Teachers' Preferences and Practices Regarding Values in Teaching Mathematics and Science

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Values are a key component of any teaching situation, yet they are rarely addressed explicitly in mathematics lessons, in comparison with values in science education. In this report, data are presented from a research study into teachers' value preferences and their teaching practice preferences in both mathematics and science. A volunteer group of primary and secondary teachers participated in the questionnaire-based study which revealed some significant differences between both levels of teaching and also the subjects taught.

Despite research into values education having a long history (see for example, Peters, 1970; Halstead and Taylor, 1996) research into values in mathematics education is relatively new, and rudimentary at present (Bishop, 1999). Indeed the construct of 'values' is itself not well defined for mathematics educational contexts, which makes research into the area both complicated and necessarily exploratory. An earlier study "Values and Mathematics Project" (VAMP) made a valuable start in exploring the topic, and in particular, data from that project showed that teachers of mathematics are rarely aware of the values associated with teaching mathematics (FitzSimons, Seah, Bishop & Clarkson, 2000). Furthermore, any values 'teaching' which did occur during mathematics classes, seemed to happen implicitly rather than explicitly. Therefore general curriculum goals which emphasise certain values are unlikely to be realised if teachers have little idea about what they are doing, or what they could do, about values teaching. This could be one reason why curriculum developments in mathematics in various countries often appear to have little effect on student outcomes. Various relevant papers from that study, and from other authors, are available from this website: http://www.education.monash.edu.au/centres/scienceMTE/vamppublications.html

In the current study, part of which is reported here, the research which began in the VAMP project is extended in two main ways:

1. Mathematics and science are both involved, in order to see the influence of the culture of the subject taught.
2. Both teachers and students are involved, in order to see what influences the teachers' values have on their students.

However in this paper, we will focus on the first of these developments, and will present some interesting data coming from the first questionnaire survey of the teachers regarding their preferred values and their preferred teaching strategies in mathematics and in science.

Values teaching in different subject areas is a relatively novel research approach and some parallel research on teachers of mathematics and history by Bills and Husbands

(2004) which builds on the ideas of Gudmunsdottir (1991) from English and history teachers, also shows what can be learnt from this approach. An important perspective on values, of relevance to this present study, is offered by Billett's (1998) analysis of the social genesis of knowledge. This analysis points to the different sources of influence on teachers' values. Billett categorises knowledge at five levels, and below is an indication of how different knowledge at these levels can impinge on and influence teachers' values.

1) Socio-historic knowledge factors affect the values underpinning decisions made by both management and teachers.
2) Socio-cultural practice is described by Billett as historically derived knowledge transformed by cultural needs; goals, techniques, and norms to guide practice; and expectations of transformed socio-historic knowledge. These are manifested by curricular decisions influenced by such factors as State or national curricular frameworks.
3) The community of practice in the classroom is identified by Billett as particular sociocultural practices shaped by a complex of circumstantial social factors (activity systems), and the norms and values which embody them.
4) Microgenetic development is interpreted by Billett as individuals' (teachers' and students') moment-by-moment construction of socially derived knowledge, derived through routine and non-routine problem solving.
5) Billett's last category is ontogenetic development, in which he included individuals' personal life histories.

This paper is in particular concerned with ideas and influences at Billett's levels 1, 2 and 3, rather than with how these play out in actual classroom practices.

Theoretical Framework

It was decided that for this study, in order to have some basis for the mathematics and science comparisons it would be necessary to have a solid theoretical framework for the value activities studied. We used the six values cluster model developed by one of the authors (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 that 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 Western 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. Bishop based these three dimensions 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 originally identified are described 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)

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 & Clarke, 2004, for more description of the discussions). In brief the discussions showed that:

1) it was preferable to change the label of the value ‘objectism’ to ‘empiricism’ to encompass more of science’s emphases,
2) the ‘empiricism’ cluster of values was much larger for science than for mathematics,
3) ‘control’ was an equally significant value cluster for science as for mathematics,
4) ‘progress’ in science was concerned more with deepening knowledge and understanding rather than developing alternativism in mathematics,
5) both ‘openness’ and ‘mystery’ were strong value clusters in science, compared to mathematics.

Further analysis of these differences, together with analysis of the contrasts with teachers’ interpretation of these values dimensions, is given in Bishop (2005). These analyses helped with the construction of the questionnaires to be used with the teachers, as did some preliminary interviews with teachers.

Teachers’ Values and Practices

We now turn to some of the data collected from the primary and secondary teachers by means of specially constructed questionnaires. These were based on the three complementary pairs, Rationalism and Empiricism, Control and Progress, Openness and Mystery, discussed above. The same structure was used for the mathematics and the science questionnaires and for the primary and secondary teachers, although there were some minor adjustments in the descriptions of teaching situations. 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 also chose secondary teachers who taught both subjects to the same classes.

Questions 1 and 2 of the questionnaires ask for the extent to which particular activities are emphasised in practice in the teacher’s mathematics (and science) classes. The items in these questions are designed to explore, in sequence, aspects of Rationalism, Empiricism, Control, Progress, Openness, and Mystery. So, the first three statements in Qustion 1 all relate to the value of Rationalism, and so on through the 18 items in Question 1.

Question 2 uses the same structure (a group of 3 items relating to each of the 6 value clusters in order) to ask about the frequency of use of specific classroom activities. In the Appendix can be seen the various statements, but not in the actual format used in the questionnaires.

For all the statements in Questions 1 and 2, we scored the responses as 4 (for “Always”), 3 (“Often”), 2 (“Sometimes”), 1 (“Rarely”), and we also calculated means. We recognise that in doing this we have taken an ordinal scale and treated it as if it was a ratio scale.

To facilitate comprehension of the results, we have combined the data for Questions 1 and 2, and in the data reported below, for example, a teacher's view of the frequency of emphasis on Rationalism in his/her class' activities is represented by the mean score for the six items relating to that value cluster in the two questions.

Questions 3 and 4 are the questions which concern the teachers' preferences for the six value clusters described above. The structure of these questions is that each question contains 6 statements to be ranked by the 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 although their order is different in the two questions. Note also that although the teachers knew we were studying values, they were not made aware of the value structure underlying the two questions and each of the six statements.

Tables 1-4 show the results from the two groups of teachers in terms of their rankings of the six value clusters. In brackets are the means of (a) the frequencies in Questions 1 and 2, and (b) the rank orders in Questions 3 and 4.

Table 1
Teachers' Preferred Values and their Preferred Teaching Practices: rank orders: Primary: Mathematics

	Rationalism	Empiricism	Control	Progress	Openness	Mystery
Qus. 1/2	4 (2.64)	2 (2.80)	1 (2.95)	5 (2.44)	3 (2.65)	6 (2.25)
Qu. 3	2 (2.30)	1 (1.46)	6 (5.23)	4 (3.15)	3 (3.53)	5 (3.61)
Qu. 4	3 (3.66)	1 (1.33)	5 (3.75)	2 (3.00)	3 (3.66)	6 (3.83)

We can see that from Table 1 that there is a close similarity between teachers' views on questions 3 and 4, and some close correlation between them and questions 1/2 particularly regarding Empiricism, Openness and Mystery. However, the ranks for Control stand out as being markedly different.

Table 2
Teachers' Preferred Values and their Preferred Teaching Practices: rank orders: Primary: Science

	Rationalism	Empiricism	Control	Progress	Openness	Mystery
Qus. 1/2	2 (3.05)	3 (2.90)	1 (3.07)	4 (2.57)	5 (2.47)	6 (1.91)
Qu. 3	2 (2.75)	1 (1.41)	6 (4.91)	4 (3.41)	5 (3.66)	3 (3.00)
Qu. 4	4 (3.41)	1 (1.41)	6 (4.75)	3 (3.33)	5 (3.83)	2 (2.58)

For science in Table 2, the primary teachers again express similar views for Questions 3 and 4, and once again the ranks for Control are markedly different from that in Questions 1/2. Mystery is also ranked differently in practice from the teachers' preferred views.

In Table 3, the secondary teachers rank Rationalism highest for mathematics in terms of their preferred values (Questions 3 and 4) but, like their primary colleagues, they place Control in the highest rank in practice.

Table 3
Teachers' Preferred Values and their Preferred Teaching Practices: rank orders: Secondary: Mathematics

	Rationalism	Empiricism	Control	Progress	Openness	Mystery
Qus. 1/2	2 (2.15)	3 (2.05)	1 (2.75)	5 (1.93)	4 (1.99)	6 (1.79)
Qu. 3	1 (1.94)	2 (2.05)	6 (4.52)	4 (3.88)	3 (3.35)	5 (4.29)
Qu. 4	1 (1.70)	2 (1.82)	3 (3.44)	4 (4.00)	4 (4.00)	6 (4.47)

Table 4
Teachers' Preferred Values and their Preferred Teaching Practices: rank orders: Secondary: Science

	Rationalism	Empiricism	Control	Progress	Openness	Mystery
Qus. 1/2	1 (2.86)	3 (2.61)	2 (2.84)	5 (2.30)	4 (2.33)	6 (2.03)
Qu. 3	4 (3.18)	1 (1.25)	6 (5.87)	4 (3.18)	3 (3.06)	2 (2.81)
Qu. 4	3 (3.12)	1 (1.25)	6 (4.12)	2 (3.00)	5 (4.06)	4 (3.33)

For secondary science in Table 4, Questions 3 and 4 show us that the teachers' main value preference is for Empiricism, but in practice they favour Rationalism with Control coming a close second. Once again we can see differences with respect to Control, but this time also with Mystery.

The comparisons between the values in mathematics and science for the two groups of teachers show interesting differences, reflecting their concerns with the curriculum and teaching at their respective levels. For the primary teachers, concerning Ideology, they prefer Empiricism over Rationalism for both science and mathematics, though both are important, rankings which are also reflected in the findings for their preferred practices. At the primary level of course much mathematical work is empirical in nature. For the Sentimental (attitudinal) dimension, Control is much less favoured than Progress also for both, but the practices are very different. Another main difference between the subjects appears in the Sociological dimension where Openness and Mystery reverse their positions with the two subjects, the first being more favoured than the second in mathematics and the reverse in science. This difference does not translate to the practices however, with the science practises being ranked much more like the mathematics practices.

For the secondary teachers, concerning the Ideological dimension, they favour Rationalism for mathematics and Empiricism for science, 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.

Conclusions and Implications

In this first comparison between the values held and practised by the same teachers when teaching mathematics and science, their rankings have shown some expected similarities between the two subjects, but also interesting differences, particularly at the secondary level where the subjects tend to diverge in their emphases. Rationalism, Empiricism and Control are strongly favoured in practice, but the other three values figure more prominently in the teachers' preferences. The stand-out value here is that of Control, often ranked low in teachers' preferences but high in practice. The significance of the Control value cluster has appeared in others of our studies.

Before jumping to too many conclusions, we must remember that the data are from questionnaires and consist of teachers' reported views of their preferences and their practices. We do not know the extent to which their rankings of these practice statements reflect their actual practices. However, the data for science at the secondary level, where teachers emphasise other values than mathematics, indicates the usefulness of comparing subjects and their value emphasis. The analysis of our data is still progressing, and in particular we look forward to seeing the relationships between the teachers' views, and those of their students.

Finally one can see that, if the data reported here are valid, the differences show that teachers' values in the classroom are shaped to some extent by the values embedded in each subject, as perceived by them. This implies that changing teachers' perceptions and understandings of the subject being taught may well change the values they can emphasise in class. Further if teachers wish to emphasise values other than those they currently emphasise, it is possible to learn strategies from their teaching of other subjects.

References

Billett S. R. (1998). Situation, social systems and learning. *Journal of education and work. 11* (3) 255-274.

Bills, L., & Husbands, C. (2004). *Analysing embedded values in history and mathematics classrooms*. Paper presented at the British Educational Research Association Conference, Manchester, UK.

Bishop, A.J. (2005, in press). Values in mathematics and science education: Researchers' and teachers' views on the similarities and differences. Paper to be presented at the Mathematics, Education and Society conference, Gold Coast, Australia.

Bishop A.J. (1999). Mathematics teaching and values education: an intersection in need of research. *Zentralblatt fur Didaktik der Mathematik, 31*(1), 1-4.

Bishop, A.J. (1988). *Mathematical enculturation: A cultural perspective on mathematics education.* Dordrecht: Kluwer.

Corrigan, D.J., Gunstone, R.F., Bishop, A.J., & Clarke, B. (2004, Aug.). *Values in science and mathematics education: Mapping the relationships between pedagogical practices and student outcomes.* Paper presented at Summer School of the European Science Educational Research Association, Mulheim, Germany.

Fitzsimons, G.E., Seah, W.T., Bishop, A.J., & Clarkson, P.C. (2000). *Conceptions of values and mathematics education held by Australian Primary teachers: Preliminary findings from VAMP.* Paper presented at History and Philosophy of Mathematics conference, Taipei, Taiwan.

Gudmunsdottir, S. (1991). Values in pedagogical content knowledge. *Journal of teacher education, 41*(3), 44-52.

Halstead, J.M., & Taylor, M.J. (Eds.) (1996). *Values in education and education in values.* London: Falmer Press.

Peters, R. (1970). *Ethics and education*. London: Allen and Unwin.

White, L.A. (1959). *The evolution of culture.* New York: McGraw-Hill.

Appendix

Question 1. When you are *teaching mathematics* to Years 7 and 8, how often do you emphasise the following?

How often do you emphasise the role of proving in mathematics?

How often do you have structured debates in class?

How often do you encourage your students to argue seriously with each other in your classes?

How often do you use diagrams to illustrate mathematical relationships?

How often do you encourage your students to invent their own symbols and terminology **before** showing them the 'official' ones?

How often do you use concrete materials (e.g. physical models) to demonstrate mathematical relationships?

How often do you emphasise the checking of right answers, **and** the reasons for other answers not being 'right'?

How often do you encourage the analysis and understanding of **why** routine calculations and algorithms 'work'?

How often do you show examples of how the mathematical ideas you are teaching are used in the real world?

How often do you encourage alternative, and non-routine, solution strategies together with their reasons?

How often do you encourage students to extend and generalise ideas from particular examples?

How often do you give the students stories and examples of recent mathematical developments?

How often do you encourage your students to defend and justify their answers and methods publicly to the class?

How often do your students create posters to display their ideas to the others?

How often do you demonstrate how mathematical ideas can be shown to be true?

How often do you stimulate your students' mathematical imagination with pictures, artworks, etc.?

How often do you use mathematical puzzles in class?

How often do you tell students stories about mathematical discoveries?

Question 2. How frequently do you use any of these activities in your *mathematics teaching at this level?*

Small group discussions

Whole class discussions

Investigations

Modelling activities

Using manipulatives

Role playing real-life situations

Practising algorithms

Memorising facts

Problem solving

Generating conjectures and hypotheses

Having students generate questions

Historical and cultural projects

Students explaining at the board
Students making posters and displays
Proving generalisations
Displaying famous ‘mathematical’ artwork
Mathematical puzzles
Using mathematical paradoxes

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.

Question 3. “For me, Mathematics is valued in the school curriculum because….”

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	☐

Question 4. “For me, Mathematics is valuable knowledge because…”

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	☐