Exploring the Nexus between Assessment and Instruction in Mathematics

Tracey Smith
Charles Sturt University
<tasmith@csu.edu.au>

This paper is the result of a school/university partnership that was formed to enhance teachers' professional development. The partnership explored pedagogical practices that promoted students' mathematical thinking and sense making. The links between assessment and instruction are described using 'accounts of practice' that are grounded in classroom contexts and provide guiding principles for mathematics educators seeking to make assessment more student centred and purposeful. The findings contribute to a growing body of empirically based knowledge related to the nexus between assessment and instruction.

The current emphasis on integrating assessment and instruction is present at a state, national, and international level (Australian Education Council, 1991; Clarke, 1996; National Council of Teachers of Mathematics, 1995; Mathematical Sciences Education Board (MSEB), 1993; NSW Department of School Education, 1996). This emphasis has evolved due to the increase in knowledge about the way students learn, and the way mathematics should be taught (Bransford, Brown, & Cocking, 1999). In essence, mathematics needs to be seen as a way of ordering and explaining our everyday lives. This occurs when teachers plan learning experiences that are relevant and meaningful to students, build on their prior knowledge, and require thinking power rather than the simple recall of known facts and procedures (Fraivillig, Murphy, & Fuson, 1999).

There is common agreement that with a change in the focus of how mathematics should be taught, there should be a reciprocal change in the way we assess students' achievement in mathematics (Bransford et al., 1999; Clarke, 1997; Kulm, 1994; Romberg, 1995). Similarly, De Lange (1995) concluded that in measuring the outcomes of the new forms of mathematics curriculum, educators needed to structure their assessment practices on the same principles. A review of the current literature related to assessment in mathematics provides a conceptual framework that highlights the following principles. Assessment should be:

- integral to, and naturally derived from good instructional practice (Clarke, 1997; MSEB, 1993; Yackel, Cobb, & Wood, 1992);
- accessible, relevant and meaningful to all students so they can show what they know, understand and can do (Lajoie, 1995; MSEB, 1993);
- on-going and cyclic in nature (Bransford et al., 1999; NSW Dept of School Education, 1996); and
- an indicator of students' thinking as well as content knowledge (Bransford et al., 1999; Clarke, 1996; De Lange, 1995).

Clarke's (1997) guiding principles of "constructive assessment" provide further insight into the importance of merging assessment and instruction. He reminds us that locating students' learning at the heart of the assessment process distinguishes constructive assessment. Clarke maintained that assessment should provide opportunities for students to display their mathematical understanding through constructed rather than remembered responses. This notion is symbiotic with authentic assessment (Kerr-Stenmark, 1991; Kulm, 1994; Lajoie, 1995) which describes any assessment that engages students in tasks that reflect "real" contexts. By its very nature, constructive, authentic methods of assessment require a merging of student centred assessment and instruction.

Sullivan (1999) suggests one way of achieving a collection of rich assessment information is through the use of content-specific open-ended tasks that, among other things:

- require a higher level of thinking, creativity and engagement;
- have more than one possible solution;
- are suitable for students at different stages of development;
- are focused on curriculum content; and
- collect rich assessment information.

According to Sullivan (1999), content-specific open-ended tasks cater for different stages of development, promote creative thinking and are an outcome of student centred learning rather than teacher directed learning. It could be argued then, that work samples constructed by students and derived from open-ended tasks provide an authentic method of assessing students' learning that is easily integrated with instruction.

Background to the Study

This paper aims to highlight opportunities for integrating assessment with instruction through accounts of authentic assessment practices from two case studies. It reports on aspects of a larger study completed for an Honours thesis that involved a school/university partnership (Bobis, 1998). The investigation documents the third and final phase of a study that generated accounts of practice taken from four case studies of teachers in a rural central school (K-12) as they incorporated the Working Mathematically outcomes (NSW Board of Studies, 1998) into their classroom practice. The seven primary classes were structured in "Stages" that are reflected in NSW syllabus documents. The teachers were all striving to promote students' mathematical thinking and sense making, characteristics that were reflected in the new outcomes. For this paper, only two of the case studies are reported.

Method

This study adopts a socioconstructivist perspective on learning (Yackel et al., 1992) where learning is seen as an active, social construction of concepts that builds on existing knowledge. This perspective sees the participants in this study as co-learners along with the researcher and the students themselves. One of the participating teachers eloquently described this perspective during a post-lesson interview when she stated:

> What we are actually doing as teachers is exactly what we are asking the kids to do. You know, reflect on what we've done, think about your thinking...verbalise your thinking.

This verbalisation of thinking forms the notion of "accounts of practice" that have been used in this case study. Simon and Tzur (1999) outline "accounts of practice" as an extension of case study research when they explain that:

> The generation of accounts of practice is not an anthropological approach, an attempt by a neutral observer to describe the life of the classroom teacher. Instead, it is an attempt to understand teachers' practice in a way that accounts for aspects of practice that are of theoretical importance to the communities of mathematics education researchers and teacher educators (p. 254).

This paper presents these "accounts of practice" using participant voices taken directly from pre- and post-lesson interview transcripts, teacher surveys and field notes from classroom observations. The accounts are then analysed using the conceptual lenses of a researcher that guide the interpretations of the data. A similar study by Fraivillig et al. (1999)

focused on strategies that promoted children's thinking. They also relied on an in-depth analysis of observed and reported data from skilful teachers in the field. In the present study, the principles for assessment that have been outlined from a review of current literature are used to interpret teachers' perceptions and classroom observations related to the links between assessment and instruction. Pedagogical practices that exemplified the integration of assessment and instruction were identified by using a line by line analysis of transcripts and field notes, combined with annotations that referred to concepts related to the conceptual framework for assessment (Simon & Tzur, 1999).

Results

Case Study One: Kim

Kim wanted to focus on the strategic use of work samples, derived from open-ended tasks and written procedures, that would enhance students' portfolios. She is relatively new to the teaching profession and has three years experience. Kim was teaching a Stage Two/ Three class (Years 4 and 5) during the project, and constantly sought to improve her practice by reading widely and trying new strategies. During this phase, Kim wanted to focus on developing authentic assessment tasks that would generate evidence of students' thinking and metacognitive processes. This evidence, in the form of work samples, was placed in the students' Progress Books, a form of portfolio, and was used during three-way interviews later in the year.

Open-ended tasks. Kim identified open-ended tasks as a key element in developing students' thinking and providing evidence of their thinking processes. One example of an open-ended task used by Kim for a unit on Volume was to Design, Make and Appraise (DMA) a container that would hold three litres. This task was accessible to all students, and directly related to a real context, which gave purpose to the assessment task. In a post-lesson interview, Kim confirmed that:

> The open-ended questions have been the biggest focus for me. I didn't do a lot of these before. The book you gave me helped to make good work samples that I could put into their Progress Books. They were practical because before I was only putting in worksheets and they were boring and didn't show their thinking and how they went about doing the task.

This excerpt demonstrated Kim's aim of developing tasks that would make thinking more visible while providing evidence of student achievement. The book Kim referred to (Sullivan & Lilburn, 1997) proved to be a valuable starting point for professional development in this area. The link between assessment and instruction was reflected in the rich, content-specific open-ended tasks that were developed by Kim and clearly linked with instruction in a post-lesson discussion when she explained that:

> When I'm programming I put in an open-ended task and I identify which tasks they will be and use these as assessment tasks...I think of assessment as I program.

This notion of planning for assessment while programming was also identified by Anna and hence Clarke's (1997) idea of constructive assessment was incorporated with Sullivan's (1999) content-specific open-ended tasks. It appears that assessment tasks that are naturally derived from learning experiences will be more likely to occur when identified during the programming and planning process.

Writing Procedures. Kim also identified the use of writing procedures as an effective assessment task that promoted student language. She cautioned that the confidence of slower learners was an important factor to monitor when asking them to write down a procedure, but it was a "good way to show their thinking". These procedures were used in an attempt to make thinking more visible and assessed students' process and communication skills. They were directly linked to learning experiences and clearly defined aspects of student achievement for assessment purposes while providing opportunities for reflective and metacognitive skills to be developed.

Sharing the purpose and role of assessment with students. Sharing the goals and purpose of assessment with students was evident in Kim's classroom practice. She placed a strong emphasis on self-assessment that involved reflective and metacognitive skills and believed that making the purpose of assessment explicit assisted the students to know which direction they need to improve on. Figure 1 provides an example of Hannah's self-assessment that was placed in her Progress Book and referred to during a three-way interview with Hannah, her parents, and her teacher.

Figu, e 1. Hannah's self assessment of her progress.

Hannah's self-reflection clearly provided an opportunity for her to assess her strengths as well as the areas she needed to focus on. Kim reflected on these points during a post-lesson interview:

I do tell them when I'm assessing their work. I don't know if that's the right thing or not. It kind of goes with our Progress Books and the idea of self-assessment and I think it's been a combined effort. Then if we do something I tell them what I'm looking for and share the criteria for assessing it. It gives them something to strive for and they know which direction they need to improve on...The students had to explain each work sample to their parents and that helped them to revise their learning. If you have to teach or explain something to somebody else, then you know it better.

Kim's explanation emphasised the important role of communication and reflection in students' learning (Brown et al., 1999). The students' perceptions of assessment were also elicited by asking them an open-ended question: How does Ms H. decide what you know in Maths? The words "test" and "assess" were deliberately left out of the question to prevent any bias towards this terminology. Although the majority of responses related to a maths test of some sort, it was interesting to note that there were a number of responses that indicated alternative ways of knowing. Responses such as "she uses a mind map to see what we know", "she looks at our progress books", and "she reads our procedures" significantly validated Kim's attempts to develop and share the purpose of authentic assessment tasks that were naturally derived from teaching and learning experiences.

Case Study Two: Anna

Anna had a strong desire to "collect effective work samples that would get their (the students) thinking on paper". She has had four years teaching experience and was teaching Stage One (a K-2 composite class) at the time of the study. Anna wanted to develop more purpose to her mathematics lessons. She felt that she was doing a "fair" job but began to wonder at the end of a unit if she and the students had achieved anything or found out anything.

Sharing the purpose of open-ended tasks. Anna's focus for this part of the study was to incorporate open-ended tasks, and develop an achievable purpose for each lesson. She worked on making the purpose of the tasks very clear to the students so they had a direction to work towards and Anna had measurable criteria for student assessment and evaluation of her teaching methods. Anna's desire to elicit students' thinking as part of the learning process fostered the notion of "thinking aloud" which she modelled as part of the teaching/learning process.

Assessment as inquiry. Anna discussed her assessment strategies during a post-lesson interview when she reflected that:

A lot of the assessment has been hands-on and using their work samples. Lots of observations and questioning and getting them to explain what they're doing and trying to relate them to other things. I use checklists to record the observations and I put comments beside them as well. The open-ended questions help to bring out their misconceptions a lot earlier. It gets the kids thinking about other ways of approaching problems and linking it to other things and see the relation between things. Now my assessment is planned to occur more as you go through.

These reflections highlighted assessment as an ongoing process that occurred naturally during mathematical inquiry. Anna used open-ended tasks at the beginning of a unit of work to find out about the students' prior knowledge and misconceptions. Figure 2 represents a work sample collected at the beginning of a unit of work on measurement. The open-ended task was designed to determine students' conceptual understanding of the metre ruler. The children were told that Mr Measurement (a personal friend) had lost his memory and was highly

embarrassed that he couldn't remember what a metre ruler looked like. The students had to draw a picture of a metre ruler and explain everything they could about the ruler to help Mr Measurement get his memory back.

Sharing the inquiry. The work samples were shared as a class group and led to explanations of a metre ruler and an in-depth discussion of how to represent centimetres accurately on the ruler. This process also fostered the metacognitive skills of reflection and monitoring of solutions. These skills were illustrated clearly when another student, Sam, told the class as he shared his drawing that he had made a mistake because he put ten dashes in between each number instead of nine. These work samples and shared explanations indicated many understandings about the metre ruler, but also identified some misconceptions which gave direction for further instruction that matched the students' levels of development.
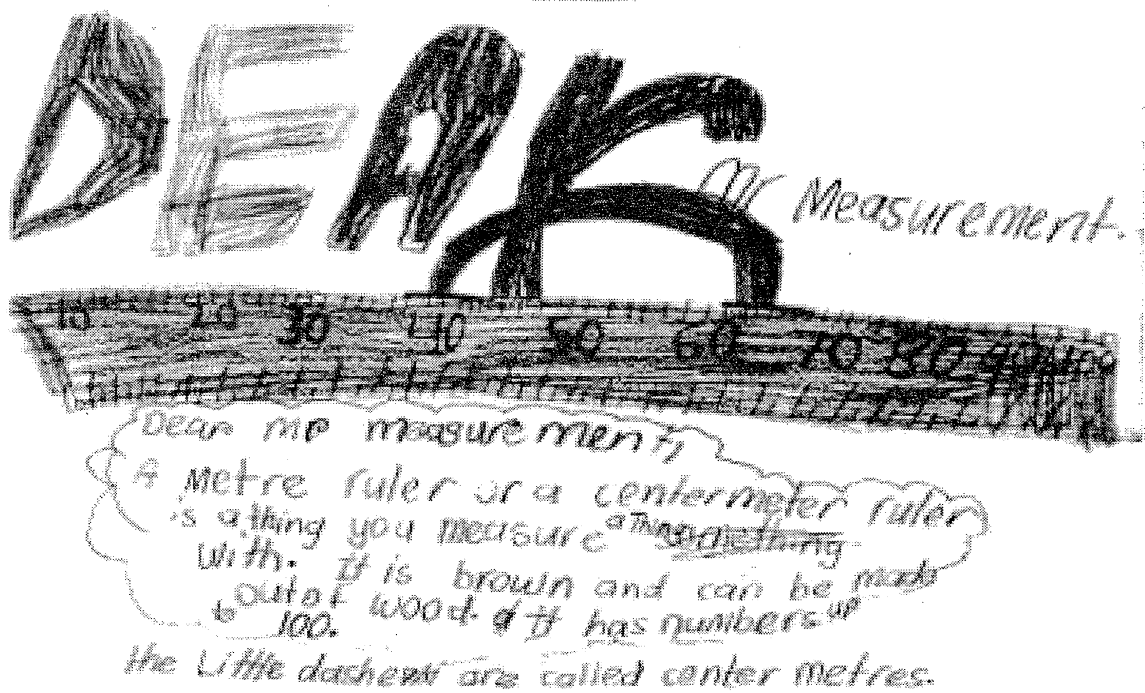

Figure 2. Annabel's explanation of a metre ruler.

The students in Anna's class were encouraged to explore open-ended tasks and were reminded that there was more than one way to get a solution and possibly more than one solution. Anna confirmed this when she stated:

> That's one good thing about this project, it's highlighted the fact that maths is not just a right or wrong answer. The open-ended questions cater for the differences much better. It keeps them much more interested and more challenged.

Both Anna and Kim used open-ended tasks as assessment opportunities and acknowledged these tasks as an important factor contributing to the students' increased interest and enthusiasm. They suggested that these tasks were more challenging for the students and catered for the differences in their ability. The use of these tasks at the beginning of a unit of work represented a change in pedagogical practice for both teachers and was identified as an effective method for deciding further direction for instruction.

Conclusion

This paper has highlighted the nexus between assessment and instruction by providing accounts of practice derived from teachers exploring their assessment practices during a school/university partnership. These accounts have highlighted the impetus for integrating assessment with instruction in a number of ways. Firstly, validity is increased by collecting evidence of student achievement that is naturally derived from, and related to everyday instruction because it reflects the intention of the teaching and learning activities. Kim exemplified this notion when she stated that:

> I've always tried to integrate my assessment with instruction. You can't assess them on something they've never done in class. I think the more assessment strategies you use you get a better picture. The more evidence you have, the more accountable you can be.

Secondly, Anna and Kim both identified using open-ended tasks at the beginning of a unit to assess students' prior knowledge as a valuable strategy for directing instruction. Thirdly, both participants in the case studies highlighted the notion of planning for assessment during the programming stage. This strategy assisted them to plan purposeful assessment tasks that were directly linked to learning experiences by nominating which classroom tasks would provide opportunities for assessing students while programming. Fourthly, work samples derived from open-ended tasks were systematically included in student portfolios for use in three-way interviews when reporting to parents. This saved valuable time during the reporting process and provided opportunities for promoting student reflection and self-assessment. Finally, the participants in this study identified the strategy of sharing the purpose of assessment tasks with the students. This involved explicitly outlining the criteria for assessing a task, which gave the tasks more meaning and purpose.

Theory into Practice. Of equal importance to teachers are the practical strategies derived from the data that illuminate how instruction and assessment can be integrated. The four principles for effective assessment that were introduced at the beginning of this paper, and the related strategies from the case studies are presented below. The strategies derived from the data are in *italics* and highlight implications for teachers that are grounded in practice. According to the current literature, assessment should be:

- Integral to, and naturally derived from good instructional practice – *developing content-specific open-ended tasks that produce work samples for assessment; seeking explanations and justifications during lessons through student modelling;*
- Accessible, relevant and meaningful to all students so they can show what they know – *sharing the purpose and outcomes of assessment and instruction; using assessment tasks that are open-ended to ensure accessibility for all students at all developmental levels;*
- On-going and cyclic in nature – *developing portfolios of work over an extended period, using open-ended tasks at the beginning of a unit to find out about learners' prior knowledge and misconceptions, and to guide instruction; planning for assessment during the programming stage;* and
- An indicator of students' thinking as well as content knowledge – *seeking clarification and justification of solutions and reflections; facilitating student modelling of solutions; eliciting work samples such as concept maps, procedures and explanations; using self-assessment and three-way interviews.*

Implications

The findings of this inquiry have shed some light on teachers' perceptions of the impetus for linking assessment with instructional practices and why they see this as an important goal. Strategies such as planning for assessment opportunities while programming, using open-ended tasks at the beginning of a unit to assess prior knowledge, and placing relevant work samples in student portfolios have been clearly identified by the participating teachers. These strategies highlight the nexus between assessment and instruction, and provide accounts of assessment practices that are grounded in real contexts. Valid and authentic guiding principles are documented for teachers seeking to make assessment more student centred and purposeful, clearly a goal worthy of pursuit.

References

Australian Education Council (1991). *A National statement on mathematics for Australian schools.* Melbourne, VIC: Curriculum Corporation.

Board of Studies NSW (1998). *Mathematics K-6: Outcomes and indicators.* Sydney, NSW: Author.

Bobis, J. (1998). Partnerships with practising teachers: Action research in practice. In N. Ellerton (Ed.), *Issues in mathematics education: A contemporary perspective,* (pp. 18-40). Perth, WA: MASTEC, Mathematics, Science and Technology Education Centre.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How people learn: Brain, mind, experience and school.* Washington DC: National Academy Press.

Clarke, D. J. (1996). Assessment. In A. J. Bishop (Ed.), *International handbook of mathematics education,* (pp. 327-370). The Netherlands: Kluwer Publishers.

Clarke, D. J. (1997). *Constructive assessment in mathematics: Practical steps for classroom teachers.* Berkeley, CA: Key Curriculum Press.

DeLange, J. (1995). Assessment: No change without problems. In Romberg, T. (Ed.), *Reform in school mathematics and authentic assessment,* (pp. 87-172). Albany, NY: State University of New York Press.

Fraivillig, J. L., Murphy, L. A., & Fuson, K. C. (1999). Advancing children's mathematical thinking in everyday mathematics classrooms. *Journal for Research in Mathematics Education, 30* (2), 149-170.

Kerr-Stenmark, J. (1991). *Mathematics assessment: Myths, models, good questions, and practical suggestions.* Reston, VA: National Council of Teachers of Mathematics.

Kulm, G. (1994). *Mathematics assessment: What works in the classroom.* San Francisco, CA: Jossey Bass.

Lajoie, S. P. (1995). A framework for authentic assessment in mathematics. In Romberg, T. (Ed.), *Reform in school mathematics and authentic assessment* (pp. 19-37). Albany, NY: State University of New York Press.

Mathematical Sciences Education Board & National Research Council (1993). *Measuring what counts.* Washington, DC: National Academy Press.

National Council of Teachers of Mathematics, (1995). *Assessment Standards.* Reston, VA: Author.

NSW Department of School Education, (1996). *Principles for assessment and reporting in NSW government schools.* Sydney, NSW: Author.

Romberg, T. (Ed.) (1995). *Reform in school mathematics and authentic assessment.* Albany, NY: State University of New York Press.

Simon, M. A., & Tzur, R. (1999). Explicating the teachers' perspective from the researcher's perspective: Generating accounts of mathematics teachers' practice. *Journal for Research in Mathematics Education, 30*(3), 252-264.

Sullivan, P. (1999). Seeking a rationale for particular classroom tasks and activity. In J. M. Truran & K. M. Truran (Eds.), *Making the difference,* (Proceedings of the 22nd annual conference of the Mathematics Education Research Group of Australasia, pp. 15-28). Sydney, NSW: MERGA.

Sullivan, P., & Lilburn, P. (1997). *Open-ended maths activities – Using good questions to enhance learning.* Melbourne, VIC: Oxford University Press.

Yackel, E., Cobb, P., & Wood, T. (1992). Instructional development and assessment from a socioconstructivist perspective. In. G. Leder (Ed.), *Assessment and learning of mathematics,* (pp. 63-80). Melbourne, VIC: The Australian Council for Educational Research.