Pre-service teachers evaluated their teaching of space lessons in early primary school by focussing on three aspects of the Intellectual Quality guidelines from Quality Teaching and Learning in NSW Public Schools document: substantive communication, deep knowledge and deep understanding. The impact of expected class behaviour, the learning experiences as planned, and the age of the students formed the reality of the classroom. The teachers struggled with the guidelines for evaluation in terms of their relevance for the stage of the students. However, it could be argued that the teachers’ expectations limited their effectiveness. This case study informs our understanding of activity theory and argumentation in primary mathematics classrooms.
The Reality of Intellectual Quality in Mathematics Classrooms

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Abstract

Pre-service teachers evaluated their teaching of space lessons in early primary school by focussing on three aspects of the Intellectual Quality guidelines from Quality Teaching and Learning in NSW Public Schools document: substantive communication, deep knowledge and deep understanding. The impact of expected class behaviour, the learning experiences as planned, and the age of the students formed the reality of the classroom. The teachers struggled with the guidelines for evaluation in terms of their relevance for the stage of the students. However, it could be argued that the teachers’ expectations limited their effectiveness. This case study informs our understanding of activity theory and argumentation in primary mathematics classrooms.

Classroom Communication

Mathematics lessons are frequently seen as a time for students to open a textbook and answer the questions. Few students are satisfactorily challenged by textbook exercises (Bell & Birks, 1990). They are either regurgitating information or they are following a method told them by the teacher, and there is little challenge other than selecting the appropriate method or words. The alternative is quality learning with students constructing their own knowledge. The reality of this approach is much more related to the cognitive challenges that students meet. These challenges need to be presented to students in a way that they will develop positive affective responses (Goldin, 2004; William, 2002). To achieve this positive response, classroom communication is critical. Both the teacher and the other students need to engage in conversations about problems. Teachers need to provide adequate support in terms of reviewing relevant approaches to the problem solving, assisting students to make links to existing knowledge and strategies, and setting up group support that will engage students and encourage students.

Engaging students requires mental activity to be at the interface between an individual and his social environment. Vygotsky asks us to start with what the child has, and connect school activities to them. Communication and culture will be related to activity. According to Mellin-Olsen (1987) in his classical discussion of activity in mathematics education, activity belongs to individuals and signals of the activities guide teachers to provide the individual students with educational tasks which can develop and promote their activities (Mellin-Olsen, 1987). More recent discussions on activities indicate the links between tools-objects-subjects (Cole & Engeström, 1991; Groves & Dale, 2004). Tools have recently been considered to be calculators or computers mediating thinking (e.g. Groves & Dale, 2004) but Mellin-Olsen (1987) referred to students’ thinking-tools and communicative tools to investigate and thus
develop mathematical concepts and processes. This study attempts to consider some of these tools and how teachers may generate their use to achieve learning.

We would assume that in many classrooms, there has been a shift from the above description given by Bell and Birks (1991) and indeed Johnson and Cupitt (2004) did find that many teachers were using group activities and concrete materials. However, they found that engaging students in mathematical enquiry and investigation is much more challenging for teachers (Johnson & Cupitt, 2004). Teachers need to develop skills in open-ended questioning, setting appropriately structured tasks, and developing group discussion that leads to students developing their concepts. One way of developing these teaching skills is for teachers to see them modelled and to discuss appropriate lesson planning and reflection (Johnson & Cupitt, 2004; Hufferd-Ackles, Fuson, & Sherin, 2004). Johnson and Cupitt (2004) worked on increasing communication. Hufferd-Ackles, Fuson, and Sherin (2004) provided a framework by which teachers could reflect on what was making a difference in their classrooms. One key was to encourage teachers to expect students would be initiating conversations, making comparisons, asking the hard questions, justifying their answers and explaining more thoroughly. Successful teachers carefully followed students’ descriptions of their thinking, and encouraged more complete explanations and deeper thinking. Teachers allowed for interruptions from students when explaining in order for students to explain or to own new strategies.

Knowledge of how communication can be successful is studied by looking at the patterns of interaction (Bauersfeld, 1988; Clarke, 2004). Some patterns that are not very effective are those in which the teacher asks a question, the student responds briefly and the teacher immediately praises (or otherwise evaluates) the response (NSW DET, 2003). Providing a step that gets all students started, then providing tasks that encourage all the students to present what they already know and to query each others’ ideas becomes a critical aspect before giving the students a bigger challenge (Williams, 2002). Bauersfeld (1988) also noted communication patterns that arise when tension increases for the teacher wanting but not yet gaining pre-specified answers from students. For example, there were gender-specific patterns with guesses by boys being positively acknowledged by teachers whereas girls waited until the teacher asked closed questions which they were not likely to answer incorrectly but which did not really lead to student problem solving.

Wood (2003) considered teachers’ questions to be critical during periods in class when students were reporting back after the task. The reporting back should not just be a report of what the students found out but strategy reporting. Wood (2003) recommended that questions such as “How did you decide this? … Are there patterns? Is there a different way you can do this?” encouraged strategy reporting. More successful mathematics lessons required inquiry and argument. These communication tools could be prompted by questions such as “How are the two things the same? Does this make sense? … Does it always work? Why does this happen?” The conversations in the classroom need to be about the substance of the lesson and be about making distinctions, critically examining each others’ ideas, forming generalisations and asking questions (NSW DET, 2003).

Mason (1994, 2003) suggested that teachers could become increasingly aware of others through awareness of their own experiences. By noticing characteristics of their own thinking and behaviour, they would be aware of those of others. We were interested in examining the reflexive reporting of preservice teachers over a series of lessons in terms of activity theory. How would they view the object (children’s knowledge) or context of reference, how would they view the sign (e.g. three sides signified a triangle) or symbol (shape name) and how would they understand the concept (Steinbring, 1989)?
As Bauersfeld (1988) said, classrooms have established routines that will influence the interaction of people within the classroom even when members of that classroom alter the intention, the means of achieving learning and a change to the rules (Cole & Engeström, 1991). We provided preservice teachers with an evaluative framework for reflection and exemplar lessons that were expected to change the classroom communication rules, the means of learning, and the fine grain intention of the lessons from focussing on knowing shape names to explaining classifications of shapes. “To develop metaconcepts, it is necessary for the pupil to discover the functionality of the symbols, which in its turn implies that the pupil has to recognise the tasks which his teacher involves him in as a component of an activity” (Barcomet Group—Christiansen, Howson & Otte, 1991, p. 105). Sign systems (e.g. using properties of shapes) are thinking rules if students discover the functionality of the sign system and then the students can adapt the sign system to new circumstances (Land & Bishop, 1966-1969, cited in Mellin-Olsen, 1987).

The focus of this study was to analyse what preservice teachers considered reflected the critical aspects of the classroom learning experiences, what they viewed as bringing about change in the rules of the classroom, and what they considered were mediating tools. We will also look for how they handled the tensions that arise from miscommunication.

**The Study**

The two preservice teachers (I will refer to them as teachers in the remainder of the paper) taught a Kindergarten class as a team over nine sessions spread over a number of weeks. Prior to teaching, the teachers were introduced to the notion of substantive communication (NSW DET, 2003), the need for strategy reporting and argumentation in classrooms (Wood, 2003), and open-ended learning experiences in the spatial aspects of mathematics (NSW DET, 2002). These approaches were modelled for the teachers. After each lesson, the teachers reflected on the teaching and learning in terms of deep knowledge, deep understanding and substantive communication (NSW DET, 2003). Six months later one of the students was observed teaching and asked whether she felt the experience of concentrating on substantive communication had affected her current teaching. The teachers’ journal writing will form the basis of this report. These entries will be analysed by a search for patterns in order to establish significant aspects of their teaching.

**Teacher Analysis of the Classroom Communication**

The teachers focussed on shape recognition during the first activity in which the students were making pictures with shapes. It was used as pre-assessment by the teachers. The teachers were pleased with their clear instructions and they asked questions like “what shape do you think you will use to make a motorbike?” They noted that students were able to trace around a shape in a picture, identify shapes in their classroom environment, and they made “complex and highly different pictures.” (teacher’s journal) Teachers were aware of their use of praise. They commented “students were encouraged to find the answer themselves through scaffolding from the teacher. Teacher provided feedback and elaborated on students’ answers and teachers attempted to foster discussion with students without much success.” They particularly noted that students varied in being able to communicate and that students were reluctant to talk to each other and “communication was not sustained but was mainly children responding to questions and communication ceased after the question was answered” (teacher’s reflective journal).

In the second lesson on shapes in the environment, the teachers said they gave good examples and a variety of explanations of the activity and they made it sound exciting to do
the rubbings of shapes in their environment. Their questions during the conclusion were “Where did you find this shape? Did anyone else find this shape? Tell me about the shape.” The teachers responded to the finding of a hexagon which was a new shape to the students “by listening and drawing the hexagon on the board and discussing it with the students” (teacher’s journal). They noted that few students would respond to the question “Tell me about it” and that they rarely communicated with each other or asked each other questions. They felt this was reflective of the general classroom milieu of sitting quietly, listening, and putting up your hand to answer the classroom teacher’s question as well as lack of group work. They decided that students should be introduced to the trapezium, rhombus and hexagon next lesson.

In the third lesson students made shapes with their bodies. The teachers noted “students were able to demonstrate their understanding of the mathematical relationships between shapes and their properties as they were actively engaged in the activity making their bodies into the forms of shapes correctly displaying the appropriate number of sides and corners. … The students were self correcting by standing back and observing. … (During the whole class reporting session) communication was one sided with the teacher providing information to students and asking questions. … One child appeared to dominate the direction the shapes took, and other students took on a passive role in shape making. IRE (initiate, respond, evaluate) communication took place during the whole lesson” (teacher’s journal). The teachers recognised a continuing lack of substantive communication but they did not realise that “understanding mathematical relationships between shapes and their properties” was deeper knowledge than the use of a sign such as three sides to denote a triangle.

The fourth lesson was introduced by revising the names and basic properties for the rhombus, hexagon and trapezium using shape cards. For example, no one could say what the hexagon was so the teacher named it and described its basic properties (e.g. number of sides and corners). Then the conversation continued:

C: It’s like the bottom of the chair
C: The signs, the lollipop ladies signs.
T: (holds up rhombus). What do we call this shape?
C: It’s a square.
C: It’s a rectangle.
T: That’s great but this shape is called a rhombus (describes properties)
(Incomplete shape drawn on board, three intervals like sides of a triangle.)
T: What is this I’ve drawn?
C: You’ve left out some spaces?
C: You’ve left out the corners?
T: Is it still a shape? Tell me about it?
C: Yes, it is?
C: (interrupting other child). No, it’s not. The lines aren’t joined.
T: Tell me why you think that.
C: A shape needs all the sides joined.

Then the teacher demonstrated making shapes with plasticene snakes including “Ms B’s Wageagon” (the name given by the teacher to an unusual shape). With the plasticine snakes, “students created complex shapes giving them names that related directly to the shape as in a ZigZagagon” (teacher’s journal). The teacher asked how the child came up with the name.

C: Cause it has zigzags on its head and legs.
T: What lines have you used the most?
C: Curved ones and sigsgs and bumpy ones
T: Great work!
However, the lack of substantive communication meant the teachers set their goal to considering a different questioning technique in the next lesson.

During the fifth lesson, students created their own triangles by drawing lines (intervals) radiating from a central point, joining the ends of the intervals, colouring in the triangles, cutting them out and pasting onto another sheet. The teachers reported that they “modelled open-ended questions and encouraged the students to discuss triangles’ shapes and sizes with the students at their tables. It was noted that some students have little to no understanding of triangles and their properties, and so further development is needed” (teacher’s journal). Some students did not notice the quadrilaterals drawn on their paper. However, “students were observed discussing their work with others at their table … each student contributed to the discussion; however most students accepted what they were being told, rather than offering their own insight into the problem” (teacher’s journal).

C1: How many triangles do you have?
C2: Four
C1: You didn’t make all triangles
C2: Yes I did
C1: This one has four sides
C1: Triangles have three sides.

However, the notes on the lesson showed that despite their good intentions, the teachers continued to ask closed questions with only one open-ended question, “What about this one?” They used some harder questions such as “Can you point to the largest triangle on your page?” but without following up the question or having a clear purpose for the question.

The next lesson consisted of students making shapes with a piece of string. The teacher demonstrated but the class were hard to get on track outside. However, the students began to pose questions.

In the next lesson, the students cut up a large triangle into several triangles. During the explanation at the start of the lesson, one child drew a line and formed a quadrilateral. The teacher asked her to have another go and when she completed the triangle the teacher said “Well done!” The other teacher in the team said she used “good praise to establish that the child has done the right thing” and the teacher re-counted the number of sides and corners for triangles. During the activity, when a child had a shape with four sides and the teacher asked her to check the number of sides, she was able to make another cut leaving triangles. This individual activity seemed to inhibit discussion. Some students found it hard to draw triangles on the sheet. The teachers were still asking the questions and students were beginning to give short sentence answers. Some children cut any shape. Others explored the properties of triangles by cutting appropriately to make smaller triangles. The teachers also realised that “some closed questions were given, resulting in yes and no answers, which did not foster any open discussions with the students. The communication that was evident appeared to occur between one child and the teacher, rather than a group discussion” (teacher’s journal). At this point the teachers were further focussed on questioning to foster communication.

The eighth lesson started successfully with a clear explanation of making a picture from tangram pieces in which the students were involved in making an example for the whole class. The students’ attention was gained. During the lesson, the teachers note the kinds of manipulations that the students used to make the picture. “A quality learning environment was established as students were responsible for their own active learning. Students were able to use their partners for support, encouragement and were able to collaborate together to solve the trangram problems. … Some children were able to express their knowledge as they manipulated shapes in various orientations to create the correct representation of the tangram.
Children expressed knowledge as they realised they had misplaced shapes in their creation, and moved shapes to fit the design, so they were responsible for their own self regulation. For other students, the teacher had to draw attention to the misplacement of shapes, which suggested further knowledge still needed to be developed” (teacher’s journal). The students used rotations. The activity involved students working in pairs. In some cases, one student dominated but others “worked well together, offering ideas to each other and exploring their thoughts” (teacher’s journal). During the conclusion, the class made the picture of a runner as a whole class except that the preservice teacher put some pieces in the wrong place. The students identified how the teacher needed to place it. For example, a child said “turn it around so that it points to the top”.

The last lesson was an assessment task. The teachers asked the students to draw each of the named shapes one at a time. In task two, they were given a sheet of shapes and asked to colour all of the named shape they could see with a specific colour before the teacher named another shape and colour. The teachers summarised the students’ achievement as follows:

- Some students who were not seen participating in communication with others or in group work showed a solid understanding of shape properties and shape recognition in different orientations.
- Some students were able to complete only one of the assessment tasks well.
- There was a varied level of understanding seen through assessment task one.
- Only one student completed assessment two entirely correctly. Most had difficulty seeing the shapes in different orientations or if stretched or skewed.

The teachers concluded that:

Aspects of the NSW Quality teaching framework may not have been developed successfully due to the following factors:

- The level of understanding and learning the students were at, being the lower level year one maths group
- Teacher questioning needed to be further developed and aimed more at getting the students to collaborate and contribute towards discussions
- Teacher questioning needed to be more focused on developing and enhancing upon the knowledge that children already displayed on the content areas.
- Students were observed to be in the routine of IRE question sequence and as the teacher we found it hard to break the students out of this, and get them to elaborate on the questions we asked them.
- Students were not used to generating their own discussions and offering new ideas and found it uneasy to do so when asked.
- Some of the lessons were based on individual completion of activities. Given the classroom setting, it may have been more beneficial for us to complete these in group work scenarios, where deep understanding can be fostered and expressed more clearly.
- Students did not seem to have much routine when it came to mathematics lessons. Students were used to completing worksheets and blackline masters, and so with our lessons being based on hands on, exploration activities without the use of handouts, students may have been put off as they were not used to doing mathematics in this way.
- During the teaching of the nine lesson plan sequences, the class had three relief teachers (not including both of us), which affected the children’s regular routine and classroom patterns.

When one of the teachers was teaching in another school some months later, I observed that she praised students readily and kept students on task by this technique and by keeping the class moving. She quickly had them working in groups and the students knew the purpose of the group activity. The teacher described her teaching as using students’ prior knowledge and expanding on it a little bit. “When they are doing group work, I am observing how students are interacting with each other, but there is not so much collaboration. One child is pushing ideas on to others and there is not much of taking ideas from each other. I allow them to reflect and vocalise how they learnt in other areas of my teaching, I like them to share it.
and explain their ideas and I involve them in ideas.” The teacher was still unaware of how to achieve substantive communication in the mathematics lessons.

Discussion

The teachers in this study began by assessing students’ knowledge of the names: “circle, triangle, square and rectangle”. The activity of making pictures with shapes and naming them was a means of giving signals of students’ mental activity. Beginning with this, they extended activities to cover other shapes—the hexagon, trapezium and rhombus—but they also dealt with different kinds of triangles. They found it necessary to talk about the quadrilateral and shapes with made-up names. In each lesson the activities resulted in the students producing a wide range of examples of the various shapes. They did this in various ways, making shapes with their bodies, with other shapes, with plasticene snakes, with string and by drawing lines and by cutting from a larger shape. Nevertheless, the teachers’ communication tended to be about naming or labelling shapes and using the properties of the number of sides and corners to help students identify the shapes. The motivation, problem solving, inherent in the tasks was not always supported by the apparent intention of the teachers, namely to label shapes.

To assist in the activity, the student has tools—thinking-tools and communicative tools (Mellin-Olsen, 1987). The thinking-tools allow the student to explore or investigate finding examples and associated rules that make knowledge a familiar process. In this study, the thinking-tools were encouraged by the wide range of open-ended physical activities such as making shapes with string, their bodies, and by cutting a shape into pieces. It meant students were directing their understanding of the concept and developing a metaconcept of shapes and types of shapes. The concept involved the shape in different orientations and with different dimensions. The words were made available by the teachers but it was necessary for the students to adequately match the words and their schema or metaconcepts. The communication from the teachers about the shapes was limited to names and the properties related to type of lines, number of sides and corners but student descriptions were also admissible especially in describing the shapes in different orientations and when shapes were given non-geometrical names.

The sign system (Steinbring’s term) was evident in these lessons when students realised the value of counting the number of sides or corners of a triangle in order to assign it the name “triangle” even when it is not the familiar equilateral triangle. The sign system can be communicated but may not be effective in achieving the motivation (engagement in problem solving) driving the activity for other students (Mellin-Olsen, 1987). To a large extent, this was where the difficulties lay in communication in this classroom. While teachers tended to use the symbols (shape names) from the start, this was a given rule limiting the degree of construction of the thinking rule by the students themselves. However, the naming of their own shapes, helped students to realise that shapes were part of a bigger group but even then the shapes were expected to have names, another rule imposed by the teachers. There were some examples given where students told each other whether a shape was acceptable as an example of the symbol (shape word). However, it seems that this may not have always lead to further conversation about the shapes, something that might have been expected should the second child be exploring and devising their own sign system.

While the students’ understanding of different shapes increased through these lessons, there were limitations on the degree of achievement by the students. Some of this will be due to the tasks not building sufficiently on student’s current knowledge as Vygotsky would recommend. There was a lack of discussion and self-developed description by students in the classroom apparently due to the well established routine that the teacher asks the question, the
student answers (usually in mathematics with a single word), followed by praise while the rest of the class remains silent and does not interrupt or express their own thoughts. The teachers used praise to direct students’ communicated knowledge. That is, if an action represented the sign, then it was praised. Praise was also used to have a positive classroom atmosphere. Students largely felt comfortable about having a go at answering questions even in front of the whole class but their skill in working in small groups cooperatively was limited. They did seem able to talk with neighbours when working on their own task but this too was kept subdued. Christianson, Howson, Otte (1991, p. 112) note that there needs to be a balance between the appropriate degree of standard language and the students developing their own. These authors and Mellin-Olsen (1987) warn against the control of language.

We can evaluate the series of learning experiences too by considering the dimensions of activity suggested by Mellin-Olsen (1987). On the dimension of past and future, the teachers began with the students’ knowledge and provided not only tasks that build on these but also an open approach that suggested to students a future exploration was expected. The tasks while sometimes narrowing in knowledge by the labelling and closed questions, there was also activity that widened students’ experiences and opportunities to explore. On the intrapersonal to interpersonal dimension, it was clear that there were individual differences between students. Students were able to show how their mental activity was creating something new. There was interpersonal and intrapersonal knowledge evident as the class were able to discuss the shapes with each other and the teacher. Interrelationship between the various components of the activity emerged for the students as they worked on the tasks which were linked by being about two-dimensional shapes.

Goldin (2004) recommended that students needed positive affective experiences but the teachers considered a positive climate was established by praising students when they were on the right track. The idea of positive affect from mental activities of a problem solving nature were not realised as part of the classroom expectations except that the teachers were modelling positive affect for the students. Indeed, the teachers hinted that they saw their open-ended questions and praise as a way of reinforcing appropriate strategies and ways of interacting in groups. Nevertheless, the observation of one of the teachers during a later practicum indicated that the teacher was aware of the interaction between students and how this was impacting on students’ mental activities.

**Conclusion**

In writing this report, I have deliberately selected references, especially Mellin-Olsen’s book, that I regard as spearheading the work on activity theory in mathematics education. Recent papers (e.g. Groves & Dale, 2004) referring to activity theory have not referred to this book and some of the papers and I wanted to redress that oversight by showing their relevance in this action research study.

In Neisser’s perceptual cycle (cited in paper 7 of the Barcomet Group in Christiansen, Howson, & Otte, 1991), schema direct exploration which samples the object (available information) and the object modifies the schema. The context in which the teachers were working (a classroom with set routines) and their own limited expectations of students, despite the open nature of the lesson plans from which they were working, meant that teachers reflected on students’ knowledge as being able to successfully label shapes. This attention to names (Mason, 2003) can limit the impact of the experience. Nevertheless, the teachers focussed on substantive communication and recognised that it was not really happening. They attempted to change this. While the activities themselves were extending students’ thinking, there was a control emphasised by the expectation that students were to learn the names of the
shape and that this was the important point. They saw the making of shapes and their questions as mediating tools in influencing learning and they attempted to modify the context for the students with limited success. Their explanation suggested that the context (classroom routines of worksheets, answering with single words) and the students’ age were affecting the learning taking place (Owens & Clements, 1998). However, it might not have been the young age of the students as much as the teachers’ difficulties in using appropriate teaching strategies to effect substantive communication.

When the teachers judged that the students did not seem to be making progress in changed schema as they judged it from the students’ naming of shapes, the teachers revised the names and the basic concepts. They made attempts to engage the students and continued to give them open-ended tasks. We can compare the classroom with the statement on activity that “the flow of a given internal or external process of activity/actions develops and proceeds with respect to the motive (the factual object) as activity, and with respect to the system of goals as actions.” (Barcomet Group in Christiansen, Howson, & Otte, 1991, p. 255). Students were using thinking tools and there were mixed motives (developing their own concepts about shapes and using teachers’ labels) but the mental objects were changing as seen in the final assessment and quotations. While the outcomes may have been less than expected, nevertheless starting with the initial knowledge of the students, there were changes in the system of goals or actions taken by students in exploring. It is not possible to describe these learning experiences as students making the connection between the verbal labels and the visual objects in their minds. The contextual influences were from the classroom routines and the teachers’ attention to recognising and naming shapes. These influences were what had to change for effective learning experiences that have a significant effect on schema development.

Paper-based lesson examples are best used by teachers who know their potential in terms of quality teaching and as a means for students to investigate and construct their own knowledge through their activities. This paper illustrates the struggle of two preservice teachers to achieve this goal, and the restrictions of the milieu of the classroom and their own limited pedagogical and mathematical knowledge on achieving their goal. Nevertheless, their action research and reflective teaching began to bring about change in their teaching and the students’ ways of learning. Consequently there was an improvement in the students’ knowledge. As teachers, we are challenged to implement learning experiences that create substantive communication for the early years of school. We need to examine our pedagogical and content knowledge and our beliefs about how students learn.

References


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