BEING EXPLICIT ABOUT ASPECTS OF MATHEMATICS PEDAGOGY

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It is conventional wisdom that contextualising mathematics tasks can make them more meaningful for students, and that open-ended questions create opportunities for student engagement. Yet concerns are emerging that strategies such as these may exacerbate the disadvantage of some. We report data from a project that seeks to address such concerns by encouraging teachers to be explicit about aspects of their pedagogy. When teachers were explicit about aspects of the pedagogy, the students responded in the direction intended.

We are reporting data from a project entitled Overcoming Structural Barriers to Mathematics Learning1. The project is motivated by concerns that reforms in the teaching of mathematics have failed to address the obvious disadvantage of some groups of students. In particular we draw on two commonly employed teaching strategies—the use of contexts, and the use of open-ended questions. We sought to identify and describe approaches to overcoming factors that may inhibit successful implementation of these strategies in classrooms.

The term *contexts* refers to real or imaginary settings for mathematical problems that illustrate the way the mathematics is used. Meyer, Dekker and Querelle (2001) discussed the use of contexts in mathematics curriculum, drawing on examples from five recent curriculum documents developed in the United States, all incorporating "pervasive use of context" (p. 522). They suggested that contexts can be used to motivate, to illustrate potential applications, as a source of opportunities for mathematical reasoning and thinking, and to anchor student understanding.

Open-ended questions and approaches are also increasingly popular. Open-ended tasks can engage students in productive exploration (Christiansen & Walther, 1986), enhance motivation through increasing the students' sense of control (Middleton, 1995), encourage pupils to investigate, make decisions, generalise, seek patterns and connections, communicate, discuss, and identify alternatives (Sullivan, 1999) and contribute to teachers' appreciation of mathematical and social learning of students (Stephens & Sullivan, 1997).

Concerns about contexts and open-ended approaches

Notwithstanding this support, more recently there have been some concerns about the effect of context based and open-ended strategies in mathematics teaching and assessment. In a comprehensive review of the national testing system in the United Kingdom, Cooper and Dunne (1999) found that contextualising mathematics tasks created particular difficulties for working-class students, so much so that they performed

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significantly poorer than their middle-class peers on these tasks whereas performance on decontextualised tasks was equivalent. Similarly, Zevenbergen and Lerman (2001) argued that some students are better able to decode mathematics tasks expressed as contextualised problems and that the capacity to answer questions appropriately corresponds somewhat with student social background. Lubienski (2000), monitoring the implementation of a curriculum and materials based on open-ended contextualised problems, found that target students who preferred the contextualised trial materials were all from high socio-economic backgrounds (SES), whereas the majority of target pupils who preferred typical non-contextualised mathematics were low SES. Many of the low SES students claimed to be worse off as a result of the style of the materials, and none found the contextualised materials easier. Lubienski stressed that some of the low SES students experiencing difficulty with the trial materials were high achievers. These studies pose new considerations in understanding how some practices in school mathematics may create unintended barriers to success for some students.

It has been suggested that the different responses of pupils is a product of the school curriculum. For example, Anyon (1981) found that what she called working-class schools tended to emphasise rote learning strategies while the schools with professional class pupils spent more time building up knowledge relationally. It has also been argued that the receptiveness of pupils to mathematics is social-class based. Cooper (1986), for example, implemented a program that aimed to improve the teaching of mathematics in a school serving a lower SES community and found that the pupils' view of what the school intended to do adversely affected the way in which they learnt. Mellin-Olsen (1981) argued that both the educational and social context influence the learning goals and strategies adopted by the pupils.

Lerman (1998) proposed that differences between the classroom expectations and the students' aspirations may exacerbate disadvantage and that classroom discourses both "distribute powerlessness and powerfulness" (p. 76). Likewise, Zevenbergen (1998) argued that pupils from backgrounds where there are discontinuities between linguistic registers and societal aspirations of home and school have difficulty interpreting some aspects of classroom processes, and that teachers should make socio-cultural norms of pedagogy explicit to students. This can mean that for children whose cultural norms are similar to those embedded within mainstream pedagogical practice, the mathematics is more accessible than for students whose culture does not fit the dominant classroom routines. Delpit (1988) proposed that schools should seek to teach their usually *implicit* values, and that to pretend that schooling (and society) is democratic actually denies groups outside the mainstream access to the opportunities that schooling is intended to provide.

In other words, there are factors inherent in the culture of schooling that may constrain the potential to engage some students in learning—one aspect of what Bernstein (1996) termed invisible pedagogy.

Seeking a solution

We are proposing that teachers who adopt strategies that seek to be inclusive of all students need to be *explicit* about factors that may inhibit participation. One framework that may be useful for guiding the development of such approaches was proposed by Dweck (1999), who argued that people's views of intelligence, whilst stable without intervention, are malleable to suggestion. Dweck suggested that pupils who have a fixed view of intelligence predominantly seek affirmation from external sources, including from the teacher. Their positive self image relies upon success on tasks. When experiencing difficulties, such pupils lose confidence in themselves, tend to denigrate their own intelligence, develop negative approaches, have lower persistence, and exhibit plunging expectations and deteriorating performance. There are other students, according to Dweck, whose view of intelligence is not so fixed, and who are more mastery oriented. The latter pupils do not view failure as an indictment on themselves, but as a necessary part of learning, and when experiencing challenge they are likely to increase their focus on task goals and utilise a range of strategies. Being within a socio-economic or cultural subgroup within a school is thought to compound the effect of these different perspectives on intelligence. Dweck argued that teachers can influence the way that students are likely to respond by teaching specific behaviours and attitudes such as decoding tasks, perseverance, seeing difficulties as opportunities, and learning from mistakes. Importantly, they can explain the purpose of particular aspects of pedagogy such as grouping, use of contexts, the type of solutions sought, the modes of communicating responses, and aspects of responses that will be valued.

It is this theme of explicitness that underpins our project. Rather than accepting concerns expressed about contextualised or open-ended strategies and thus suggesting that teachers should avoid these, we believe that teachers can take action to make *explicit* various aspects of hidden pedagogy that we term *implicit*. Our aim is to create environments that assist all students to participate fully in learning mathematics.

OVERCOMING BARRIERS TO MATHEMATICS LEARNING

One of the goals of our project, called *Overcoming Barriers to Mathematics Learning*, is to design, implement and describe teaching approaches that incorporate attention to explicit pedagogies.

The process used to identify and describe aspects of implicit pedagogy was described in Sullivan, Zevenbergen and Mousley (2002). An outcome was the production of a manual that lists a range of particular strategies that teachers could use to make implicit pedagogies more explicit (Sullivan, Mousley, & Zevenbergen, 2002) and so address aspects of possible disadvantage of particular groups.

Essentially the project uses multiple case studies to examine the classroom implementation of explicit mathematics pedagogical strategies. The data are based on a model, developed from Clark and Peterson (1986), that has teacher beliefs and understandings interacting with opportunities and constraints, each influencing (and influenced by) the teacher's intention and actions.

The teachers in our project had three days of professional development where we outlined the project and our expectations of their participation, presented the research-based manual of advice about explicit pedagogies, and considered a range of key elements of contextualised open-ended teaching approaches for primary mathematics classrooms. The teachers from each of the schools involved also carried out initial planning for teaching their first unit of work at this stage.

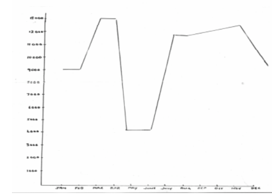
Data were collected by a questionnaire on aspects of their beliefs and understandings, and through interviews on what they saw as some opportunities and constraints. A planning survey was used to gain insights into their intentions for teaching a unit of mathematics. Structured observations of teaching were undertaken then descriptions of the teachers' actions and classroom interactions were compiled.

The data presented below are from just three of the lesson observations. A variety of naturalistic and structured lesson observation schedules had been trialled, and the instrument selected was adapted from that used by Clarke et al (2002). This consisted of (a) a form for the collection of overview comments; (b) a naturalistic report using two columns, one for a record of what happened and one for the observers' impressions; and (c) a framework to structure observer's post-lesson reporting of their immediate impressions. These notes from the lesson observers were used as the source of the data presented below. There were two observers for these three lessons.

ONE LESSON THREE TIMES

To present the sense of the extensive and rich data and some issues associated with the implementation of the explicit pedagogies, the following are selected excerpts from the observations of one of the three lessons. The teachers of Grade 6[2] in this school worked as a team, planning together and essentially seeking to teach the same lessons in their own classrooms. The focus here is on the extent to which they chose to be explicit about some of the aspects of pedagogy outlined in the manual.

The lesson was described in the plan as follows:



> Present children with a line graph. Tell students this is a graph of the number of worms in the worm farm. Write a story about it.

The task material consisted of a graph as shown[3]. The axes were labelled with months, and numbers of worms, in thousands. The text on the page read: "Look at the line graph. The graph represents the population of worms in our worm farm at particular times throughout the year. Write a story about it. (Use up all the space below the graph.)" Pre and post lessons were implemented that supported this lesson. This ensured that students were familiar with the content and processes needed in this lesson. In each of the three teachers' versions of this one lesson there were three phases: a review of the previous lesson, the main story-writing activity and reporting back, then a follow up task.

The first teaching of the lesson was by Shelley[4], who appeared to emphasise the mathematical aspects of the lesson, but who made only limited effort to make explicit aspects of the pedagogy. For example, the observation notes recorded that, during the introduction, in which Shelley reviewed the strip and pi graphs, she:

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[2] 7th year of schooling, with children aged about 12.
[3] The gradient of some parts of the graph is not mathematically ideal, but this did not affect the quality of the experience.
[4] All names in the paper are pseudonyms.

> … was most explicitly probing their thinking. "Can you see the different sections?" Could you tell me how many pieces of passionfruit?" etc. There was even significant extension by asking what else could be shown.

Shelley posed the task for the lesson using an A3 page on which the line graph and text as shown above were presented. She explained that the graph showed the amount of food in the worm farm over time. The lesson observation recorded that:

> She used an open ended prompt of "If there was not writing what might the graph be?"

While this was a useful mathematical extension, not only focusing attention on the key features of the graph but also alerting the students to the possibility of transfer of the information to other contexts, it is a relatively abstract way to pose the task.

Shelley was explicit about the intention for them to create their own story, as was recorded:

> … attention to the fact there is no right or wrong answer, but they are just writing their story.

The students then were set to work:

> They chose their own partner, collected sheets from the teacher and went to the tables. There was some initial puzzling over the task. Interestingly, even though they were paired up for this aspect, there was quite little talking initially. This did build up. … Clearly they are required to take responsibility for their own management and behaviour.

Even though instructed to work with a partner, there was no explanation of why they should do this, or in what ways the partner was intended to assist. It was also noted that

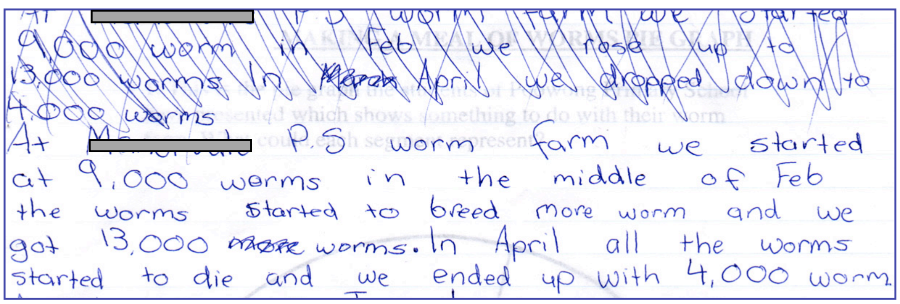

Figure 1: A shift from a descriptive to a more creative outcome.

the mathematical aspects of the task were made clear, but not the practical or even the creative. As was noted by one observer:

> On looking at the work, they seemed to have done mathematically correct descriptions of the graph, but they were not particularly creative in their interpretations. The issue of their initial lack of creativity was interesting. Perhaps they have too little scope in their knowledge of worm farms to be creative. Alternatively perhaps they did not link the creative interpretation with maths.

One observer casually turned to a pair of students nearby. They had started giving a mundane decontextualised numerical description of the graph. The observer asked them whether there might be reasons for the graph changes. The students adapted their work as shown in Figure 1. In other words, it took little prompting for them to respond in a more creative way. This perhaps highlights the need for making this expectation explicit in the first place.

Nearing the end of the lesson, Shelley asked each pair to work with another pair to share their stories, again without any explanation of why they should do this, or what they should look for. She then led a final review that focused on the explanations. As was noted:

> Teacher made insightful comments drawing their attention to important mathematical elements.

In the evaluative notes, the two observers agreed that this teacher was explicit about the openness of the task and that the students could choose their own style of answer, but was not explicit about the purpose of the task, any linking to the curriculum, the sequence of activities, the process for undertaking the activity, the reasons for grouping, or any mathematical terminology. These were all elements that had been part of the professional development undertaken by the teachers involved in the project. There was no obvious acknowledgement of differences between students' capabilities or backgrounds, although none appeared to be necessary.

The data gathered on the second teacher, Greta, indicated that she was explicit about more aspects of the pedagogy, although she had a less mathematical approach to the teaching, resulting paradoxically in more creative mathematical responses from the students. One difference from Shelley's lesson was that a similar line graph to the above was drawn on the board, but with no labelling. Her students were asked to suggest what the graph might represent, and suggested hospital charts, bank account balances, etc. The observers later agreed that the absence of the labels provided a better prompt for the students than asking them to imagine the labels not there in that creativity, use of graphical clues, and aspects such as scale were appreciated explicitly. In giving directions for the story writing, Greta was more explicit about the opportunity for creativity, the connections to the given context and the need for realistic contextualised explanations. Somewhat in contrast, she was more directive about how they should work, and actively monitored their products, but did not make any statements about the purpose of having the children work with partners. In the review stage of the lesson, Greta was explicit about a number of aspects of the pedagogy, but was not explicit about the mathematics and did not pursue any mathematical opportunities, and did not evaluate the children's responses. The observers both collected evidence to show that aspects of pedagogy about which Greta was explicit had a positive effect on corresponding aspects of the responses of the students.

Like Greta, the third teacher, Simone, was explicit about aspects of the open-ended approach and about the types of responses being sought. Simone had repeatedly stressed the potential for creative and realistic dimensions of their stories. In commenting on the review, an observer noted that:

> They came back together. Again (Simone) emphasised the possibility of multiple correct answers. Even though it is a line graph there is much we can find out.

Throughout the lesson, but especially in the review stage, she emphasised the mathematics and its connection to the context. For example, as one student read a story Simone traced the line graph on the board with her finger. As a result, the children's attention was focussed on specific mathematical ideas and language. As with both of the other teachers, the majority of the students seemed to react to the explicit directions that were given by responding in the way the teacher intended.

DISCUSSION AND CONCLUSION

We are reporting here on ways that three teachers used an open-ended question set in a practical context. These three teachers planned together an interesting lesson directly connected to a class project, that of managing a worm farm. The open-ended nature of the set task allowed potential for use of appropriate mathematics and student creativity. The lessons were structured to ensure students' involvement, and it seemed clear enough to the students what they were expected to do. Clearly it was possible for the teachers to be explicit about a range of aspects of the pedagogy, and this explicitness contributed to the students' experience. For example, all three teachers were explicit about the possibility of multiple responses, Greta and Simone emphasised the potential for the students to be creative, and these same two teachers incorporated the context of the worm farm explicitly. Shelley and Simone emphasised the mathematical dimension of the task both in posing the task and in the review of student products. The students generally responded to this explicitness in both their written work and reporting back. It seemed to be effective in shaping the nature of their learning. In other words, it seemed that there was a direct link between the intentions that the teacher communicated, the ways the students responded, and the understandings that they developed about the nature of the task.

There were other aspects of the pedagogy that were not made explicit by any of the three teachers. These included:

> (1) the purpose of working with a partner; (2) the expected nature of communication with the partner; (3) the purpose of working on an open-ended question; (3) the criteria for evaluating student responses; (4) the rationale for using a context, and that context in particular; (5) the aspects of mathematics it was intended the students would learn; (6) expected strategies for organising and pacing of the work; and (7) expectations regarding use of specific mathematical terminology.

All of these aspects of pedagogy remained implicit, and students were expected to do their own interpreting. There was no evidence that students worked any of these out for themselves or that they saw the need to do so. While the children would be seen as working in a self-directed way in all three classrooms, they merely followed the teachers' expectations, picking up any subtle hints offered.

In summary, the findings of the project to date include aspects of implicit pedagogy that may be more apparent to some students than to others, and we now have a better understanding of both explicit and subtle ways that teachers' expectations are conveyed in mathematics classrooms. We believe that we have learned more about how to create environments that will assist students to participate more fully in the learning of mathematics. In the lessons observed, including the three reported above, making aspects of the pedagogy more explicit resulted in productive responses by most of the children. Interestingly though, even where teachers were explicit about aspects such as creative use of the mathematical information and the use of the given context, some students did not heed that advice. It seems that being explicit about particular requirements does generally produce positive outcomes, but it is not a guarantee.

Further, in most lessons observed the students worked on tasks fairly independently of teachers, and the teachers gave little progressive feedback or further assistance to groups of students from minority groups. Other than a few specific reactions to anticipated discipline problems, there was no differentiation between students that was evident to the observers. This was disconcerting because one of the assumptions in our project—and a focus of the professional development that it included—was that pedagogical strategies commonly associated the use of contextualised open-ended tasks are likely be clearer for some students than others. This implies that some particular actions are needed to address the needs of specific students. The teachers neither planned nor taught in a way that indicated their acceptance of this contention. This aspect of our project requires further examination.

References

Anyon, J. (1981). Social class and school knowledge. *Curriculum Inquiry, 11*(1), 3–44.

Bernstein, B. (1996). *Pedagogy, symbolic control, and identity: Theory, research, critique*. London: Taylor & Francis.

Christiansen, B., & Walther, G. (1986). Task and activity. In B. Christiansen, A. G. Howson, & M. Otte (Eds), *Perspectives on mathematics education* (pp. 243–307). Dordretcht: Reidel.

Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. C. Wittrock (Ed.) *Handbook of research on teaching* (pp. 255–296). New York: Macmillan.

Clarke, D., et al. (2002). *Early Numeracy Research Project report*. Victorian Department of Education and Training, Catholic Education Office, Association of Independent Schools.

Cooper, B., & Dunne, M. (1998). Anyone for tennis? Social class differences in children's responses to national curriculum mathematics testing. *The Sociological Review*, (Jan), 115–148.

Cooper, T. (1986). Negative power and negative processing. *Proceedings of the 11th Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 29–41) Launceston, Tas: MERGA.

Delpit, L. (1988). The silenced dialogue: Power and pedagogy in educating other people's children. *Harvard Educational Review, 58*(3), 280–298.

Dweck, C.S. (1999). *Self theories: Their role in motivation, personality, and development*. Philadelphia: Psychology Press.

Lerman, S. (1998). A moment in the zoom of a lens: Towards a discursive psychology of mathematics teaching and learning. In A. Olivier & K. Newstead (Eds), *Proceedings of the 22nd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 1, pp. 66–81). Stellenbosch, South Africa: PME.

Lubienski, S. T. (2000). Problem solving as a means toward mathematics for all: An exploratory look through a class lens, *Journal for Research in Mathematics Education, 31*, 454–482.

Mellin-Olsen, S. (1981). Instrumentalism as an educational concept. *Educational Studies in Mathematics, 1*, 351–367.

Meyer, M., Dekker, T., & Querelle, N. (2001). Contexts in mathematics curriculum. *Mathematics Teaching in the Middle School, 6*(9), 522–527.

Middleton, J. A. (1995). A study of intrinsic motivation in the mathematics classroom: A personal construct approach. *Journal for Research in Mathematics Education, 26*(3), 254–279.

Stevens, M., & Sullivan, P. (1997). Developing tasks to assess mathematical performance. In F. Biddulph & K. Carr (Eds), *People in mathematics education. Proceedings of the 20th Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 470–-477). Rotorua, NZ: MERGA.

Sullivan, P. (1999). Seeking a rationale for particular classroom tasks and activities. In J.M. Truran & K. N. Truran (Eds), *Making the difference. Proceedings of the 21st Conference of the Mathematics Educational Research Group of Australasia* (pp. 15–29). Adelaide: MERGA.

Sullivan, P., Zevenbergen, R., & Mousley, J. (2002). Contexts in mathematics teaching: Snakes or ladders? In B. Barton, K. C. Irwin, M. Pfannkuch & M. Thomas (Eds), Mathematics Education in the South Pacific. *Proceedings of the 25th Conference of the Mathematics Educational Research Group of Australasia* (pp. 649–656), Auckland: MERGA.

Sullivan, P., Mousley, J., & Zevenbergen, R. (2002). *Overcoming barriers to mathematics learning: Advice to teachers*. Bundoora: La Trobe University.

Zevenbergen, R. (1998). Language, mathematics and social disadvantage: A Bourdieuian analysis of cultural capital in mathematics education. In C. Kanes, M. Goos, & E. Warren (Eds), *Teaching mathematics in new times. Proceedings of the 21st Conference of the Mathematics Education Research Group of Australasia* (pp. 716–722). Gold Coast, Qld: MERGA.

Zevenbergen, R., & Lerman, S. (2001). Communicative competence in school mathematics: On being able to do school mathematics. In J. Bobis, B. Perry, & M. Mitchelmore (Eds), *Numeracy and beyond. Proceedings of the 24th Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 571-578).