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ORAL LANGUAGE, REPRESENTATIONS and MATHEMATICAL UNDERSTANDING: INDIGENOUS AUSTRALIAN STUDENTS

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Abstract

This paper explores the role of oral language and representations in negotiating mathematical understanding. The data were gathered from two Indigenous Australian classrooms in Northern Queensland. The first classroom, a Year 6/7 consisted of 15 students whose ages range from 10 years to 12 years with eight being Aboriginal, six from Torres Strait and one from Papua New Guinea. The second classroom, a Years 4/5/6 classroom consisted of 14 Year 3/4/5 students, with eight being Aboriginal and six of Torres Strait Island origin. Both teachers had been working in this context for up to five years and were perceived by both the school community and local educational consultants as exemplary teachers of Indigenous Australian students. Data were gathered from conversations with the two teachers, and from videos of their lessons especially designed to illuminate issues they negotiate on a day-to-day basis when teaching mathematics. The results indicate that explicit consideration needs to be given to the careful development of precise mathematical language and concrete mathematical materials, the use of questioning in establishing classroom discourse, and the recognition that many of these classrooms are bilingual.

Introduction

The balancing act facing many educators and researchers working in Indigenous contexts is; how do we attend to upholding and maintaining cultural difference while producing outcomes that allow Indigenous Australian students to participate on an equal footing in mainstream society? Nakata (2003) suggests that one of the major influences on policy has been anthropological knowledge; a recognition that Indigenous Australian people are culturally different. This has been both empowering and limiting. It has resulted in allowing characteristics previously seen as inferior to be viewed as positive, calling on classroom teachers to (a) incorporate Indigenous Australian contexts in the classroom teaching, (b) acknowledge that Indigenous Australian culture has its own mathematics, that in many instances is different from Western mathematics, and (c) cater for learning that incorporates group work and hands on activities. There has been much research on Indigenous Australian students' mathematical learning that reflects these dimensions (e.g., Bucknall, 1995; Ngurruwutthun, 1991; Potter, 1994). Many of the results from this research suggest that positive outcomes for Indigenous Australian students recognise cultural differences such as learning styles and communication. It also includes acknowledging the mathematics that exists within Indigenous Australian culture, such as kinship relationships, a system recognised as a mathematical structure due to consistent relationships that apply to various family groupings. While these approaches have assisted student and Indigenous Australian community engagement in mathematics, there are instances where "the infiltration of anthropological schemas into Indigenous educational policies and practices has been counterproductive, giving the anthropological discourse primacy over the educational context" (Nakata, 2003, p. 9). Nakata believes that the cultural difference schema also stands to provide a convenient explanation of students' failure and exonerates teacher practice.

Many researchers have found there is a mismatch of conditions for learning for young Indigenous Australian students as they enter school (Bliss, 2004; Clancy, 2005; Dunn, 1999; Simpson et al., 1999; Zevenbergen, 2000). Tension still exists between policy and suggested strategies for Indigenous Australian students. The reality of responding to cultural differences and practices and

adjusting the interactions and strategies for teaching and learning in classrooms is still far from ideal (Simpson & Clancy, 2005). The use of spoken language in school and the types of interactions teachers utilise can either advantage or disadvantage Indigenous Australian students. Furthermore, the importance of spoken language as the foundation for all learning is often not fully recognised and many young Indigenous Australian students are not able to make a strong start in the early years of schooling as the discourses of their family often do not match that of the school (Cairney, 2003). This mismatch of home and school language has been shown to disadvantage Indigenous Australian students' achievements in literacy and numeracy in the long term (Dickinson et al., 2006; MCEETYA, 2004). Understanding and accepting Aboriginal English (AE) as a dialect of spoken English used by most Aboriginal and Torres Strait Islander people is vital and knowing that there are variations across particular communities is important (Haig et al., 2005). While Standard Australian English (SAE) is the discourse of the school, and it is conjectured that teachers need to create a bridge for young Indigenous Australian students between AE and SAE as they grapple with both the new language and new concepts, little is known about what this means in terms of practice.

Patterns of classroom interactions have been shown to disadvantage some students particularly the interaction of teacher questioning as Indigenous Australian students do not commonly experience this type of interaction at home or within their community (Galloway, 2003; Haig et al., 2005). Unjustified blame has been placed upon Indigenous Australian students in the past with absenteeism, disadvantaged social background and culture all viewed as contributing factors (Bourke & Rigby, 2000). This is seen as irresponsible (Cooper et al., 2004). Insufficient consideration has been given to the complexities that confront young Indigenous Australian students as they enter school. Educators have not lifted the blame and given sufficient positive consideration to ways of adapting the conditions for learning for these students to prepare them for success rather than failure. Thus the dominant view of society in blaming aspects of culture, disadvantage and maintaining low expectations needs to be turned around so that a positive framework can be adopted in order to improve the educational outcomes for Indigenous Australian students (Matthews et al., 2003; Sarra, 2003).

The stance taken in this research is that Indigenous Australian students do have mathematical concepts but that they express them differently from non-Indigenous students; and that there is a need for Indigenous Australian students to engage in high levels of Western mathematics. Disallowing them the opportunity to do so is depriving them of employment opportunities and is disempowering, as they will lack the tools to understand that Western mathematics is culturally based and can be utilised to oppress particular socio-economic groups. This paper explores how Indigenous Australian students and two non-Indigenous teachers negotiate mathematical understanding, with a particular focus on the roles oral language and representations play.

Methods

Given that the focus of this paper is primarily on cognitive development, the epistemological stance taken in this analysis is the science of semiotics; a means of addressing signs, their connections and meanings. In this instance signs refer to external representations. Presmeg (1997) suggests that when one recognises the structure of the system in which he or she engages, is capable of explaining that structure to others by such means as encoding it in a diagram or applying some overarching framework, then mathematics exists. So while semiotics is commonly used to construct links between cultural and historical practices and mathematics (Presmeg, 1997; Radford, 1997) it also assists us to understand classroom discourse in mathematics (Saenz-Ludlow, 2001; Warren, 2003). Sign interpretation is a personal process with some students being unable to move beyond the physical characteristics of the sign (the external representation). Peirce (1960) believes that the sign relation is inherently triadic, linking an object, a representation and an interpretation so that the object determines the representation and in turn determines the interpretation. Semiosis involves the process of going beyond particular signs to more and more complex representations incorporating new signs and generalisations (Peirce, 1960); an evolving process. Vygotsky regarded signs as tools that were capable of influencing one's inward behaviour and the behaviour of another. Thus the teaching and learning process can be seen as a process of semiosis where the teacher and students become both contributors and interpreters.

Participants

This paper reports on how students and teachers use the language of mathematics and representations in their mathematical learning. The school chosen for this study is a P-13 school, a large boarding school catering exclusively for Aboriginal and Torres Strait students. This school prides itself in offering quality education for Indigenous Australian students in far North Queensland. In 2006, 47% of Year 3 students, 69% of Year 5 students, and 17% of Year 7 students achieved above the national benchmark for numeracy. In addition, approximately 30 students successfully completed Year 12. Two teachers, David and Melissa, volunteered to participate in this pilot study. David teaches 15 Year 6/7 students whose ages range from

10 years to 12 years with eight being Aboriginal, six from Torres Strait and one from Papua New Guinea. Melissa's class consisted of 14 Year 3/4/5 students, with eight being Aboriginal and six of Torres Strait Island origin. Both of these teachers had been working in these types of environments for up to five years and were perceived by both the school community and local educational consultants as exemplary teachers of Indigenous Australian students.

Data sources and analysis

The data were gathered from three main sources, namely, (a) open ended interviews with the two teachers before the teaching began (pre-interview), (b) videotapes of two lessons especially constructed by the teachers to illustrate the adaptations they made to heir teaching in these environments when teaching mathematics, and (c) a reflective interview with each teacher at the end of the teaching episode (post-interview). All lessons were videotaped and field notes were taken. At the completion of the lessons, the researcher and teacher reflected on the researcher's field notes, endeavouring to minimise the distortions inherent in this form of data collection, and arrive at some common perspective of the instruction that occurred and the thinking exhibited by the students participating in the classroom discussions. The videotapes were transcribed. The videos and participant observation scripts served to provide insights into the learning of the community and particularly identifying specific actions, specific use of representations and conversations that supported this learning.

Results and discussion

Pre-interview

Both teachers commented on the difficulties they experienced on a day-to-day basis in these environments. These related to the language difficulties that they experienced, the need to relate all of their examples to relevant real world contexts, and the use of a variety of visual aides needed to allow access to the ideas. There was also tension between what they perceived as "talking about mathematics in Indigenous Australian English" and precise mathematical language, for example, using "big" and "big up" for tall and taller, and the need to ensure that Indigenous Australian students had the opportunity to communicate with "proper mathematical language". This last issue relates to a notion of empowerment. They believed that "setting the benchmarks" too low was in fact an act of "keeping Indigenous Australians in their own class", denying them the opportunity to move out of their low socioeconomic circumstances and act as "activists for real social change". Both presented two lessons that they believed exhibited these characteristics. They

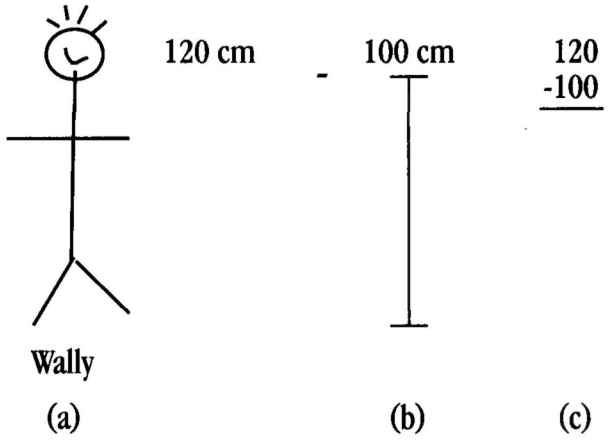

Figure 1. Diagrams drawn on the board at different stages during the discussion.

perceived that teaching in these classrooms required a high use of oral language, hands on experiences, a range of representations and an ability to continually adapt the learning trajectory to maximise access of the participants to the mathematical concepts. The data reported in this paper is one excerpt from the Year 3/4/5 classroom and one short excerpt chosen from the Year 6/7 classroom. The first illustrates the use of different representations and contexts to assist students to solve a problem involving the comparison of the heights of two students, and the second illustrates students' "code switching" as they engage in an activity involving calculation of the volumes of a variety of shapes made from blocks. Figure 1 illustrates the particular representations utilised by Melissa as she discussed the problem with the students.

Excerpts from the Year 3/4/5 classroom (Melissa's classroom)

Teacher: Wally was 120 cm tall. (Both Wally and Aldo are students in the class).

Students: OOOHH.

T: Here is Wally. Now Aldo, he's a little bit younger so he is a little bit shorter. Aldo was 100 cm tall. [Draws Figure 1 (a) on the Board]

T: How much taller, listen carefully to the question. How much taller was Wally than Aldo? How much taller was he than Aldo? Think about it very very carefully. How much taller? [Paused]

T: We sometimes say what is the difference between them.

C1: 220cm.

T: That would be if he jumped up on his head.

[Gesturing the action of one jumping up on top of the other]

T: That's how much they would be altogether. How much taller?

T: Here is 100cm which might be about here. [Marking off in the air 100cm with her left hand]

T: Wally is 120cm tall which might be about here. How much taller? [Gesturing 120 cm as a point above 100 cm and using both hands to focus their attention on the gap].

T: What is that difference between 100 and 120cm. What is that difference in there?

[Moving both hands backwards and forwards to emphasis the focus is on the gap between the two hands] Do you know?

C2: It could be 100 and something.

T: No that is an excellent go though. What is the difference between 100 and 120? What is that difference in there? How much is it? Do you know Marley?

T: Let's look at this way. We have 120 cm is up here and 100cm is to here?

[Draws Figure 1 (b) on the board].

T: What is that difference in there? This is 100cm. What is the difference in between there?

[Pointing the difference between the two heights].

T: What is the difference in there? How many marks are between there?

C3: 50.

T: No it's not 50.

C4: 100.

T: No it is not 100. Think about it carefully. How many points go in between there and there. Very, very tricky. Think about it carefully.

C4: 10.

C5: Eight.

C6: [shouted out] Miss 20.

T: This is an easy way of doing this. We can do the difference between something by doing a take away. 120 take away 100.

C7: Two.

C8: 200.

T: Let's think of it this way if you had 120 dollars and you took away 100 dollars how much is left. 120 dollars and you gave away 100. How much is left?

[Gestures with her closed fists the action of take away and then draws Figure 1 (c) on the board].

C9: 120.

At this stage nearly all the class were whispering 20.

Students in unison: 20.

Melissa then worked through the algorithm with them. In this conversation the focus was on subtracting 100 from 120. Students progressively moved through the process of first considering the ones and ascertaining if there were any to "take away" (0 take 0), and recording 0 in the ones column. They then moved onto the tens and discussed if there were any tens to "take away" (2 tens take 0 tens), and recording 2 in the tens column. Finally the discussion focussed on the hundreds (1 hundred take 1 hundred), thus obtaining the answer 20. In this conversation Melissa ensured that all the mathematical language associated with this process was explicit and that each student could follow the language and process used to reach the answer of 20.

The object is considered to be the beginning task, namely, "If Wally is 120 cm tall and Aldo is 100 cm tall, how much taller is Wally than Aldo?" and the signs are the various representations that assisted in understanding the object. The interpreters were the students themselves. Melissa continually adjusted her representations as a response to students' interpretations. The first representation (Figure 1(a)) did not appear to be interpreted by students as a difference representation, hence the introduction of the gesture, illustrating that the focus was on the difference between the students' two heights. This was further represented as a diagram with horizontal bars used to again focus attention on the difference (see Figure 1(b)). As Melissa proceeded along this trajectory she also changed the object itself from a comparison problem to a subtraction problem (by introducing the language of difference and then take away). Finally, she switched into the context of money thus the original

object changed from *how much taller is Wally than Aldo* to *if you had 120 dollars and gave away 100 dollars how much is left*. This process illustrates a common strategy used in many Indigenous Australian classrooms – the context of money as a bridge to understanding mathematics. While the students successfully answered this problem, does this assist them in reaching an understanding of the original problems and do they see the analogy between each? This requires further research.

Also another common characteristic of this conversation was the lack of ongoing dialogue about the problem itself. The students volunteered answers (which were often incorrect) but there was no ongoing conversation about their thinking. A concern for these teachers was the "shame factor". Melissa was aware that Indigenous students do not like being asked questions in front of the whole class, and especially did not like their incorrect answers to be pursued, hence her continual positive reinforcing comments, such as, "good try" as the lesson proceeded. In some instances it appears that students are unable to go beyond the written mark; the literal interpretation.

The tasks presented in this research induce an interaction between the task, representations of the task and students' interpretations, but in this instance whether the interplay between different representations and their interpretations bring deeper meaning to the object itself is the key question. The use of gesturing was also explicit throughout the lesson. In fact the role of gesturing within a culture with a strong oral history, may in fact prove to be an important representation in the interpretation process. Recent research has evidenced that students are significantly more likely to reiterate the teacher's spoken strategy when it is produced in conjunction with gestures that conveyed the same strategy than when it is produced with no gestures at all (Goldin-Meadow, 2006).

Excerpt from the Year 6/7 classroom (David's classroom)

The students were given a sheet with two dimensional drawings of three dimensional shapes constructed from cubes, a standard volume activity that many middle school students experience in a mathematics classroom. This activity was one of four that the students worked through on a rotational basis. There was no discussion as to whether they understood the task or as to whether they could interpret the diagrams presented on the task sheet. In mathematics classrooms students are typically exposed to two dimensional drawings of three dimensional shapes from the beginning of schooling. While this exposure occurs, they are not often asked to construct the three dimensional shape from the two dimensional drawing, especially in the later years of primary schooling. The common assumption is this is a trivial task. Figure 2 presents a sample of the drawings.

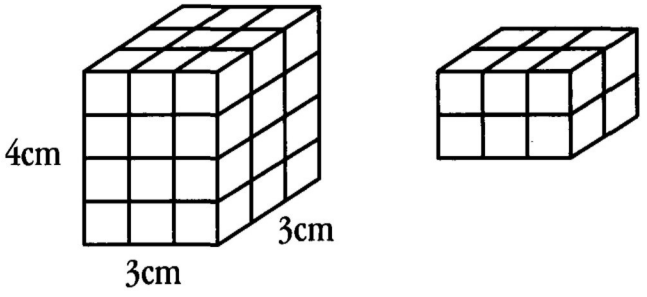

Figure 2. Examples of tasks presented to the students.

They were asked to work in pairs to construct the shapes using blocks and record the number of blocks each shape consisted of, that is, record the volume of the shapes. Most students struggled with this task, especially interpreting the diagram as a three dimensional shape and then using the cubes to reconstruct a real world model of the shape. Classroom observation indicated that they appeared to be able to "see" the flat face of the shape (for Figure 2(a) it has 9 blocks) but experienced difficulty in recognising its depth (3 blocks) It is conjectured that this was not due to a lack of spatial ability but rather experiential resulting from having limited experience with playing with blocks and interpreting diagrams such as "lego plans", a common early childhood activity in many white students' home environments.

The second excerpt was chosen for inclusion in this paper as it demonstrates students "code switching" as they interacted in the classroom context. The lesson began with a general discussion about what we mean by the term volume, how it differs from capacity, and the processes commonly used to calculate the volume of a three dimensional cuboid. The students were then split into three rotational groups. The following excerpt is from a conversation between an Aboriginal student and a Torres Strait Islander student:

C1: (Singing out loud in own language)

C2: You killed it.

C1: You starting dissing each other.

C2: You were going to start dissing, then they're going to start dissing and then your going to diss them.

C1: Hello, Miss where are you from?

Researcher: I am from Brisbane and where are you from?

C1: No, I'm from, I'm born in Rockhampton but I rear up in Yarrabah.

C2: How many are there? [referring to the diagram of cubes]

> C1: 24, yes that's right. One, two, three, four, five, six, seven, is that seven? Yep, it's seven. Twenty-four and I still need to do this one. [counting up the cubes in the diagram]

This short extract illustrates a typical conversation that occurred in the classroom. As the students worked and conversed with each other they continually switched between their own languages, but when it came to discussing mathematical concepts they expressed their ideas using the language of mathematics. It is conjectured that a possible reason for this is that their own language lacks the specific vocabulary needed to describe these mathematical situations. This is a common problem for most students engaging in mathematical learning. Laborde (1990) claimed there are language structures peculiar to mathematics that a student must learn as they do not occur frequently in the student's natural language.

Post-interview

The reflections at the end of the lessons between the teachers and the researcher focused on four broad themes. First, there are tensions between all the languages that exist in these situations and the need to pave the way to high levels of achievements in mathematics. There were at least two different languages in these classrooms, Indigenous Australian English and Creole. Both teachers, while they knew something about these languages felt that both languages lacked aspects that assisted them in working in a mathematical environment. For example, there appeared to be little attribute language in their home language. For length the predominant comparative words were "big", "bigger up", "small", and "boney". Hence, they felt a need to ensure that their lessons provided opportunities for Indigenous Australian students to learn about and use the explicit language of mathematics. Second, there are culturally different styles in communication between home situations and school situations, especially when it came to direct questioning. Past research has evidenced that if an Indigenous Australian student cannot answer the question then they experience a feeling of "shame", especially if they are singled out in front of others. Hence in both instances classroom discourse tended to avoid probing "incorrect thinking". Third, Indigenous Australian students' engagement increases if the examples are related to their world and the approach is very hands on. Melissa commented that she always endeavoured to use the students themselves as the context she used when discussing mathematical ideas, hence the choice of Wally and Aldo for her comparative measurement problem. Fourth, given that their culture's communication is based on oral language there is a reluctance to "write" things down. All of these impacted on how both teachers conducted their lessons.

Summary and implications

This study begins to tease out particular issues that need to be taken into consideration as young Indigenous Australian students engage with Western mathematics. The first implication is the need to explicitly link home environment to school environment, with the specific aim of allowing young Indigenous Australian students access to Western mathematics. The theoretical frameworks provided for this analysis give some insights into the classroom discourse. In the case of Melissa's class semiosis assisted in viewing the classroom interchange as consisting of three main dimensions, namely, object, representations and interpretations. It also assisted in documenting how she changed the representations to assist the students reach some meaning about the object. But in this instance it was a backward mapping, starting with school and working back to home and the context of money. In Presmeg's framework the objectification of a concept occurs through a layering process with each layer adding a deeper understanding. Interpreting different representations of the same concept adds a richness of understanding of the concept. As Radford et al. (2005) stated, the point where all signs interact reveals the concept's mathematical essence. Thus it is important to not only assist students solve problems by choosing representations that allow access but then to use this understanding to help them interpret other representations of the problem, a flexible mapping between varying representations. For the main project a more appropriate framework could be the notion of semiotic chaining, a means of building links between cultural practices and the teaching and learning of mathematics in school (Presmeg, 2005). An example of this was given by Walkerdine (1988) in her seminal work on mother – daughter relationships in the home environment. Semiotic chaining exemplifies the notion of layering to abstraction where the object and sign relationship build from the concrete to the abstract by the sign itself taking on the role of the "new object" for each subsequent layer (Presmeg, 2005). In this instance the initial object is situated in the home environment (e.g., guests coming to visit) and the final object is in the school environment (e.g., whole number). The impact of this framework on Indigenous Australian learning needs further investigation.

The second implication is the recognition that Indigenous Australian classrooms are bilingual and their home language, while sounding like English is in fact different from Australian Standard English. The two instances reported in this paper show that in their home language there is a lack of the vocabulary commonly used to describe mathematical situations (e.g., the lack of attribute language and the need to switch to mathematical code when describing mathematical situations). There also appears to be a lack of experience with models that are typically used

to represent mathematical concepts (e.g., blocks). While this has been recognised as a problem in past research, there is a paucity of research focusing on the development of mathematical language (and verbalisation of mathematical concepts) and the use of concrete representations with Indigenous Australian students and its impact on mathematical achievement.

The third issue relates to the type of classroom discourse and choice of representations used to explore mathematical concepts. In particular, what style of discourse encourages students to engage in classroom discussions about mathematics concepts? How do we walk between the idea of justification and cultural notion of shame? What role do gestures have in supporting a culture based on an oral language tradition? But as Nakata (2003, p. 10) says so succinctly "we insult the intelligence of our students if we think that they cannot learn to distinguish what behaviors are appropriate to what contexts, and cannot learn to switch between them". An important dimension of the dialogue presented in the results for classroom 3/4/5 was the explicit use of mathematical language as students moved through representations. This is an important common feature within these classrooms. Tall (2004) claimed expression and language are essential to this journey as they give subtle shades of meaning that arise from human thought. As classroom teachers engage in conversations with Indigenous Australian students it is important to remember that direct questioning can cause shame for these students. Aboriginal students prefer to try things in private and demonstrate in public when they have acquired skills (Ionn, 1995).

Although there is some recognition that many Indigenous Australian students have English as a second language, their educational outcomes indicate there is still room for improvement. It is well recognised that oral communication is dominant in the lives of these students and that their experience with print and other literacies is often limited. This study begins to map the territory and provide indicators for the road ahead. In this perspective oral language is a vehicle for student engagement with mathematical concepts. It is also acknowledged that is in important for students to "write things down". But to start from this context can be very disempowering for all. As such, the research recognises the considerable capabilities of young Indigenous Australian students as they commence school and aims to assist them to engage in meaningful dialogue concerning literacy and numeracy in order to meet the challenge of improving long-term educational outcomes.

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