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A Teaching Experiment to Foster the Conceptual Understanding of Multiplication Based on Children's Literature to Facilitate Dialogic Learning

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Abstract

The importance of conceptual understanding as opposed to low-level procedural knowledge in mathematics has been well documented (Hiebert & Carpenter, 1992). Development of conceptual understanding of multiplication is fostered when students recognise the equal group structure that is common in all multiplicative problems (Mulligan & Mitchelmore, 1996). This paper reports on the theoretical development of a transformative teaching experiment based on conjecture-driven research design (Confrey & Lachance, 1999) that aims to enhance Year 3 students' conceptual understanding of multiplication. The teaching experiment employs children's literature as a motivational catalyst and mediational tool for students to explore and engage in multiplication activities and dialogue. The SOLO taxonomy (Biggs & Collis, 1989) is used to both frame the novel teaching and learning activities, as well as assess the level of students' conceptual understanding of multiplication as displayed in the products derived from the experiment. Further, student's group interactions will be analysed in order to investigate the social processes that may contribute positively to learning.

Introduction

The world is changing rapidly and future members of the workforce will need to reason mathematically to use technologically sophisticated equipment and resources (English, 2002). As future members of this workforce students require access to a quality mathematics education otherwise their personal and economic success may be limited (Tate & Rousseau, 2002). Further, a recent policy document from the Department of Education, Training and Youth Affairs (DETYA) (2000) stated that the economic well being of the nation is contributed to by the mathematical capabilities of its citizens. DETYA highlighted a growing number of early numeracy programs that embrace the "research in children's learning of mathematical understandings and concepts" (p. 33) to guide teaching and learning practice, and suggested this practice would improve the numeracy outcomes for students in later primary years. Most modern curriculum documents encourage teachers to engage students in mathematical activities that develop depth of conceptual understanding, affording them the ability to both think and communicate mathematically (Board of Studies, 1995; Education Queensland, 2002; Queensland Schools Curriculum Council, 2001). The key intention of mathematics curricular is to enable students to function within a society that commonly uses mathematical models and calculations for decision making and to develop the logical functioning of students to enable them to use mathematics in a variety of contexts (Biggs & Collis, 1989). Thus, mathematics education must include key concepts and processes for a student to have the opportunity to be successful in the 21st century (English, 2002).

To this end, Confrey and Lachance (1999) highlighted the need to establish a stronger connection between educational research and the practice of teaching by moving research from ‘out-of-school’ conditions and embedding it in the constraints of the classroom. They suggested that one of the main purposes of educational research is to “invent, develop and test novel ways of teaching mathematics” (p. 231). Teachers are one of the consumers of research and rather than have research stand apart from practice, placing these investigations within the context of instructional settings would further the relationship between theory and practice (Cobb, 1999; Confrey & Lachance, 1999). Another argument is presented by Kennedy (1997) who suggested that placing research findings in physical reach of teachers will not guarantee they will be encouraged to examine their practices. It is only when research is placed within conceptual reach of teachers that change may be imminent and a significant purpose of educational research is to inform and enhance educational practice (Lester & Wiliam, 2002).

The purpose of this paper is to report the theoretical development of a transformative teaching experiment based on conjecture-driven research design (Confrey & Lachance, 1999) that aims to enhance Year 3 students’ conceptual understanding of multiplication. This teaching experiment aims to develop a strong conceptual connection between educational research and the practice of teaching mathematics (Confrey & Lachance, 1999; Schoenfeld, 2002). The teaching experiment will be formally trialed in 2004. Results from the trial will be reported in future papers. It may be possible to discuss some findings from the trial during the presentation of this paper.

Current theory and practices in mathematics education

The theoretical orientation of current curriculum documents is mostly founded in the developmental psychological research conducted by Piaget, with a major influence on current pedagogical practices related to a Vygotskian sociocultural approach (Doig, McCrae, & Rowe, 2003). The Piagetian psychological perspective acknowledges the social aspect of classrooms only as a catalyst for learning and a student's mathematical development as exclusively psychological. The polar position of a Vygotskian sociocultural approach foregrounds the social activities of learning. Cobb (1999) described a middle ground between these two researchers which he termed the "emergent perspective" (p. 309).

A central tenet of Cobb's (1999) emergent perspective is that learning is both a process of active individual construction, where students construct new knowledge through reflection upon their physical and mental actions, and the social process of classroom mathematical practices, both operating collectively and with equal significance. The assumptions of constructivism, where knowledge is not passively received by a student as it is passed by language from the teacher, but rather, actively constructed within the social context of a classroom community (Doig et al., 2003; von Glasersfeld, 1991) values both the cognitive and social perspectives and recognises them as complementary (Wood, Cobb, & Yackel, 1995). The classroom community influences the student's mathematical experiences and beliefs about what it means to know and do mathematics as they negotiate the constraints of the classroom (Cobb, 1999; Wood et al., 1995).

However, Willis (1990) stated mathematics teachers embrace procedures, methods, skills, rules and algorithms, in an unthinking, non-reflective fashion despite current research. Further, in traditional mathematics classrooms students are indoctrinated to accept what they don't understand and have a passive involvement in an environment that requires unthinking responses. In most western countries standardised tests measure low-level mathematical skills and strategies but rarely conceptual or higher order thinking. The unfortunate response to these tests is the pressure for the classroom teacher to focus on these basic skills as a priority (Lambdin, 1993). Schools are social institutions, and arithmetic, recognised in most classrooms as basic facts and simple procedures for adding, subtracting, multiplying and dividing, is the core of primary school mathematics. This type of mathematics curriculum, consisting of rule following and rote memorization, where belief of success in low-level procedural knowledge is aligned to achieving in mathematics, is ingrained in our schools and society in general (Wood et al., 1995). In this ingrained teaching style both rote acquisition of knowledge and mindless procedures are rewarded rather than true conceptual understanding and reflective deployment of strategic know-how.

Unfortunately, successful mathematics performance in these procedural activities does not demonstrate, nor provide a foundation for, the understanding of core mathematics concepts (English, 1998; Walkerdine, 1998; Wood et al., 1995). Clearly, 'doing' mathematics' does not necessarily lead to 'understanding' mathematics. Rote and rule practice are related to 'doing' and research has highlighted that a large proportion of school mathematics is 'doing' (Mousley, 1999; Swan, 1990). Von Glasersfeld (1991) raised an interesting parallel where the research on literacy was hampered by the superficial notion that literacy was simply a matter of recognising written letters and being able to vocalise words. The overwhelming body of educational research is telling us to promote learning with understanding (Hiebert & Carpenter, 1992) and this should therefore be one of the fundamental goals of mathematics education (Hiebert et al., 1997). Further, education researchers have a responsibility to demonstrate to teachers a clear link between research and classroom practice in mathematics.

The teaching experiment

The methodological framework used to guide the development of the teaching experiment described in this paper was based on Confrey and Lachance's (1999) Transformative Teaching Experiments through Conjecture-Driven Research Design Model. These researchers described mathematics as a human construction. They also stated that limited access to, and significant gaps in achievement between different cultural and social groups, is caused in part by how mathematics is taught. Their research model was motivated by an ideological equity-based stance and as depicted in Figure 1 has a teaching experiment at its core. Central to the model is also a theoretical framework so that classroom activities and research methodologies can be structured and interpreted. The use of this methodological framework to underpin research in mathematics education, we believe, will provide the conceptual bridge between research and classroom practice that teachers require to make sense of and use educational research more productively in their classrooms, and which will in time, assist to create curriculum change in mathematics education (Kennedy, 1997).

A conjecture, in this model, differs from a hypothesis in that unlike a hypothesis it is not waiting to be proved or disproved. A conjecture evolves whereas a hypothesis remains static. The conjecture must have two dimensions, one dimension is mathematical *content* and the other is a *pedagogical* aspect that is linked to the content to be taught (Confrey & Lachance, 1999). The most significant features of a conjecture however, are its flexibility, reviseability and scalability throughout the research period. These features add to its appeal in dynamic classroom contexts where learning is never static.

The teaching experiment described in this paper conjectures that student's conceptual understanding of multiplication (content) may be advanced through the use of a dialogical approach to learning (pedagogy) that uses children's literature as a mediational tool (Van Boxtel, van der Linden, & Kanselaar, 2000) to scaffold conceptual level raising (Dekker & Elshout-Mohr, 1998; Dekker, Elshout-Mohr, & Wood, 2004). The teaching and learning activities that comprise the experiment (1) integrate components of Bruner's Theory of Learning (1964) that requires learning tasks to progressively move from concrete to abstract; (2) make links to different ways to represent multiplication (concrete and pictorial, real world and symbolic) (Hiebert & Carpenter, 1992); and (3) use the framework of the SOLO taxonomy to both plan instructional activities and assess student conceptual change over time.

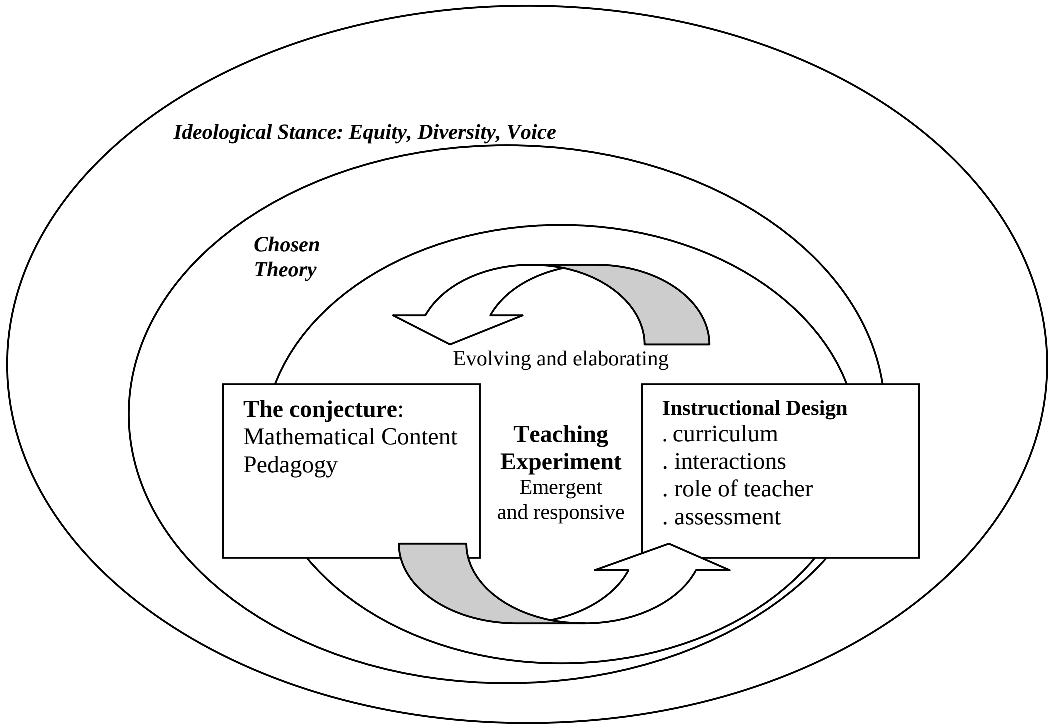

Figure 1. A model for the transformative and conjecture-driven teaching experiment adapted from (Confrey & Lachance, 1999).

Developing a transformative and conjecture driven experiment

There are four major components to the design of instruction for any teaching experiment as per Figure 1 above, namely (1) curriculum, (2) interactions, (3) role of the teacher, and (4) assessment (Confrey & Lachance, 1999). In this experiment the four components will entail:

1. <u>The Curriculum</u> that is comprised of the initial planned content students are expected to cover or learning outcomes they are expected to achieve, as well as the emergent curriculum from the research as it unfolds (Confrey & Lachance, 1999). In this teaching experiment, the curriculum content is built around the conceptual understanding of multiplication, as opposed to the 'times tables' procedural knowledge that is usually the focus in classrooms. The concept of multiplication is initially based on repeated addition of equal groups with the aim of eventually understanding multiplication to be 'doing something to a chosen

number, a number of times'. This conceptual understanding can be fostered by helping students make the connection between concrete, real world and symbolic representations of multiplication (Hiebert & Carpenter, 1992) rather than limiting their representations to pictorial or symbolic which is the current widespread practice in classrooms (Mulligan & Mitchelmore, 1996).

Conceptual knowledge in mathematics involves more than just a recall of facts and rules for common examples. A student who has conceptual knowledge can draw on related networks and adapt and adjust procedural knowledge to help solve unfamiliar problems (Hiebert & Carpenter, 1992). The ability to extend the range of applications for procedural knowledge is the type of flexibility that is often described as essential learning for future citizens. Without a conceptual framework, knowledge will be fragmented and effective problem solving will be impeded (Hiebert et al., 1997; van Boxtel, van der Linden, & Kanselaar, 2000). According to Mulligan (1998) it is essential that students develop conceptual understanding of multiplication as without it they may experience difficulty in general mathematical development in secondary school. The development of concepts and processes such as ratio and proportion, area and volume, probability and data analysis are dependent on a student's multiplicative reasoning (Mulligan, 1998; Mulligan & Watson, 1998). Walkerdine (1998) highlights the contrast between conceptual knowledge and low-level procedural knowledge in multiplication as "understanding multiplication as cumulative addition" and in contrast "only being able to chant one's tables" (p. 29). Only being able to 'chant one's tables' is evidence of an insufficient conceptual knowledge and has most certainly resulted from the inadequate instructional and curriculum experiences in one's mathematical education (Verschaffel, DeCorte, & Lasure, 1999). Students need to be provided with the opportunity to construct connections between concrete and pictorial; real world and symbolic representations if they are going to develop conceptual understanding (Hiebert & Carpenter, 1992).

Contemporary constructivist theories of mathematics learning contend that students develop understanding by moving along a path from concrete to abstract. Students firstly build up multistructural **(The SOLO**

Taxonomy: Biggs & Moore, 1993) mental representations of mathematical knowledge (e.g., concrete, pictorial and symbolic). They then progress towards relational understandings of mathematical concepts by making connections between these various modes of representation and their existing knowledge. Ultimately therefore, *mathematics learning* is about refinement and abstraction of ideas and concepts, and *mathematics teaching* is about facilitating this process of refinement and abstraction. Current pedagogical beliefs emphasise that this abstraction process is best served by a combination of: (a) work with appropriate manipulatives or mediational tools; and (b) discussion and reflection with peers and teacher (English & Halford, 1995).

Bruner's Theory of Instruction (1964) from four decades ago underpins these pedagogical beliefs. His theory encompassed four major features of: (1) experiences which provide a predisposition towards learning; (2) structuring or sequencing knowledge from simple to complex, concrete to abstract; (3) effective sequencing of materials from concrete to abstract; and (4) specifying the nature and pacing of reinforcement. The effective *sequencing* of knowledge in mathematics logically supports the building of concepts before procedures. Before practicing a procedure, students must understand the mathematical concept to which it pertains. Time spent practicing procedures or skills should not outweigh time spent developing understanding (Reys, Lindquist, Lambdin, Smith, & Suydam, 2001). Hiebert & Carpenter (1992) stated that students who have well practiced rules that have become automatic, can have difficultly in thinking of problems in other ways, or connecting to other meanings. The *structuring* of knowledge to facilitate concept attainment is represented in the following 3 modes: (1) *Enactive Representation:* Student is involved in manipulation of concrete materials or actions; (2) *Ikonic Representation:* Student uses a set of images or graphics which represent the concept without defining it completely; and (3) *Concrete Representation:* The student moves to symbolic representation of the concept drawing from a symbolic system, which in the case of mathematics would be domain specific symbols. Figure 2 represents these modes on the language model for the teaching and learning of mathematics (Irons & Irons, 1989). The language model for mathematics teaching and learning foregrounds the progressive abstraction of both language and mediational tools used in mathematics classrooms as students move through the Enactive, Ikonic and Concrete Representational modes.

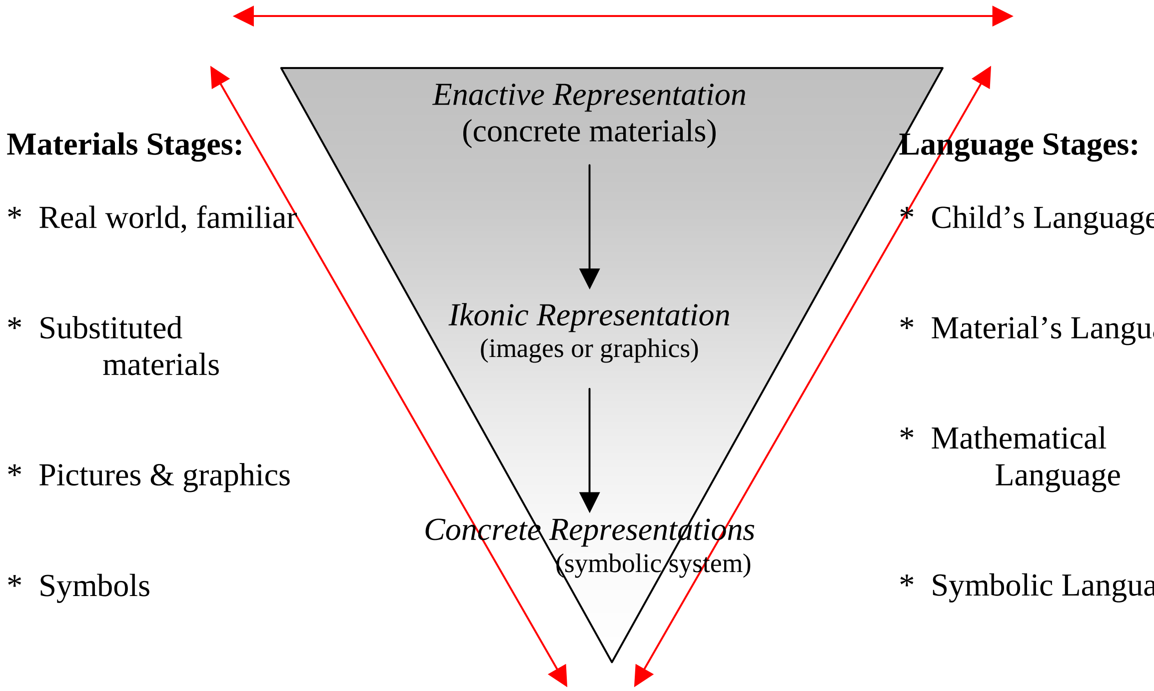

Figure 2. The language model for Mathematics teaching and learning (Irons & Irons, 1989) based on Bruner's (1964) Theory of Instruction.

In this teaching experiment, the primary mediational tool will be children's literature (Big Books) that contain stories relating to the concept of multiplication (Irons & Jahn, 1999; Irons & Power, 1999; Irons & Reynolds, 1999; Irons & Vanzet, 1999; Irons & Webb, 1999). Secondary mediational tools will be concrete materials that students use to model these multiplication stories (e.g., toys, counters, their own bodies, pictures, drawings, diagrams).

2. Classroom Interactions that are influenced by the underpinning theoretical framework for teaching and learning chosen by the instructional designer (Confrey & Lachance, 1999). In this teaching experiment the chosen theoretical framework supports the major assumption of constructivism, namely, conceptual knowledge will not be passively acquired by a student from a teacher, but rather, it must be actively

constructed by the student within the social context of the classroom community (Doig et al., 2003; von Glasersfeld, 1995). Social interaction in this teaching experiment will be achieved through the class sharing of the multiplication stories (Big Books) and collaborative small group work based around creating their own multiplication stories as a culminating activity.

It is clear that mathematical concepts can not be developed in the absence of language (Australian Education Council, 1991). ‘Language’ as it is used here refers to the students need for opportunities to talk about, share solutions and strategies to problems and explain mathematical ideas to each other and the teacher to help them work through and clarify their thinking (Australian Education Council, 1991; Doig et al., 2003; von Glasersfeld, 1991; Wood et al., 1995). Thus language in this teaching experiment is used to underpin a dialogic approach to curriculum implementation that derives from three main educational theorists: (1) the Socratic tradition of dialogic inquiry; (2) the dialogic relationship between teacher and student of Paulo Freire; and (3) the language dialogism of Bakhtin that focussed on the role of language for the construction of meaning and understanding. This dialogic curriculum is more than the linear processes of instructional design, implementation and evaluation, but rather it is a cultural practice that is defined by the social relationships and experiences that constitute the interactions between students and teacher (Renshaw & van der Linden, 2004). Burbules (1993) distinguished between four types of classroom dialogue, namely: (1) dialogue as instruction; (2) dialogue as conversation; (3) dialogue as inquiry; and (4) dialogue as debate. The teacher in this experiment will encourage students to discuss, during extended Socratic dialogues, the multiplication stories in order to make sense of the multiplication concept and various representations presented in the stories. All students will be encouraged to contribute their views in order to arrive at a consensus of opinion about the multiplication concept. Questions such as “Why does the octopus always have to have eight objects to decorate her arms? What is multiplication? What does multiplication mean? What is it like? How else could you work out the total?” will be discussed in a collaborative environment of enquiry. Students will be always asked to explain and support their ideas with evidence (What do you think? Why do you think that? Show us how you worked this out?). The teacher and students will be co-participants in the dialogic inquiry aimed at transforming their shared understanding of multiplication.

The constructivist approach sees social interactions as an essential component of the acquisition of knowledge, as interactions provide opportunities for language, and reflection and learning as participants make sense of each other's mathematical ideas (Cobb, Wood, & Yackel, 1991; von Glasersfeld, 1995). To think about and communicate mathematical ideas such as the concept of multiplication, we need to represent them in some way (Hiebert & Carpenter, 1992). Children's literature can provide the representational mechanism (mediational tool) that affords students the opportunity to think about, communicate and share ideas about multiplication. For example, *The Monster Circus* (Irons & Vanzet, 1999) provides an opportunity for children to kinaesthetically experience equal groups and the commutative property of multiplication. The story is about 24 monsters, that group themselves into 3 groups of 8 or 8 groups of 3, and 4 groups of 6 or 6 groups of 4, and so forth. With 24 children in a class, the children themselves can operate as secondary mediational tools by forming and reforming equal groups to total 24 like the monsters in the story. Discussion such as "we've got three groups of 8", "now we are in eight groups of three and that is the same" can be facilitated.

A further benefit of using children's literature in developing mathematical ideas with children is that it shows that mathematics develops out of human experience rather than standing apart from it. The children's experience of mathematics through literature will not simply be a set of algorithms but a powerful mathematical way of thinking about their world (Whitin & Gary, 1994). Children's literature invites students to connect their own interests and background to mathematical concepts and to see mathematics as part of their everyday experiences (Moyer, 2000). Children's literature provides a meaningful, familiar and non threatening context to explore mathematical concepts and mathematical language (Reys et al., 2001; Whitin & Gary, 1994). It also invites multiple interpretations and encourages the "sound of different voices to mathematical discourse" (Whitin & Gary, 1994, p. 399).

Sociocultural theories emphasise the collaborative construction of knowledge, the mediational role of tools and the historical and cultural settings in which knowledge construction occurs (Van Boxtel, 2004). The classroom context, incorporating the physical and social environments, are integral to the cognitive activity. Situations, encompassing mediational tools like children's literature, facilitate knowledge construction. Mercer (1995) described speech as a social mode of thinking, as it provides both a means for sharing thoughts, as well as a tool for the joint construction of thinking. Van Boxtel (2004) stated that "from this perspective the learning and understanding of concepts is distributed over persons and tools, whereas the meaning of concepts are jointly constructed through communication, from which they can be appropriated by each individual" (p. 133). Further, she stated that the appropriation process involves a transformation process that is far more than the simple copying of meanings and ways of reasoning. By using children's literature to initiate class dialogue the meaning of multiplication (the concept) can be co-constructed via accumulation and integration of ideas or by productive argument, questioning and exploration. Also, in this experiment students in small groups of 4-5 students will be challenged to create their own story about multiplication to share with their class. In these small groups students will be given the opportunity to not only reflect upon and elaborate their own contributions, but to also integrate and/or elaborate the input of their partners, which may make elaboration more intense and possibly result in a more complete and scientific understanding of the concept under investigation (Van Boxtel, 2004).

3. The Role of the Teacher as both facilitator of learning and researcher (Confrey & Lachance, 1999). In this teaching experiment the first named researcher will assume the role of the classroom teacher. This teacher / researcher will facilitate language, reflection and discussion about multiplication using the shared literature. She will also facilitate student to student interactions by grouping students into small (4-5 students) groups that will be scaffolded in the creation of their own multiplication stories to share with the class. These created stories, along with other measures described in the next section, will then be evaluated in order to ascertain the level of student conceptual understanding of multiplication.

The whole class and small group social interactions, focussing around literature, will provide learning opportunities as children learn from each other through communicating and listening to each other's ideas, all aimed at facilitating individual and collective knowledge building (Mitchelmore & Mulligan, 1996; van Boxtel et al., 2000).While teachers often perceive small group collaborative learning to be problematic in many classrooms, the student interactions that they facilitate foreground genuine mathematical problems that will provide rich learning opportunities. Roschelle (1992) stated that when peers work together on a common task, such as writing a multiplication story in this experiment, mutual understanding must be created and sustained continuously for the duration of the task. In this classroom environment, the teacher's role becomes one of facilitator of the children's co-construction of knowledge. The teacher provides the initial experience of sharing the multiplication Big Books that afford the explicit experiences to which the groups can continually refer. She opens the way for whole class and peer-to-peer dialogue. These experiences should be both motivational and challenging.

4. <u>Assessment</u> that is informed and consistent with all aspects of the content, the pedagogy and theoretical framework. It would normally encompass multiple assessment practices including group projects, assignments, homework, open ended tasks and non routine problems, skills tests and standardized achievement tests (Confrey & Lachance, 1999). In this teaching experiment a range of assessment strategies will be used including (1) pre and post assessment questions to assess entering and exiting levels of conceptual knowledge with respect to multiplication (e.g., Tell me what you think multiplication means? Write a number sentence that shows how we could work out the total number of decorations on the octopus's arms? How could we work out the answer to a multiplication story another way without multiplying? How do you know when you should multiply? Model and tell a story about multiplication. Explain why you think it's about multiplication.) administered individually in an interview situation with each student; and (2) an open-ended task in which students demonstrate individually and in small groups their level of understanding of the concept of multiplication by creating their own multiplication stories,

which will be assessed using the Structure of Observed Learning Outcomes (SOLO) Taxonomy (Biggs & Collis, 1982, 1989).. The pre and post assessment items will include items that assess understanding of the four different *models* for multiplication (e.g., equal groups, array, comparison and combination models) operating within the three different *modes* (e.g., enactive, ikonic and concrete representational). For example, students may be asked to “Model this story: Four children were having a picnic lunch and they put out one plate each. Two ladybirds landed on each plate. How many ladybirds are there altogether?” This item requires students to *enact* an *equal groups* model of multiplication to arrive at an answer.

Studies have found that the dominant assessment tasks used in mathematics are pencil and paper tests that concentrate purely on procedural knowledge, testing students recall of facts, procedures and applications, and that very few involved tasks that required higher order thinking (Pfannkuch, 2000). It has been suggested that these traditional narrow forms of assessment may be the reason why classroom practices have not mirrored the changing beliefs about mathematical learning (Leder, 1992). These traditional forms of assessing and reporting have been in place for decades and are difficult to change, and more innovative methods are unlikely to succeed without the support from all stakeholders in the education system breaking with tradition (Lambdin, 1993). Conceptual understanding cannot be judged effectively using traditional pencil and paper testing alone as accurate answers do not necessarily demonstrate understanding (English, 1998; Gay & Thomas, 1993). Recall of rules and procedures to operate on common examples does little to provide evidence of a student’s knowledge and understanding of a concept. Verbal interactions and open ended tasks are needed to assess conceptual understanding (Gay & Thomas, 1993). Further, there is a lack of assessment instruments and techniques available, especially in early numeracy for educators to model their assessment practices on in order to gain this information efficiently (Doig et al., 2003).

Conceptual understanding is evident, it is suggested, when a student displays connections between concrete and pictorial; real world and symbolic representations (Hiebert & Carpenter, 1992) and it is these connections that we should be assessing (Huinker, 1993). In order to focus on the teaching and assessment of conceptual understanding the Structure of Observed Learning Outcomes (SOLO) Taxonomy (Biggs &

Collis, 1982, 1989) will be used in this teaching experiment to assist in the development of novel learning activities and assessment items as well as to analyse the data obtained from the products of the learning activities (e.g., group and individual multiplication stories, statements about what multiplication is etc.).

Bloom's Taxonomy (Bloom, 1956) is a widely used hierarchy of increasing abstraction – knowledge, comprehension, application, analysis, synthesis and evaluation – that can guide teachers in planning quality instructional activities. Similarly, Biggs and Collis (1989) agree with the need for qualitative learning in levels that are ordered in terms of increasing abstraction with characteristics increasing to the most complex where hypothetical or individual principals are used. Biggs and Collis (1982) designed the SOLO framework to not only plan quality instruction but also to evaluate student responses and the success of instruction.

SOLO supports the principle that there are natural stages of learning growth that are similar, but not identical to, the cognitive stages of development of Piaget. Whilst learning quality is influenced by both intrinsic factors such as learners motivation, developmental stage and prior knowledge a key concern of SOLO is extrinsic, the learning event itself. SOLO is clear about describing the student's *response* as opposed to the *student*. Teachers should be interested in how a student's level of knowledge is changed by instruction and the use of SOLO to frame the planning of learning activities, the assessment tasks and the ultimate evaluation of learning success used in this teaching experiment is theoretically sound.

The SOLO Taxonomy incorporates a consistent sequence of levels that people display as they learn (Biggs & Collis, 1982; 1989; Biggs & Moore, 1993). Learner's responses following a learning episode can be classified into one of 5 levels of increasing complexity: Prestructural, Unistructural, Multistructural, Relational and Extended Abstract. The level of abstraction that the learner uses during the learning episode is called the mode and it progresses from very concrete actions to abstract concepts. Biggs and Collis (1989) also distinguish 5 modes, namely: Sensorimotor (from birth)**:** Ikonic (from 18 months): Concrete

Symbolic (from 6 years): Formal 1 (from around 16 years); and Formal 2 (from around 20 years). These modes they suggest, do not replace each other, but rather build upon each other, as learning progresses from very concrete to abstract. Primary students are most often situated in the concrete-symbolic mode. Further, the focus of all teaching concentrates on the middle three learning levels – uni-structural, multi-structural and relational – and this learning cycle repeats itself in each mode. Using the concept of mode and the levels of learning, a desired level of learning for a topic may be established and it can also be determined if a student has or has not achieved the required level of competence (Biggs & Collis, 1989). The SOLO Taxonomy provides a tool to frame curriculum activities, observations of student learning and to draw a veil of authentic assessment over a variety of learning tasks. An example of how the SOLO Taxonomy might be used in this experiment to assess student pre and post test responses would be if student responses to the question requiring them to tell what they think multiplication means engendered responses such as: "you take something away" (pre-structural); "means times" (unistructural); "groups of, lots of, rows of" (multistructural); and "adding the numbers in groups" (relational).

Beyond using the SOLO Taxonomy to evaluate the products of the learning activities, the level and type of peer interaction also need to be analysed as in the process of creating their stories students will be engaged in the co-construction of knowledge and individual level raising. The key activities in the process of conceptual level raising, namely showing, explaining, justifying and reconstructing one's work (Dekker et al., 2004) will all be used as the instructional cycle for both individual and group story writing. The teaching sequence will involve students writing individual stories which they will present to their small group, the teacher or the whole class. Their stories will be explained by the writer and discussed with their peers and/or the teacher and they will be required to justify how their story relates to multiplication. This dialogue will either result in a reinforcement of their knowledge ("What a great multiplication story!") or a reconstruction of their knowledge ("No? I need to change that. Maybe we should say altogether instead of now."). The same cycle will be followed for the writing of the group stories. Groups of students will be video taped and their dialogue will be analysed for evidence of conceptual level raising. Van Boxtel (2004) stated that when peer interaction contributes positively to concept learning it is characterised by: (1) talk about the concepts to be learned; (2) elaborative contributions from the participants; (3) a continuous attempt to achieve a shared understanding of the concept (co-construction of knowledge); and (4) making productive use of the mediational tools available. A coding system based on this framework will be developed to afford the opportunity of answering questions such as “Is the ability to write conceptually sound multiplication stories related to the extent to which a particular student talked about the meaning of multiplication with her/his peers or to the amount of talk about the concept by the group as a whole?” During a collaborative concept-learning episode elaboration and co-construction are social processes that may contribute positively to learning and as such also require analysis. An analysis of the peer interactions within a group makes it possible to compare the quality of peer interaction between groups. These data can then be used to create a fuller picture of how students come to understand concepts such as multiplication in classroom contexts.

Conclusion

This teaching experiment will be piloted in a Year 3 class at a large suburban primary school on the Gold Coast in Queensland, Australia in 2004. The teaching experiment will run for approximately 4 weeks. The results will be used to modify the experiment and further refine the curriculum activities, type and quality of interactions, the role of the teacher, and the assessment strategies used.

The student’s level of conceptual understanding of multiplication as displayed in their individual and group products will be assessed using the SOLO Taxonomy, and peer interaction and dialogue will be coded and analysed using the Van Boxtel (2004) framework. The pre and post assessment items will be structured to focus on the conceptual understanding of multiplication as opposed to simple procedural knowledge (e.g., Tell me what you think multiplication means. When we multiply what does that mean to you, how would you explain it to someone else?).

We believe that this teaching experiment promotes learning with understanding and demonstrates to teachers a clear link between research and classroom practice in mathematics. Our conjecture that student's conceptual understanding of multiplication may be advanced through the use of a dialogical approach to learning that uses children's literature as a mediational tool to scaffold conceptual level raising is worthy of further investigation.

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