mathematics and science

There appear to be considerable similarities between the disciplines of mathematics and science in relation to education. For example, both mathematics and science are taken as ways of understanding that are embedded in rational logic – focusing on universal knowledge statements. Both are seen by society in general as essential components of schooling, rivalled only by literacy. Hence, teachers of each face substantial political and social pressures from outside the school (*e.g.*, system-wide assessments of student performance; purposes for teaching seen as being directly related to technological development). In their teaching, both involve following routines, although not exclusively. Both involve modelling, albeit with different emphases. Similarly, each is incorporated into the other's applications but in an asymmetrical relationship.

On the other hand, science curricula/texts commonly contain a section on *The nature of science*, whereas mathematics rarely contains the equivalent. While the values embedded in mathematics teaching are almost always implicit, in science teaching some are quite explicit. For example, curriculum movements such as *Science-Technology-Society* make some values explicit and central to the intended learning outcomes; laboratory work seeks to make explicit such values as "open mindedness" and "objectivity"; and content described as *The nature of science*, for example, also makes some values explicit (see also UNESCO, 1991).

Among the general public, although the concept of 'a science industry' or 'scientific industries' is widely recognised, this is not the case for mathematics. In the popular media (*e.g.*, magazines, newspapers, books, radio, television), science receives much more attention than mathematics, despite a few recent movies featuring mathematical prodigies. Even when it is present, mathematics is generally subsumed under science. In the case of the popular pursuit of gambling, where mathematical thinking might be considered to play an important role, this is generally not the case as 'luck' seems to be considered a critical factor for many people.

Yet mathematics plays a much more prominent role as a gatekeeper in society than does science. For example, it is often used as a selection device for entry to higher education or employment, even when the skills being tested are unrelated to the ultimate purpose. In broad terms (*e.g.,* modelling or simulations that reduce costs and/or danger), mathematics is considered to be publicly important; at the very same time as it is considered to be personally irrelevant (Niss, 1994), apart from the obvious examples of cooking, shopping and home maintenance. Politically, mathematics has also been ascribed a *formatting role* in society (Skovsmose, 1994).

So, for our project we had a considerable background of ideas that could relate to values and their development. For this article, we are interested in comparing the views of the researchers with those of the teachers in the project, to see what useful differences and similarities can be found. In particular, the differences may reveal some important implications for values development in mathematics.

Conceptual differences in values between mathematics and science

The earlier VAMP project used, as the basic conceptual framework, the six-values-cluster model of Bishop (1988), based on his analysis of the activities of mathematicians throughout Western history and culture. It is important to stress that the emphasis in this analysis was not primarily on which values might be, are, or should be, emphasised in mathematics education but rather on the development of mathematics as a subject throughout history.

In this model, six-value clusters are structured as three complementary pairs, related to the three dimensions of ideological values, sentimental values, and sociological values. These three dimensions are based on the original work of White (1959), a renowned culturologist, who proposed four components to explain cultural growth. White nominated these as technological, ideological, sentimental (or attitudinal) and sociological, with the first being the driver of the others. Bishop (1988) argued that mathematics could be considered as a symbolic technology, representing White's technological component of culture, with the other three being considered as the values dimensions driven by, and also in their turn driving, that technology.

The six-value clusters that Bishop (1988) originally identified are as follows:

> The particular societal developments which have given rise to Mathematics have also ensured that it is a product of various values; values which have been recognised to be of significance in those societies. Mathematics, as a cultural phenomenon, only makes sense if those values are also made explicit. I have described them as complementary pairs, where *rationalism* and *objectism* are the twin ideologies of Mathematics, those of *control* and *progress* are the attitudinal values which drive Mathematical development and, sociologically, the values of *openness* and *mystery* are those related to potential ownership of, or distance from Mathematical knowledge and the relationship between the people who generate that knowledge and others. (Bishop, 1988, p. 82, *original emphasis*)

This project involved two mathematics educators and two science educators, and in the first part of the project there was considerable discussion and analysis of this initial framework, particularly in relation to whether the same structure could hold for science (see Corrigan, Gunstone, Bishop and Clarke [2] for more description of the discussions). As a result of this analysis, a comparison of value clusters between the mathematics and science educators regarding their two subjects was undertaken (see Figure 1).

As can be seen, there is considerable agreement but also some important differences. As far as the *Ideological* dimension is concerned there are both similarities and differences. In the cluster of *Rationalism* there is much agreement, as both subjects require the use of all the logic skills available and thus emphasise the range of values associated with those skills. With the value cluster of *Objectism*, which became

Mathematics educators' views	**Science educators' views**
Rationalism Reason Explanations Hypothetical reasoning Abstractions Logical thinking Theories	***Rationalism*** Reason Explanations Hypothetical reasoning Abstractions Logical thinking Theories
Empiricism Atomism Objectising Materialism Concretising Determinism Symbolising Analogical thinking	***Empiricism*** Atomism Objectising Materialisation Symbolising Analogical thinking Precise Measurable Accuracy Coherence Fruitfulness Parsimony Identifying problems
Control Prediction Mastery over environment Knowing Rules Security Power	***Control*** Prediction Mastery over problems Knowing Rules Paradigms Circumstance of activity
Progress Growth Questioning Cumulative development of knowledge Generalisation Alternativism	***Progress*** Growth Cumulative development of knowledge Generalisation Deepened understanding Plausible alternatives
Openness Facts Universality Articulation Individual liberty Demonstration Sharing Verification	***Openness*** Articulation Sharing Credibility Individual liberty Human construction
Mystery Abstractness Wonder Unclear origins Mystique Dehumanised knowledge Intuition	***Mystery*** Intuition Guesses Daydreams Curiosity Fascination

Figure 1: Comparison between values associated with mathematics and science.

recast as *Empiricism* in order to accommodate the scientists' approach, there is also some agreement, but the highly empirical nature of science means that it has many more value aspects there than does mathematics. The experimental and observational activities of science seem to foster other values than we can find in mathematics development.

For the *Sentimental* (or attitudinal) dimension, with the complementary pairing of *Control* and *Progress*, there was once again some agreement between the mathematics and science educators about the *Control* value cluster, with its emphasis on prediction, mastery, and procedural rules. However, the circumstances of the activity and different paradigms are significant in science but have little meaning in mathematics. Likewise with *Progress*, the idea of the cumulative development of knowledge is clearly similar, but the role of science in continuing to deepen understanding of a phenomenon again appears to have no parallel in mathematics development.

Some other differences appear with the *Sociological* dimension, which is the way individuals relate to the knowledge of the subject and to those who develop it. In relation to the *Openness* value cluster, the emphasis of science on credibility and human construction are significant, compared with the idea of 'facts' in mathematics and the value of verification, sometimes via proof. With *Mystery*, which itself is a rather mysterious category, the dehumanised nature of mathematics with its abstractness and unclear notions of the origins of ideas contrasts strongly with the intuition, daydreaming, and empirically-based guesses of the scientists.

When considering these contrasts it is important to remember that this framework involves pairs of clustered values along the three dimensions. So the two clusters should not be considered as dichotomous, but rather as complements of each other. For example, *Openness* is the complement of *Mystery*, and therefore both clusters are present to some extent in that *Sociological* value dimension. Furthermore, what the model suggests is not that science and mathematics are markedly different but rather that there are strong similarities in their values, as befits their common heritage. There are, however, some interesting and, in terms of education, revealingly different values represented also.

Teachers' views of mathematics and science values

We now turn to the views of primary and secondary teachers based on some of the data collected from specially constructed questionnaires. They are based on the three complementary pairs, *Rationalism* and *Empiricism*, *Control* and *Progress*, *Openness* and *Mystery*. Only part of the questionnaires will be considered here, the questions concerning the relative emphasis given by teachers to these values (see Figure 2).

The statements in these two questions are the same for mathematics and science, and 13 primary and 17 secondary teachers volunteered to answer these questionnaires. Primary teachers in the state system in Australia teach both subjects to their classes, and we selected secondary teachers who also taught both subjects to the same classes.

The structure of the questions 3 and 4 is as follows – each question contains 6 statements to be ranked by the teachers;

For the next two items please rank the six statements accordingly in the accompanying boxes, where '1' indicates your first choice, '2' your second choice, '3' your third choice, etc. Note that the same ranking value can be given to more than one statement. Please rank each statement.

3. "For me, Mathematics is valued in the school curriculum because…."

	Ranking
It develops creativity, basing alternative and new ideas on established ones	☐
It develops rational thinking and logical argument	☐
It develops articulation, explanation and criticism of ideas	☐
It provides an understanding of the world around us	☐
It is a secure subject, dealing with routine procedures and established rules	☐
It emphasises the wonder, fascination and mystique of surprising ideas	☐

4. "For me, Mathematics is valuable knowledge because…"

	Ranking
It emphasises argument, reasoning and logical analysis	☐
It deals with situations and ideas that come from the real world	☐
It emphasises the control of situations through its applications	☐
New knowledge is created from already established structures	☐
Its ideas and methods are testable and verifiable	☐
It is full of fascinating ideas which seem to exist independently of human actions	☐

Figure 2: Questions 3 and 4 from the Mathematics Questionnaire for Teachers.

each statement relates to one of the values clusters, for example, the statement "It develops creativity, basing alternative and new ideas on established ones" relates to the value of *Progress*. The other statements follow closely the other value descriptors in Figure 1 although their order is different in the two questions. Note also that although the teachers knew we were researching the area of values, they were not made aware of the value structure underlying the two questions and each of the six statements. Figures 3 and 4 show the results from the two groups of teachers in terms of their rankings and the means of the rankings for the six values clusters.

For Question 3, "Maths (or Science) is valued in the school curriculum because…", the primary teachers showed considerable similarity between the orders for mathematics and science with *Empiricism* and *Rationalism* being the most important values for both. *Control* was seen as by far

(a) Primary teachers

Value	Rationalism	Empiricism	Control	Progress	Openness	Mystery
Maths rank (mean)	2 (2.30)	1 (1.46)	6 (5.23)	4 (3.15)	3 (3.53)	5 (3.61)
Science rank (mean)	2 (2.75)	1 (1.41)	6 (4.91)	4 (3.41)	5 (3.66)	3 (3.00)

(b) Secondary teachers

Value	Rationalism	Empiricism	Control	Progress	Openness	Mystery
Maths rank (mean)	1 (1.94)	2 (2.05)	6 (4.52)	4 (3.88)	3 (3.35)	5 (4.29)
Science rank (mean)	4 (3.18)	1 (1.25)	6 (5.87)	4 (3.18)	3 (3.06)	2 (2.81)

Figure 3: Table showing rank orders and mean ranks for Question 3.

the least important value, which is surprising given the findings about *Control* in the textbook study of Seah [3]. For the secondary teachers we can see an important difference between the rankings for mathematics and science between *Rationalism* and *Empiricism*. Also once again *Control* is a distinct last choice for both, and there are also interesting differences between the rankings of *Mystery* for mathematics and science for both groups of teachers.

For Question 4, "Mathematics (or Science) is valuable knowledge because…", once again the primary teachers put *Empiricism* firmly at the top of the list for both subjects, but their second choices are interestingly different. For mathematics they favoured *Progress* while for science they favoured *Mystery*. Their last choices are also markedly different, with *Mystery* being given that place for mathematics and *Control* for science. For the secondary teachers, *Rationalism* and *Empiricism* stand out as the top values for mathematics, while *Empiricism* stands alone at the top for science. At the bottom, the pattern is the same as for the primary teachers, with *Mystery* occupying that place for mathematics and *Control* for science.

Conclusions and implications

The comparison of the values described by the science and mathematics educators in the project has revealed perceptions of some important differences between the two subjects. It has also helped to clarify the values structure underlying the current project. In particular, regarding the *Ideological* dimension, there was evidence that the mathematics educators favour the cluster of *Rationalism* while the science educators emphasise *Empiricism*. With the *Sentimental* dimension, while both groups favour *Control*, the values of *Progress* differ, with the scientists seeking to deepen understanding of relationships rather than constructing new knowledge as in mathematics. Concerning the *Sociological* dimension, there are important differences in both the *Openness* and *Mystery* clusters with science being related more to the humanising aspects of knowledge compared with mathematics.

The comparisons between the values in mathematics and science for the teachers also show interesting differences, reflecting their concerns with the curriculum and teaching at their respective levels. At the primary level the teachers favour *Empiricism* over *Rationalism* for both science and

(a) Primary teachers

Value	Rationalism	Empiricism	Control	Progress	Openness	Mystery
Maths rank (mean)	3 (3.66)	1 (1.33)	5 (3.75)	2 (3.00)	3 (3.66)	6 (3.83)
Science rank (mean)	4 (3.41)	1 (1.41)	6 (4.75)	3 (3.33)	5 (3.83)	2 (2.58)

(b) Secondary teachers

Value	Rationalism	Empiricism	Control	Progress	Openness	Mystery
Maths rank (mean)	1 (1.70)	2 (1.82)	3 (3.44)	4 (4.00)	4 (4.00)	6 (4.47)
Science rank (mean)	3 (3.12)	1 (1.25)	6 (4.12)	2 (3.00)	5 (4.06)	4 (3.33)

Figure 4: Table showing rank orders and mean ranks for Question 4.

mathematics, though both are important, and this contrasts with the findings above. At the primary level of course much mathematical work is empirical in nature. For the *Sentimental* dimension, *Control* is much less favoured than *Progress* also for both groups. The main difference between the subjects appears in the *Sociological* dimension where *Openness* and *Mystery* reverse their positions with the first being more favoured than the second in mathematics and the reverse in science. This difference shown by the primary teachers reflects the educational implications of the educators' views.

For the secondary teachers, the *Ideological* dimension reflects the educators' views, with mathematics favouring *Rationalism* and science favouring *Empiricism*, disagreeing with the primary teachers. For the *Sentimental* dimension, the secondary teachers largely agree with their primary colleagues and for the *Sociological* dimension, they again agree with their primary colleagues favouring *Openness* for mathematics compared with *Mystery*, and reversing these for science. Indeed *Mystery* for science is ranked 2 and 4 by the secondary teachers and ranked 2 and 3 by the primary teachers, showing how significant they consider that aspect to be.

In general, the conceptualisation put forward for this project has begun to show interesting and interpretable results. Discussions with the teachers have revealed an interest in the issues of values teaching in all subjects, but also a lack of vocabulary and conceptual tools to enable them to develop explicitly the values underlying mathematics education. One of the goals of this project is, by contrasting mathematics and science, to help teachers develop those conceptual tools further. The contrasts between these two closely related forms of knowledge are provocative, and already reveal worthwhile challenges for mathematics teaching to pursue.

For example, the difference between the emphasis on *Empiricism* at primary level and on *Rationalism* at secondary level implies some important challenges for explicit values development in the teaching of mathematics at those two levels. How should that values development be smoothed across the primary/secondary divide?

The differences in the views on *Progress* are also revealing, with the development of understanding in science contrasting with the construction of new knowledge in mathematics. How can we reconstruct our views of the mathematics curriculum so that progress through that curriculum is not just a matter of acquiring new knowledge but of ensuring that it also deepens learners' understanding of what has been taught before?

Finally, could the dehumanised, highly abstract and mystique-laden value of *Mystery* of mathematics, which appears to be such an obstacle to mathematics learners, be made more explicit so that it could be challenged by the more humanised and personal intuitive nature of that value that science appears to enjoy?

Notes

[1] For more information about VAMP and for accessing papers from that project visit: http://www.education.monash.edu.au/centres/scienceMTE/vamppublications.html, accessed 5th January, 2006.

[2] Contact the authors to obtain a copy of the unpublished paper by Corrigan, D., Gunstone, R., Bishop, A. and Clarke, B. (2004) 'Values in science and mathematics education: mapping the relationships between pedagogical practices and student outcomes', paper presented at a Summer School of the European Science Educational Research Association, Mulheim, Germany, August, 2004.

[3] Seah, W. (1999) *The portrayal and relative emphasis of mathematical and mathematics educational values in Victoria and Singapore lower secondary mathematics textbooks: a preliminary study*, unpublished Master of Education thesis, Monash University, Melbourne, Australia, weetiong.seah@education.monash.edu.au.

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