Contexts in Mathematics Teaching: Snakes or Ladders?

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This paper reports analysis of discussions between mathematics educators about ways in which the contexts in which classroom tasks are embedded can have the effect of alienating some students, especially those who may have less appreciation of the purposes of schooling. The results suggest that some care could be taken in the choice of and introduction of contexts of mathematical problems, in order to ensure that all students relate appropriately to the contexts as well as the mathematics.

Introduction

> The *Melbourne Age* of 12th of January reported that some members of the Chinese Army are overweight. They suggested that for soldiers between the ages of 20 and 29 their weight should be their height less 105 with a tolerance of 10%. For soldiers between the ages of 30 and 34 their weight should be their height less 100 with a tolerance of 10%, and with a 12% tolerance for 35 to 39 year olds.

This is an example of the context that could form the basis of a mathematical experience. Before using such a context teachers would need to make judgments about its mathematical suitability, the interest or relevance to the students, the potential motivational impact, and the possibility of negative effects or tendency to exclude some students.

This paper is a report of some data related to the use of contexts from the first phase of a project, entitled *Overcoming Barriers to Mathematics Learning*, that is exploring a range of such aspects of mathematics pedagogy. Our basic contention is that there may be some aspects of currently recommended approaches to mathematics teaching that improve the learning of most students but that may be alienating for some.

Theoretical Bases of the Project

We base the project on the use of open-ended questions since it seems that they incorporate many aspects of current approaches to mathematics teaching, and have been demonstrated to be effective generally with students at a variety of levels (see Sullivan, Bourke, & Scott, 1997; Sullivan, 1999). What has not been researched is whether such tasks, and the associated pedagogies, advantage *all* students. It is recognised that students from socially and culturally divergent backgrounds are the most at risk of mathematical failure. It has been suggested that the very socio-cultural nature of mathematics and mathematics education has led to a differentiation amongst its learners between those who can engage with the presentations of the subject and those who are unable to do so (Burton, 1996; Dengate & Lerman, 1995; Salomon & Perkins, 1998). Thus we are concerned that the very characteristics that make open-ended tasks effective for many students may create

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difficulties for others. For example, at least part of the way that open-ended tasks function is by removing some of the detailed task demands, making the requirements less explicit; yet this may have the effect of creating insecurity in some students.

A further theoretical basis of this research is a construct proposed by Bernstein's (1990, 1996) pedagogic discourse. Bernstein claimed that through "visible pedagogy" and "invisible pedagogy", students receive messages about both the overt and the hidden curriculum of schools. He suggested that middle-class students are able to make sense of invisible pedagogy more effectively than their working class peers, due to their familiarity with the embedded social values and norms; and hence they have more chance of success.

A third body of work that we draw on is Cobb and McClain's (1999) use of a socio-mathematical framework where two complementary norms of activity in mathematics classrooms are delineated: mathematical and socio-cultural norms. Wood (2001) elaborated these two dimensions, emphasising the social nature of children's learning and the way that rich social situations contribute to this, noting that a key element is the way that children try to make sense of the classroom culture. Wood described the other dimension as the interplay of children's developing cognition and the structure that underlies mathematics. Based on this work, we define "mathematical norms" to be the principles, generalisations, processes, and products that form the basis of the mathematics curriculum and serve as the tools for the teaching and learning of mathematics itself. The "socio-cultural norms" are the usual practices, organisational routines, and modes of communication that impact on approaches to learning, types of responses valued, views about legitimacy of knowledge produced, and responsibilities of individual learners. These two dimensions underpin our project, and we argue that it is important to make social norms comprehensible and communicable. Of course, as our goal is to explore mathematics, then this also needs to be explicit. Thus in this project processes and ideas typically used with open tasks (mathematical inquiry, creation of multiple solutions, etc.) are one focus, while teachers' and classrooms' pedagogical activities (mode of introduction and explanation of the tasks, and patterns of interaction during discussion of the varied responses, etc.) are another. We do not see these as discrete phenomena; and in fact we are investigating, in the context of open-ended tasks, the *intersection* of the mathematical and socio-cultural norms and their joint impact on learning outcomes.

Contexts of Tasks

In this paper we are focussing on the use of relevant contexts to make problems seem realistic and relevant. This strategy has both mathematical and socio-cultural aspects, and is an example of a commonly accepted aspect of mathematics teaching that, if not used carefully, has potential to restrict the mathematical development of some students.

Borasi (1986) defined context as a situation in which a problem is embedded, and proposed that the role of context is to provide problem solvers with information that may enable the solution of the problem. 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. Meyer, Dekker and Querelle argued that high quality contexts should support the mathematics and not overwhelm it; be real or at least imaginable; be varied; relate to real problems to solve; be sensitive to cultural, gender and racial norms and not exclude any group of students; and allow the making of models.

We accept a somewhat broad definition of a relevant context, including everyday and imaginary situations that may appeal to children. Wiest (2001) studied the responses of 273 children, in six Year 4 classrooms and six Year 6 classrooms in the USA, to various contexts. Equivalent problems had the same mathematical structure and demands on problem-solving skills. The sets were categorised as low fantasy, high fantasy, children's real-world, and adults' real-world. Wiest found that the context of problems affected a range of variables including the children's interest in, attentiveness to, and willingness to engage with problems; the strategies they used; the effort they expended; their perception of and their actual success; and the extent to which measurable learning outcomes were attained. Wiest suggested that while the general type of context did not appear to affect children's actual performance, fantasy responses evoked stronger affective responses than the other types of problems.

While the general consensus among teachers is that the practice of embedding school mathematics into some "real" context supports learning, this consensus requires some further exploration. For example, in their comprehensive review of the national testing system in the UK, Cooper and Dunne (1999) argued that contextualising mathematics creates another layer of difficulty for students. They undertook a sociological analysis of learning tasks and children's performance, concluding that contextualising tasks creates particular difficulties for working-class students, so much so that they performed significantly poorer than their middle-class peers on these tasks whereas performance on decontextualised tasks was equivalent. Drawing on a large sample, these findings are important as they pose a new dimension to understanding how some practices in school mathematics—and in this case contextualising tasks—create further barriers to success for some students. Cooper and Dunne argued that the process of recontextualisation whereby school mathematics is connected to another field—in this case the everyday experience and knowledge of students—creates a new set of demands previously not recognized. They proposed that students need to identify the recontextualisation process so that they recognise the demands of the task as being school mathematics in spite of its immediate appearance of being an everyday task.

To examine further the problematic nature of using contexts, consider the following examples drawn from authoritative sources of information about mathematics teaching. The National Council of Teachers of Mathematics (1989) argued that problems using contexts enrich the experience of learning mathematics. They gave an example of a contextual problem, supposedly arising from a social studies lesson about commerce between North America and Hong Kong. The problem is about a pilot for a major airline transport company being curious about the shortest route between New York and Hong Kong. The problem is clearly unrealistic in that no airline pilot would sit down to work out the shortest route. (It is more likely to be the airline accountant!). The context neither provides a rationale for exploring the mathematical problem nor in any way contributes towards clarifying the problem or making it more accessible.

Another example is from Stern (2000), who used problems with multiple entry points as a way of teaching all students without using ability groups. She presented, as an example, a problem related to an iced cake which, when sliced, had pieces with different numbers of faces with icing. The task was to infer the number of slices of cake. Again, the task is unreal in that no one ever works backward from the appearance of slices of a cake to work out how many slices there were originally. No doubt there would be children who would not appreciate the significance of the icing; as in no way did it contribute to an understanding of the mathematics involved, make the problem more accessible, or give the children a sense of real purpose.

A further example is from Brinker Kent (2000) who used contexts in a culturally diverse elementary school and concluded that all students are capable of learning significant concepts when they have the opportunity to explore the ideas in meaningful contexts. The example she provided is about teaching integers, using the process of ships moving from a canal filled with water at one level to a river that has a different water level. This context is also problematic. If students are unfamiliar with river shipping then it is no more meaningful than frogs jumping backwards on lily ponds. Even for students familiar with the context, the link to the mathematical concepts is somewhat doubtful. It is not really a suitable model of negative integers, since the negative heights are only negative in a relative sense.

We stress that these problems are drawn from rigorously reviewed sources, indicating the complexity of selecting appropriate contexts. We hasten to add that we are not being critical of teachers using such contexts, or even these authors. Indeed we have used similar contexts ourselves, both in our teaching and in our research. We are suggesting that there has not been enough critical examination of this aspect of the debate.

We are *not* arguing that contexts should not be used, indeed we believe that contexts have much to offer. The issue for us is that teachers need to be fully aware of the purpose and implications of using a particular context at a given time with particular students; to choose contexts that are relevant to both the content of problems and children's experience; and to develop strategies for making uses of contexts clear and explicit to students.

Overcoming Barriers to Mathematics Learning

The data reported in this paper arose from the first phase of a larger project exploring barriers to learning mathematics. The intention of this phase was to collect information from a range of educators on what they saw as the challenges and opportunities of open-ended approaches to teaching, with the aim of articulating some specific teaching strategies that could contribute to the second phase of the project.

In this first phase of the project we conducted three discussion groups: one mostly teachers, another all academics, and a mixed group (see Mousley, Zevenbergen, & Sullivan, in press). Each of the groups included people with expertise in aspects of minority-group pedagogy (e.g. Aboriginal education, or literacy for children with non-English-speaking backgrounds). Some of the teacher educators involved were from mathematics education while some were from other fields.

Each of the groups was shown some short excerpts from videotapes of mathematics lessons. The focus groups viewed the videotapes and responded to the prompt "Did you see any aspects of the classroom interaction or activity that may not suit some children?" Participants' contributions were audio recorded and the tapes were transcribed then entered into NVIVO software, coded and categorised. That is, using a grounded theory approach (outlined by Richards & Richards, 1989, and described in Mousley, Sullivan & Waywood, 1998), a list of nodes and sub-nodes was created and refined progressively until the data were grouped under useful headings.

We focus here on one particular excerpt that all three groups watched. The point of the mathematics lesson shown in this extract was to teach about the notion of mathematical mean. The core activity was an open-ended task posed to the class:

The mean height of three people in the room is about 155 cm. You are one of those people. Who might be the other two?

The main purpose of the learning experience was to focus on different ways of examining the meaning of "mean" and ways of arriving at it, although estimation of height was a dimension of the lesson.

The basic task has two features that are relevant for our project overall. One is that the task was open-ended and so allowed a range of possible approaches, procedures and answers for any student. It was intended that the openness of the question would provide an environment for the learning of mathematics that emphasised the possibility of multiple responses, making explicit to the students that it was their own exploration that was required, and both valuing and learning from the range of responses produced. The second relevant feature of the task is that it had a personal dimension. That is, the students were working in a practical context that was directly relevant for them—the estimation or measurement of their heights.

In order to establish a realistic context for this problem, the teacher on the video extract had chosen a poster that projected five people being presented as part of a police lineup. In using this initial context, the teacher attempted to give some rationale or meaning to the context in which the estimation of height and the calculation of means would be enacted. However, it is this context that was the focus of much of the discussions by the groups who viewed the videos.

Data

Our intention was to identify issues related to any aspects of the high-quality teaching shown on the videotapes that practitioner and expert panels would raise in a group discussion. Of course we had prior conceptions of necessary considerations for such teaching, yet by creating forums for discussion among educators we hoped to hear alternate perspectives. The focus groups covered many aspects of mathematics teaching, but we restrict the discussions here to the comments on the context in which the particular problem above was embedded.

The main focus of the lesson was the problem for each student of finding two other students so that together the group had a given mean height. Perhaps thinking that this problem would be unrealistic by itself, the teacher used a police line-up poster as a preliminary context, and it was this element of the lesson's introduction that provoked the most critical comment.

Many of the participants affirmed the strategy of setting problems in realistic contexts:

> The kids get a certain message about the nature of mathematics [that] it's cut off from the world; it's no use to anybody.

Some were concerned, however, about the appropriateness of this context. There were comments about the importance of awareness and sensitivity. For example:

> Dad's off in gaol or someone else has been arrested in the community, so they know about line-ups. They know about the police, they know about the justice system by what's happening to them. So you could use it if it wasn't that sensitive. It comes down to knowing their backgrounds and the sensitivities for the children that you're teaching.

In the same vein, one participant raised the issue of teachers' knowledge of the familiarity of particular situations:

> Should one always use a familiar context? It would depend on the relationship between the school, the community, the teacher and those children. If the teacher knows what's going on at home and …

Others noted the potential ambiguity of the student responses to the prompt:

> What I was concerned about (is) engagement in the task, because one of students said, "Yes, we want to cooperate with the police, we want to find out the clues." The other type of students: it could be their dad!

Some participants also discussed how children's responses to the context might be related to socio-economic status. For example:

> It's a middle class thing—the criminal is more threatening and you have vested interest in identifying them to police. If you are a student from working class, chances are you are on the operative side of things.

Clearly an important issue is that of choosing appropriate contexts. The tenor of discussion was to suggest that the context used in this case was inappropriate and different ones would be preferred. For example, when we asked participants to suggest characteristics of a context that might be culturally positive as distinct from culturally negative, the responses included:

> Australian netball, and a football team. There you have gender equity and the netball teams are sort of a star team. Or the cricket team—cricket mightn't be very relevant—maybe soccer [would be okay], and most kids have a knowledge of an AFL team.

> It would be interesting to choose a context like several sports because the heights are so different. What do we think is the average height of a basketballer? How high might that be on the wall? And what about footballers and what about soccer players?

> Drag in a few Year 12 girls. You'll find none of them are six feet tall and yet every netballer is six feet tall. Who won gold medals for Australia at the Olympics? The Tai Kwon Do person was this big, and the rowers were that big.

> The context needs to be close to the kids but not so close that it's an emotive issue.

In summary, it was suggested by members of all three of the focus groups that before being used a context needs to be considered appropriate in terms of familiarity to the students, culturally sensitivity, and appropriateness in terms of their socio economic background.

We recognise that it is difficult, especially within the usual time constraints on planning teaching, for an individual teacher to consider fully the ramifications of a variety of specific contexts, or to allow time for children to create their own relevant contexts especially with new mathematical concepts. The alternative may be to avoid some potentially interesting contexts and to use somewhat less exciting ones.

This raises, in turn, the related issue of whether mathematics teaching is politically or culturally neutral. On one hand there were arguments to the effect:

> What would be the purpose of teaching? If it's mathematics then your aim really isn't to teach about the justice system or educate in that sense. It may come up but [the] aim is to teach about mathematics. The poster was just an introduction to the point of the lesson, which was estimation.

Another participant recognised the relevance of politically sensitive topics, but suggested a cautious approach to their use:

> Politics and issues of race and culture could enter maths classrooms, but you've got to recognise that it's very dangerous stuff. A lot of teachers stay away from it because they think they're going to get into trouble if they introduce those [issues] into their teaching.

We suspect that this is not a strong rationale for a choice to use or not use a particular context. Consider again the context posed for the middle-secondary problem at the start of this paper—optimum weight for members of the Chinese army. It is reasonable to argue that using such a context with teenagers could be alienating for some. Yet, body image and health and employment opportunities are important issues for teenagers. There is also potential for looking at how cultural groups vary on typical physiques and how these are changing over time. Perhaps such issues may well be amenable to some mathematically oriented investigation, and in that way, explicate the context in a way that illustrates mathematically based analysis of a relevant, socio-culturally situated and practical context.

As an aside, the misconception that the lesson was about estimation of height was common. It is reasonable to assume that the children experiencing the same introduction would also see it as a lesson on estimation, although the focus was the notion of "mean". This illustrates how contexts can add layers of complexity.

Conclusion

With respect to the choice of context in which a task is set, the focus group participants were concerned about (a) appropriateness of the context, particularly considering sensitivity to the background of the students; (b) whether there is an inherent class bias, either positive or negative in the context; (c) whether the focus and purpose of the mathematics learning remain clear; and (d) whether and in what ways relevant but sensitive topics could be used.

Our project is working with teachers in four schools who will use open ended questions as the basis of units of work as part of their regular curriculum. One of the outcomes of the project will be the provision of written advice for teachers—and we will be providing particular advice. With this objective in mind, we have identified pedagogies that are important for learning and in particular those which may not be explicit to all students in the class, with the deliberate intention to find ways of making those pedagogies explicit. Our intention is also to measure the way that this affects learning. The determination of this advice is part of the focus of the second phase of this project.

To differentiate our work from Bernstein's invisible pedagogy, we are using the term "implicit pedagogy", because we intend to make explicit particular aspects of invisible pedagogy that have been identified. This "making explicit" needs to take two forms. First, teachers need to become more aware of specific, common aspects of teaching that may not be optimal for certain groups of pupils, and then address these when working at improving their typical patterns of interaction in mathematics classrooms. Second, aspects or approaches to teaching that they decide to use purposefully need to be made more explicit to the children so that potential for confusion is reduced and reasons for using particular strategies are well understood.

If you, the reader, have already worked out whether you would be accepted into the Chinese army then that context has excited your interest. You may have asked yourself questions, such as, "What are the rules for other age groups?" or "Is it different for women?" If so, you have seen the mathematical potential. You may be reluctant to use such a context with teenagers because of the potentially alienating effect on some students although teachers of other subjects presumably have ways of coping with such issues. Clearly the use of such a contextual prompt is potentially ambiguous, yet even that ambiguity is contestable, and we suspect that avoiding the use of interesting but potentially difficult contexts is not the solution.

The difficulties in more commonly-used contexts are often not as obvious, yet they may exist. Hence while we agree with the mainstream belief that contexts can be useful, it is clear that teachers need to develop sensitivities and take appropriate steps to avoid the potential for contexts selected to be alienating, excluding or exacerbating of disadvantage.

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