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Remote Indigenous Students' Understandings of Measurement

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Abstract: It is widely accepted that mathematical learning builds upon students' prior knowledge and understandings, and their identities. In this study this phenomenon is explored with Indigenous students in remote community schools in outback Australia. Through one-on-one task-based interviews it was found that these students had some clear understandings of the measurement concepts involved, although these understandings were often idiosyncratic to these students in this context. The task-based one-on one interview gave better insights into students' knowledge than the written form of the NAPLAN assessment. Nevertheless, the students' conceptions provide a useful basis upon which to build subsequent knowledge, understanding and skills in the forms required by the formal mathematics curriculum.

Key words: *Measurement, Indigenous learners, assessment, contexts*

It is well known that students' learning builds on what they already know and understand (Hattie & Timperley, 2007; Tzur, 2008). Indeed, new learning that can connect with students' broader mathematical identities is more likely to be understood and retained. While the above authors were drawing on results from middle class and/or metropolitan students, it can also be assumed that the learning of Indigenous students will also build on what they know already. Unfortunately, there appears to be limited research into the formal mathematical knowledge and understandings these students bring to their learning. This study seeks to investigate the measurement knowledge of some (n=56) Indigenous[1] students in remote Aboriginal schools in Australia.

Education and Indigenous Learners

Despite research and theorizing about what constitutes good pedagogy with Indigenous learners in a range of contexts, there has not been consensus about

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[1] We acknowledge that the term 'Indigenous' aggregates a range of people groups. The term is used here for expediency and to aid interpretation by international readers, but the participants involved in this study were Australian Aboriginal people.

what might constitute good practice. However, studies conducted in Australia have identified some general principles and pedagogical approaches that appear to work well with Indigenous students (e.g., Frigo, Corrigan, Adams, Hughes, Stephens, & Wood, 2003). The principles included sound school leadership working in partnership with local Indigenous leaders and the promotion of active student engagement in their learning. Furthermore, Aboriginal leader and educational academic Paul Hughes (2010) argued that what Indigenous students need is the opportunity to achieve in the standard Australian curriculum that is experienced by all Australian students – that is, not a special modified curriculum. Indeed, Gutierrez (2002) strongly advocated that students, who have historically been marginalized in mathematics education, including Indigenous learners, should learn and achieve in "standard mathematics". She suggested that "equity is threatened by the underlying belief that not all students can learn mathematics" (p. 146). Our position is that schools should offer Indigenous students access to the same experiences that other students receive, and the expectations for their achievement should be as for all other Australian students.

Indigenous Students and Learning Mathematics

Given this position advocated by Hughes (2010) and Gutierrez (2002), there is a need for renewed and revitalized understandings of what might constitute good mathematical pedagogy with Indigenous learners, because the evidence suggests that in general, current practices are not proving effective (Meaney, McMurchy-Pilkington, & Trinick, 2008). While ideally all students across Australia should have access to a conventional mathematics curriculum[2], Indigenous learners, and particularly those in remote communities, have not achieved well. Thus, there is a need to reconsider mathematical pedagogy in these sites and with these students. In their seminal study in the USA, Boaler and Staples (2008) found that the mathematical performance of disadvantaged students improved markedly when the pedagogies matched their expectations and backgrounds. The approach was characterized by demanding (conventional) mathematical content and high expectations, and students' achievement in standardised assessments improved to be above the state average. In Australia, Frigo et al. (2003) noted a number of

[2] At the time of this study there was no national Australian curriculum, but the mathematics curricula in each state were relatively similar, and not dissimilar to those around the world.

features of effective numeracy education in schools that had a significant proportion of Indigenous students, including using ‘real-life’ contexts, having an explicit focus on the language of mathematics, and building on students’ existing knowledge, understandings, and skills. However, these ideas do not seem peculiar to Indigenous learners, but in many respects seem consistent with notions of good mathematics teaching.

Emphasizing ‘Building-on’ in Mathematical Pedagogy

One of the successful approaches noted by Frigo et al. (2003) was to begin instruction from what the students already know. However, beginning instruction from the students’ current capabilities and experiences is broader than just their mathematical knowledge and skills (Grootenboer & Zevenbergen, 2008). Teachers can also consider their students’ mathematical identities – their knowledge, skills, attitudes, dispositions, beliefs, and prior mathematical experiences. If teachers appreciate something of the personalities and general interests of their students and their lives outside of school, then they are more likely to be able to provide mathematical pedagogy that is more relevant and accessible to the students (MacDonald & Lowrie, 2011; Palmer, 1993). Indeed, there appears to be philosophical and empirical support for pedagogy that begins with the students’ knowledge and identities, and below a brief discussion of the theoretical support is outlined.

The idea that teachers should develop their pedagogy so that student learning builds on what they already know and understand is grounded in constructivist theory (Ernest, 2010). Social constructivist theory posits that learning is interactive and personal, and is built upon previous knowledge conceptions and ideas (Cobb, Wood, & Yackel, 1990; Ernest, 1994). Epistemologically, knowledge is developed through social practices and therefore, knowledge is dynamic and culturally situated. Learning takes place when activities are within a student’s *zone of proximal development* (Vygotsky, 1978), which is the range of ideas that they might successfully grasp with support and scaffolding (Bobis, Mulligan, & Lowrie, 2009). From this perspective, student mistakes and errors are seen as emerging conceptions –as part of their prior knowledge, and therefore, a site for developing new understandings. The implications of social constructivist theory for classroom practice include starting learning with students’ prior knowledge, understandings and conceptions, and creating learning events where students are involved in rich mathematical dialogue with their peers and teachers.

The Choice of a Focus on Measurement

The focus of our data collection was on the topic of measurement. Measurement is an integral and important part of the mathematics curriculum (Smith, van den Heuvel-Panhuizen, & Teppo, 2011) and more than most of the other aspects of mathematics, measurement is eminently practical and useful. It is foundational to other mathematical domains and other subject areas. Students ‘measure’ every day, and therefore, “measurement is among the most sensible, contextually situated and practical domains of mathematics for students” (Smith et al., 2011, p. 618). Indeed, MacDonald and Lowrie (2011) highlighted the “social and cultural” (p. 28) nature of measurement, and the need for experiences that are in this sense meaningful when children are learning measurement concepts in mathematics. According to Baturo and Nason (1996), “the measurement process is invoked when there is a need to determine the size of an attribute” (p. 238), and this involves identifying, comparing, ordering and quantifying qualities such as length, area, volume, weight and time (Hogan & Brezenski, 2003; Kordaki & Potari, 1998). However, a number of researchers have noted that in general measurement has been difficult for students to learn well (Towers & Hunter, 2010).

The development of measurement concepts has been generally seen as a sequence that, in simple terms, sees learners progress from identifying an attribute, to direct and indirect comparison, to the use of informal measurement, then the use of more formal and standard units, and culminating in the application of the learned measurement concept to solve contextual problems (Bobis, Mulligan, & Lowrie, 2009). However, as noted above, measurement is by its nature, contextual, and so it seems somewhat contradictory to have a developmental sequence that places application only at the final stage. Through their research, MacDonald and Lowrie (2011) proposed “that measurement development ‘sequences’ instead be considered ‘cycles’, whereby ‘application’ may come first rather than last, and the stages of development become blurred” (p. 39). Also, Towers and Hunter (2010) suggested that to develop and assess measurement concepts, the use of contextual open-ended questions was important, because they were more consistent with the nature of measurement tasks and they included opportunities for students to reason mathematically.

Understanding Indigenous Students' Prior Knowledge

The current study was designed to gain insights into the prior mathematical knowledge of 56 Indigenous primary students in remote Aboriginal schools in north-western Australia. In particular, we investigated their responses to contextualised and decontextualised questions about measurement concepts. It was envisaged that the insights gained from this study would aid teachers and educators to better design appropriate robust approaches to teaching mathematics to Indigenous students, not because they necessarily will have the same prior knowledge as these particular students, but because they will more thoughtfully consider their own students in their specific context. Our research questions were:

- What insights into the existing measurement knowledge of these students can be gained through a task based interview using both contextualised and decontextualised questions?
- Are the students' responses to contextualised questions different from responses to decontextualised questions?

The Study

This study was part of a larger project – *Maths in the Kimberley*[3], which focused on the development of effective mathematics pedagogy in remote Aboriginal community schools in the Australian outback. The community leaders expressed a desire for their children to achieve in the standard mathematics curriculum that is experienced by their non-Indigenous and/or metropolitan counterparts. Also, approval for the project and data collection in the schools was sought and given by the community leaders in each school sites through their governing councils. Approval was given by the school principals in each school and their participation was voluntary.

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[3] The Maths in the Kimberley project was an ARC-Linkage project funded by the Australian Research Council and the Association of Independent Schools Western Australia. The opinions expressed in the article are those of the authors.

The five schools were in the Kimberley region of northern Western Australia and were located, owned and overseen by a local Aboriginal community. The school communities are made of almost entirely Indigenous people and the only non-Indigenous people are professionals such as the school teachers, nurses, and rangers, with a range of other visitors who offer occasional services. The communities are characterised by high unemployment and limited opportunities, and the only facilities in the communities are usually a general store, some sports courts and fields, and the school. The communities have made active decisions to move away from towns to minimise access of young people to alcohol, drugs and other health threats such as sugar. While most of the children attend school regularly during the primary school years, the attendance in the secondary school program is less consistent. Some students leave the community to attend boarding schools elsewhere but most students do not process with formal education. In the community a form of Kriol was spoken, but the language of instruction in the school was English. All of the communities were at least 400 km from the nearest major town, and many were located down long unmade roads. The schools catered for primary and secondary students, and they ranged in size from the smallest with 15 students, through to the largest with 80 students. The teachers in the schools were all non-Indigenous and generally were young and inexperienced. They moved to the communities from across Australia to take up their teaching positions and they generally stayed for about two years. Some of the classrooms also had Aboriginal Education Workers[4] (AEWs) who assist the teachers in a range of ways.

The Participants

A total of 56 students in Years 3 to 6 participated in this study. While this is not a particularly large sample, it does represent all of the children in this age group at the three largest schools. The participating students were aged between 8 and 12 years old, and had lived in their isolated communities for all of their life.

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[4] AEWs are Indigenous people whose work is similar to that of a teacher aide, with a focus on language support and assistance in some classroom management issues.

Data Collection

The data for this study were collected through a task-based, one-on-one interview that focused on mathematical concepts related to measurement. The tasks and protocols for the interview were established by the researchers and then a teacher (non-Indigenous) from one of the schools was trained to conduct the interviews. This training involved working through the interview items and discussing expected responses, a simulated interview with the researchers, and a pilot interview with students from different levels. The teacher, who was familiar with many of the students and knew the communities involved, was released from her teaching duties for a week and she travelled to the schools to collect the data. The interviews were conducted with each participating student in a room separate from the regular classroom, and were conducted at a table and generally lasted for about 30 minutes. After the data were collected, the teacher again met with one of the researchers to go through the data and to clarify the students' responses. Because the veracity and usefulness of the task-based interview is a central part of this study, the various aspects are now outlined in turn.

The Task-based One-on-One Interview

The interview was structured and somewhat scripted so each participating student had the same opportunity to show their understanding of the measurement concepts involved.

In the first part the students were given seven (students in Years 3-5) or eight (students in Years 6-7) measurement questions from the 2009 NAPLAN test[5] for their Year level. This meant that the students in Years 3-5 did one set of questions, and those in Years 6 -7 did another set. The questions were almost all multi-choice (4 options) and they were copied directly from the NAPLAN test and presented individually on a card. The interviewer offered no assistance (i.e., she did not read the questions or provide any prompts). This was done to ascertain an understanding of how well the students could express their understandings in this format. One of the items is shown below in Figure 1.

[5] NAPLAN is a national testing program in Australia. All students in Years 3, 5, 7 and 9 in Australia complete the NAPLAN tests in May every year.

This is a train timetable.

DEPARTURE TIMES				
Central	6:20am	9:50am	2:52pm	7:00pm
Rainer	6:31am	10:01am	3:03pm	7:11pm
Bradford	6:43am	10:13am	3:15pm	7:23pm
St Marks	6:53am	10:23am	3:25pm	7:33pm

What time does the last morning train depart from Central?

Figure 1: NAPLAN measurement question (Question 14, Year 5 non-calculator, 2009)

In this question the students were asked to identify the time that the "last morning train" leaves from Central station, but clearly this is well outside the experience of these students. The brief details of the Part 1 items are outlined below in Table 1

Table 1:
Part 1 Items

Year 3–5	Year 6–7
1. Identifying the instrument used to measure length (from pictured options)	1. An analogue clock with the minute hand missing – asked "what time could this clock be showing?"
2. Finding the 3rd Sunday on a calendar of October	2. Finding the 3rd Sunday on a calendar of October
3. Identifying the amount of liquid in a jug (diagram with scale)	3. Diagrams of 4 different beakers with scales – 'Which one holds the least liquid?'
4. Area – Rectangle partially covered in mats. Asked, "How many mats to cover the floor?"	4. Reading a train timetable (see Figure 1)
5. Time – 'Which [digital] watch shows a quarter to nine?'	5. "A rectangular paddock has a perimeter of 50m. Each long side has a length of 15m. What is the length of each short side?"
6. Time - converting minutes to hours (with rounding) in the context of a movie length.	6. Calculate the time between 11:36am and 12:19pm (context of a 'fun run')
	7. Converting centimetres to metres (no context)

The students' answers were recorded and the interviewer also noted any pertinent observations of the student as they attempted to answer the question.

In the second part of the structured interview, the students were given tasks and questions that focused on five aspects of measurement:

- Time, calendars and timetables

- Volume
- Area
- Length
- Estimation

In each case, the questions/tasks were designed to connect to the student's experiential world by using contexts and themes from their local community and their hobbies, interests and activities. For example, "how far is it to the river?", and, "is it further to the river or the shop?"[6]. Also, many of the questions involved appropriate physical objects for the students to manipulate as they pondered the problem/question. For example, the students were presented with 3 solids (a cube, a cylinder, and a square-based pyramid) and asked, "which container do you think holds the most?, and then "how did you work this out?". The interview also contained a number of more open-ended questions or prompts, such as, "could the table we are working on fit out through the door?", "how could you work it out?" and, "would you need any equipment?"

As with the first part of the interview schedule, the interviewer recorded the students' responses, and also made notes about her observations of the students as they attempted the problems and the language they used. However, unlike the first part, the teacher interviewer engaged with the students as they attempted the question. In particular, she modified the context if it appeared that the student was unfamiliar or struggling with it, explained terms or read texts, and gave prompts if it was clear that the students were progressing down an irrelevant path. The purpose of this part of the interview was to give the students the best opportunity to display their mathematical understanding; hence the professional judgment of the teacher conducting the interview was important. This was also a justification for a teacher from one of the schools conducting the interviews rather than the *external* researchers.

The data analysis process has centred on the researchers' etic perspective of the students' mathematical responses. This has meant that the researchers' focus on mathematics education from a non-Indigenous perspective has been highlighted, and the study does not provide a rich account of the mathematical experiences from the indigenous students' view. It is stressed that while there is a strong

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[6] Each school community is relatively near the Fitzroy River, and each community has one shop.

knowledge tradition in the communities involved in this study, and explicit ways of communicating that knowledge, the communities also express their intention that their children learn the mathematics that would give them access to employment and further study. Nevertheless, we believe that further research that focuses upon and examines these students' mathematical experiences from an emic perspective would be useful, particularly in the light of the findings presented here.

Assessing Indigenous Students' knowledge of Measurement

Formal Testing

In this section the students' results from attempting the questions are outlined. First, the percentage of correct responses to the NAPLAN measurement items are shown in Table 2. It is important to note that the Year 3 students would not have been familiar with the NAPLAN items because they did not sit the tests the previous year. Also, as noted previously, the Year 3, 4 and 5 students did one set of questions (from the Year 3 NAPLAN test the previous year), and the Year 6 and 7 students did a different set of questions (from the Year 5 NAPLAN test the previous year).

Table 2:
Part 1: Percentage of students who provided correct responses.

Year 3 – 5 (N = 38)	Percent Correct
1. Instruments used to measure length	76
2. Finding the 3rd Sunday on a calendar of October	34
3. Amount of liquid in a jug (diagram with scale)	24
4. Area – 'How many mats to cover the floor'	55
5. Time – 'Which [digital] watch shows a quarter to nine?'	3
6. Time - converting minutes to hours (with rounding)	32
Year 6 – 7 (N = 18)	
1. Analogue clock	44
2. Finding the 3rd Sunday on a calendar of October	78
3. Identifying beaker that holds the least liquid	22
4. Reading a train timetable	6
5. Perimeter (rectangle) with problem solving	22
6. Time between 11:36am and 12:19pm	6
7. Converting centimetres to metres	33

The Part 1 results indicated that in general, the students in Years 3-5 were able to identify the tape measure as the appropriate instrument to measure length (76%), but only one student could correctly identify “a quarter to nine” on a digital watch (almost all the students selected the ‘9:15’ option). The results for the other four items also indicate limited success in the NAPLAN items, and the interviewer noted that she thought that a number of the correct responses were guesses in the multi-choice questions.

Some of the students in Years 5 and 6 showed the capacity to read the calendar (78%), but overall they also performed poorly on the NAPLAN items. In particular, only one student could read the train timetable (Item 4) and calculate the time difference (Item 6). As with the junior students, these results are somewhat inflated due to the students successfully guessing the right multi-choice option. It is possible to infer from these results that the students have limited knowledge of measurement on which the teacher might build.

Task-based Interview Assessment

The results for the second part of the interview are shown in Table 3, although in this case all the students undertook the same questions. The percentage correct for the Year 3–5, and the Year 6–7 students are shown separately and together.

Table 3:
Part 2: Percentage of students who gave ‘correct’ responses

	Year 3-5 (N=38)	Year 6-7 (N=18)	Combined (N=56)
1.Calendar			
a. The football final is on the 3rd Saturday in October, what date will that be?	34	64	44
b. The netball final is the following Sunday. What date will that be?	11	0	7
c. Winston is having a party on 13th October. Is this the 1st, 2nd, 3rd, 4th, or 5th Wednesday?	18	22	20
d. The class will go on camp from 25th to 28th October. How long is the camp?	42	47	44
2. Television Program Guide			
a. What time is the AFL game on Channel 10?	81	83	82
b. Can you write the time in another way?	3	6	4
c. What show is on Channel 7 at 10am?	66	83	71
d. How long is this show?	11	42	21
e. What show is on Channel 2 at 1 o’clock in the afternoon	34	56	41
f. What show is on Channel 9 at 15:00?	66	83	71
3. Volume (with a cube, pyramid and cylinder)			
a. Which container holds the most?	68	78	71
b. Which one holds the least?	53	64	57
c. How did you work this out? (Could give an	0	0	0

explanation)			
d. How could you measure to see which one holds the most?	13	36	25
4. Area			
a. Could the table we are working on fit out through the door?	53	56	54
b. How could you work it out? Would you need any equipment?	22	42	29
c. How many sheets of A4 paper will I need to cover the top of the desk?	26	39	30
d. How could you work it out? Would you need any equipment?	7	25	13
5. Weight (with 3 packets of groceries weighing 0.7kg, 1kg, and 1.5kg)			
a. Which object weighs the most?	63	83	68
b. How do you know?	36	8	27
c. The packet of flour weighs 1kg, how many grams is that?	0	0	0
d. The flour weighs 1kg, how much do you think the other 2 packets weigh?	0	0	0
6. Estimation			
a. How far (in km or m) is it to the river?	0	11	4
b. Is it further to the river or the shop?	87	94	90
c. How far is it to Fitzroy Crossing?	3	8	5
d. How long do you think it would take you to walk that far?	3	6	4
e. What is the temperature today?	11	6	9
f. What is the temperature on a hot day? On a cold day?	3	3	3
g. How long do you think we have been doing this interview?	21	22	21
h. What is the biggest classroom in the school?	12	25	16

The results overall indicated that there were some mathematical ideas and concepts that were quite well understood, and others that were relatively under-developed. In the ‘Calendar’ section, the results indicated that in general the students were not able to consistently read or deduce information, even when the students were using a ‘real calendar’ and using contexts that were considered quite familiar to them (sports games). Interestingly, the interviewer noted the item contexts actually made the questions more difficult for many of the students because they answered from their knowledge of the ‘real context’ and/or the context was still unfamiliar (e.g., parties, class camps). For example, when examining a calendar to answer a question about the date of a netball game, Marta only looked at the ‘Saturdays’ on the calendar, because in this region netball is always played on a Saturday. She then said; “Dunno [don’t know] Miss”. It seems that for some students the contexts were either too familiar or not familiar enough. The role of question contexts is discussed later.

The students showed that they were generally good at reading information from the television guide, thus indicating a capacity to read a familiar-type timetable.

Similarly, many of the students showed an understanding of volume (Item 3), area (Item 4) and weight (Item 5) when they were given questions that involved materials and/or equipment that they could experience in a tangible way. Indeed, the interviewer noted that the students seemed to quite enjoy ‘playing’ with the manipulatives, and she had to regularly ask for them back so she could move on. The final item in Part 2 focussed on estimation in a range of contexts that were seen as familiar. Again, the raw results here were not strong, but through the task-based interview format greater insights were gained. In Item 6a the students were asked how far it was to the river and very few could provide a reasonable response in metres or kilometres, but almost all of them could provide an accurate answer in terms of minutes and/or hours. This result is also discussed later. The interviewer noted again that some of the context frames of the questions were not helpful or relevant to the students. For example, no-one would consider walking into Fitzroy Crossing (a town about 100 km from the schools), and so the question directed at this was seen as ridiculous by the students. Similarly, the students did quite poorly on the temperature questions even though they do have a general understanding of the concept, and perhaps this was because they rarely use numerical values to describe temperature.

The student responses to certain items are now discussed, and field notes are used to elaborate the discussion of the task-based interview and the findings it generated.

Measurement Understandings and the Significance of Context

The discussion of the findings and the interview process is structured around two broad areas related to: (1) the measurement knowledge and understandings of the Indigenous students who live in remote locations, and; (2) the significance of meaningful contexts. Finally, we look at the possibilities for enhancing students' mathematical learning through consideration of these points. It seems to us that while these findings relate specifically to Indigenous students in these remote Australian schools, aspects of the issues are pertinent for learning and teaching mathematics more broadly.

The Students’ Measurement Knowledge and Understandings

There was evidence in the data that the Indigenous students in this study had some sophisticated and well-developed measurement concepts. It was also clear that the students in this study performed substantially better in the task-based interview than the NAPLAN assessment items. This is not surprising, given the very different nature of the assessment processes, and the more conceptually sympathetic nature of the open-ended, task-based interview. However, for the Indigenous students in Australia, the NAPLAN tests have consistently indicated that their mathematical knowledge and skills are poor (Thompson, Bortoli, Nicholas, Hillman, & Buckley, 2010). The findings of this study suggest that, at least in part, the under-achievement of these students in these formal tests may be due to the relevance and veracity of the assessment instrument. It seems teachers would benefit by using one-on-one interviews early in the school year to assess students’ knowledge.

Measuring Distance

In the last section of Part 2 of the interview, the questions and tasks focused on estimation. The participants were asked, “how far is it to the river?” The school communities involved with this study are all quite close to the Fitzroy River (between 500m and 5km) and all the children would spend some time at the river. In response to the question, virtually all of the students provided an answer that was reasonable and accurate, but not one used standard units for length (e.g., metres or kilometres). All of their responses were about how much time it would take to walk (or some, to drive) to the river. For example, Errol[7] responded “15 minutes walking down the track” and the length of the walking track to the river was about one kilometre.

Our findings indicated that the Aboriginal students in these remote community schools had a good understanding of distance. Also, they were able to express their estimation of the distance using the most appropriate units for the context of the question. Many of the students would have regularly visited the river and it would be relevant for them to have some idea of how much time it takes to get there (or home), but it is also unlikely that they would need to know how many

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[7] Pseudonyms are used throughout this report

metres (or kilometres) it is to the river. While this was an interesting finding for us, on reflection it is not such as unusual phenomenon. Often when we are driving and someone asks “how far is it to …?”, the response is often given in terms of time (e.g., 25 minutes). Clearly the units used to measure distance are contextual. The responses also indicate a reasonable appreciation of time by these students. The students’ displayed understanding of measurement in the second part of the interview is unlikely to be recognized in the current external assessment regimes in Australia, and obviously this is something that should be acknowledged in the reporting and reading of the NAPLAN results. But it is unlikely that the assessment regimes will change in Australia in the near future, so it is important that students like those at these remote Indigenous schools are given the opportunity to display their formal mathematical understandings. Indeed, the communities often expressed the view to us that they want their students to achieve in the standard prescribed curriculum. From the data we know that the students had a conception of distance, and these understandings can be the foundation upon which a more formal understanding of measuring length/distance can be developed.

Reading Timetables

The students’ responses to the NAPLAN question about a train schedule (see Figure 1) indicated that they were very poor at reading a timetable. Only 6% of the students could answer this question correctly (see Table 1). However, In Part 2, the same students were given a similar question based on a television timetable taken from the newspaper, and 83% were able to answer correctly (and 81% of the students in Years 3, 4, and 5 could also answer correctly). Clearly, the student’s performance in the task-based interview where the familiar context of a television schedule was used showed that many were able to read and interpret a timetable (the issue of context is discussed further in the next section). Even Merryn, one of the youngest students, could identify what time the nominated television show was scheduled using the information contained in the ‘TV guide’. The mathematical skills and knowledge required in both questions were similar, and yet these learners would have been incorrectly seen as incompetent based on their performance on the NAPLAN test item. This reinforces the importance of both the relevance of the items and the interview format.

Area, Capacity, Volume, and Weight[8]

When faced with problems that included tangible materials the students seemed to display greater familiarity and understanding of measurement concepts related to area, capacity, volume and weight. For example, in Part 2 (Item 5), when working on the weight of common objects, the students all picked them up and held them while they pondered the tasks/problems. The students were shown three common objects (e.g., a bag of flour) that varied in weight from 700 grams to 1.2kg. Each object had its weight printed on it. The students were simply asked, “Which one weighs the most?”, and all the students hefted them in turn as they considered their response. No students used the weight printed on the object. Sixty-three percent of the students in Years 3-5 and 83% of the students in Years 6-7 correctly identified the heaviest object through this process. The success of the students in this question and the others with manipulatives is perhaps not surprising given the tangible nature of the concepts involved. Similarly, the students approached the area questions (Part 2, Item 4) by moving themselves and the materials to try and work out the appropriate response, albeit with less success than the weight and volume items[9]. However, this suggests that these students do have conceptions and understandings of these measurement concepts, and this is the foundation upon which teaching can develop the more abstract representations of these concepts required by the mathematics curriculum and formal external testing regimes.

The Role of Contexts

It was clear in the findings that the students’ capacity to engage with tasks and questions was influenced significantly by the context of the problem. For some of the questions, the context seemed to all but prohibit the participants from displaying their mathematical abilities and understandings because the contexts were foreign. However, when the same mathematical ideas were assessed in a familiar context, many of the students were able to show that they did have some comprehension of the mathematics involved. This was starkly illustrated in the

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[8] We recognise that the appropriate term is “mass” but the term :”weight” is a better match to the concept for these students

[9] The area item was conceptually more difficult than the volume and weight items

questions about timetables in Part 1 and Part 2. As was noted previously, in Part 1 the Year 6 and 7 students were given a question about a train timetable (see Figure 1) and only 6% of them could correctly answer the NAPLAN question. This is not surprising given that most of the students in these Kimberley schools would have never seen a train (except on the television), let alone a train timetable, or have any conception that ‘Central’ might be a train station. Alwyn asked the interviewer, “What is Central? That is about footy” (Central is a well-known football club in this region). Clearly the question was completely inaccessible. However, when asked to read information from a television program guide (Part 2, Item 2), in general the students could answer well (see Table 3). For these students this was an authentic question couched in a familiar and appropriate context frame that allowed the students to display their capacity to read a timetable.

That said, it would be an over-simplification to suggest that just having a familiar context is required, because there were some (n=12) students who struggled when the context was familiar, but not authentic vis-à-vis their experiences. For example, in the Calendar section (Item 1) of Part 2, the students were asked to identify the date of the netball final if it was to be played on “the following Sunday”. For many of the students this question was contextually problematic because they knew that netball was not played on Sunday, and subsequently this may have inhibited their capacity to respond.

Furthermore, it is important to note that the contextual nature of measurement (MacDonald & Lowrie, 2011) means that some concepts are likely to be more difficult for students if the inherent conceptual context is unfamiliar and redundant. For example, when the students were asked, “what is the temperature today?” (Part 2, Item 6e) very few could give a reasonable numerical response. However, they would all say something like “hot”, or “warm”. The interviewer, who lived in the community, made it clear that this was because they rarely used numerical values (i.e., the temperature in degrees Celsius) to describe the ambient temperature, but rather they always used adjectives. In this case, it appears as if the students simply did not have or need the required numerical system to describe temperature, but of course, they could learn this at school even if it was just to complete required assessments.

Implications

Given the findings that have emerged from this study, there are a number of recommendations that emerge. Indeed, there are real concerns about national testing regimes that discriminate against some students, and the use of these flawed results to make claims about the students' mathematical (or other subjects) knowledge and understandings. Nevertheless, we confine our discussion to pedagogy and classroom practice. Our purpose is to explore ways to improve the mathematical learning of the Aboriginal students in these community schools and increase their achievement in the mandated assessment programs (e.g., NAPLAN). We have not structured the implications around the research questions, but they are addressed in the points we make below that are practical and focus on classroom practice, and they may well be relevant to some degree in a range of settings.

Task-based One-on-One Interview

First, it was evident that the task-based one-on-one interview was a useful way to access the understandings and knowledge of the Aboriginal students in this study. This appears to be widely understood as forms of task-based interviews are already being used in a range of mathematical programs (e.g., *Early Numeracy Research Project*; Clarke, Cheeseman, Gervasoni, Gronn, Horne, McDonough, et al., 2002), but it is important to state that this assessment format provided valuable insights into the students' mathematical identities (Battista, 2004). Information like this is vital for teachers so they can build their pedagogy from their students' prior knowledge, understanding, beliefs and attitudes (Grootenboer, 2009). It is widely acknowledged that educational assessment needs to be valid and reliable, and our findings indicate that the task-based interview is closer to providing such qualities than externally prescribed assessments.

Building Instruction from Prior Conceptions

Previously we outlined a particular finding related to measuring length, and this was a quite a revelation for all (researchers and teachers) involved. This insight provided a solid foundation for pedagogical development related to measuring distances and lengths. In particular, the goal was to provide the students with opportunities to develop the measuring skills and knowledge that are outlined in the standard curriculum and assessed in the standard assessments. In this case the pedagogical task is to take the students' understanding of measuring distance using 'time' and to connect this to measuring distances in standard units (i.e., metres and kilometres). Fundamentally, this means that the students need to develop a parallel scale for quantifying distance to put alongside their existing scale (Frigo et al., 2003). Importantly, it is not about developing a brand new concept. Of course, this can be done in a range of ways. One example is a simple card matching activity using cards like the ones shown below (see Figure 2). In activities like this, students could match cards to link the knowledge they already have (e.g., how long it takes to drive to Fitzroy Crossing) with the SI units they need to understand.

From the classroom to the basketball court	3000 metres	3 km	45 minutes (walking)
From the school to the river	150 metres	0.15 km	3 minutes (walking)
From Yiyili to Fitzroy Crossing	100 000 metres	100 km	1 hour (driving)

Figure 2: Card matching activity (3 sets of cards shown only)

This also highlights the importance of a teacher knowing their students well (Grootenboer & Zevenbergen, 2008; Palmer, 1993), and appreciating their understandings in ways that are broader than what might be indicated by traditional assessment techniques in mathematics. This would appear to be particularly important for teachers who are working in contexts where the life-world of the students might be quite different from their experiences (Frigo et al., 2003). While this is evident for the teachers who work in these isolated remote Aboriginal community schools, it will also be the case to a greater or lesser extent, in a range of educational sites across Australia and indeed elsewhere in the world.

Contexts

It was clear to us that the understandings these students have of measuring length and distance is unlikely to be effectively assessed through formal external pencil-and-paper testing. These forms of assessment regularly contain questions that are set in contexts, but the context may well not be meaningful for the students, and this can distract them from the more formal mathematical response that may be required. For example, if the students involved with this study were asked a ‘distance question’, they may respond with an answer in terms of time. Also, the question about the ‘train timetable’ was completely inaccessible to these students, not because they did not understand the mathematical ideas, but because the context was completely foreign. Thus, even a ‘real life’ context may not be a meaningful context (MacDonald & Lowrie, 2011).

The confounding role that contexts can play in mathematical assessments has been noted before in a range of other countries (Cooper & Dunne, 1998; Lubienski, 2000; Towers & Hunter, 2010). However, a common theme in these studies was that contextualized assessment tasks disadvantaged those from already marginalized groups. For example, Lubienski (2000) reported that students from low socio-economic backgrounds were disadvantaged when mathematical tasks were set in a context. Also in the United Kingdom, Cooper and Dunne (1998) found that low SES students performed well below that of their middle-class peers on mathematical tasks that were set in a context. Interestingly, the results of both groups of students were equivalent on non-contextual problems. Indeed, this is a complex issue and it requires further investigation but when students, already disadvantaged due to factors such as SES, indigeneity and remoteness, are further hampered by the nature of the mathematical problems, action is required at both the research and policy levels.

Conclusions

Poor mathematical achievement by Indigenous Australian students in external testing has been consistently reported in Australia for many years, and the underachievement has been particularly notable for students in remote locations. This has meant that the mathematical knowledge and skills of these students have been consistently maligned, and this has in turn diminished the engagement of these students in mathematics (Hughes, 2010). It would be an oversimplification to think that the issues raised here are solely responsible for this situation, but our study has shown that these Indigenous students who live in remote locations do have mathematical understandings, specifically here about measurement. Indeed, we are convinced that the current national testing programs in Australia do not provide a fair platform for remote Aboriginal children to display the extent and complexity of their mathematical knowledge and skills, and the validity of their results in these assessments need to be viewed with some scepticism. However, we are also convinced that these same students are capable of achieving on these assessments. The results of this study have shown that many of the students did have mathematical understandings and skills that could engender success if they experienced mathematical pedagogy that builds on from their existing conceptions and knowledge. To this end, teachers need to have an appreciation of the mathematical identities, conceptions and strengths of their students, and therefore, processes like task-based interviews may well be useful (Battista, 2004). This would enable teachers to provide mathematical pedagogy that promotes deep and robust mathematical knowledge that can be revealed in a range of formats, including national pencil-and-paper testing (Sullivan, 2009).

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