Challenges in Responding to Scaffolding Opportunities in the Mathematics Classroom

Sarah Ferguson
Australian Catholic University
<sarahferguson@exemail.com.au>

This paper reports on a study that explored the use of cognitively challenging tasks with low-attaining mathematics students and in particular, their teachers' attempts at scaffolding. A major finding was that responding appropriately to scaffolding opportunities was challenging for the teachers. In this paper two main factors are discussed which impacted on the teachers' responses to scaffolding opportunities: teacher knowledge of appropriate tools and representations for particular mathematical concepts, and teacher response to student prior knowledge and understanding.

Introduction

Scaffolding holds promise in allowing teachers to assist students without diminishing the cognitive challenge of tasks. Goos, Galbraith and Renshaw (2002) described scaffolding as "mutual adjustment and appropriation of ideas rather than a simple transfer of information and skills from teacher to learner" (p. 195). However, it appears effective scaffolding remains a difficult task for teachers. In their study of scaffolding in classrooms, Bliss, Askew and Macrae (1996) found many instances of "missed scaffolds" (p. 48) where "conditions for scaffolding were present but not noticed by the teacher" (p. 47). In these instances, "pupils are crying out to be scaffolded" (p. 47). It is such instances that I have described as "scaffolding opportunities".

Scaffolding opportunities are similar to teachable moments. Teachable moments have been described as "the set of behaviours within a lesson that indicated that students are ripe for, or receptive to, learning because they express confusion, misunderstanding, uncertainty, struggle, or difficulty with a mathematical problem, concept or procedure" (Arafeh, Smerdon & Snow, 2001, p. 3). Muir (2008) described teachable moments as "a teacher's simultaneous act in response to a student's answer, comment or suggestion and is utilized to either address a possible misconception or to enhance conceptual understanding" (p. 362). Effectively dealing with teachable moments as they arise demands teachers have a high level of mathematical knowledge for teaching (Muir, 2008). Responding to teachable moments or scaffolding opportunities is a difficult task. Two key factors emerged in my study that appeared crucial in determining if a scaffolding opportunity was taken or missed. These were teacher knowledge and use of appropriate materials to illustrate concepts, and the teacher responding appropriately to the students' prior knowledge.

Literature

Using appropriate materials and representations has been found to have benefits both cognitively and affectively for students (Sowell, 1989). Sowell's analysis of 60 studies on the use of manipulative materials found that two factors were essential for the use of such materials to be effective in student learning. First, the materials needed to be used over the long-term, such as a full school year or more. Second, teachers needed to be knowledgeable about their use. Boulton-Lewis and Halford (1992) described a distinction between representations that are "concrete embodiments of mathematical concepts and processes" and those that are "inherent in the discipline of mathematics (e.g. number lines and

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symbols)" (pp. 1-2). In the present study, materials or representations that were "concrete embodiments" and illustrated concepts were more successful than those that used mathematical symbols (Ferguson & McDonough, 2010).

Successful scaffolding relies on the teacher being able to bridge the students' current known understanding with understanding that is not yet known. Vygotsky (1978) described this as the "zone of proximal development". Tasks that fall outside this zone will either be too easy, falling within a students' known understanding, or too far from the students' known understanding and therefore too difficult. In order to ensure learning that falls within this zone, teachers need to know their students' prior knowledge and understanding that may impact on their ability to learn a particular concept. Sullivan, Mousley and Zevenbergen (2006) proposed that teachers should set one core task for the class to work on but that "different students may follow different pathways to the ultimate task, and may be supported or detoured along the way" (p. 120). For students who find the core tasks too difficult for example, Sullivan et al. advised the teacher use "enabling prompts" where "the teacher can explore ways to give the student access to the task without the students being directed towards a particular solution strategy for the original task" (p. 124). This assistance without the teacher being directive resonates with the notion of scaffolding.

In this paper I discuss examples of attempted scaffolding from the mathematics classrooms of two teachers of upper primary children. The responses of two low-attaining students from each class, four in all, will be discussed to explore the challenges of responding effectively to scaffolding opportunities.

Method

This study used a case study research design (Stake, 1995) to build up a rich and detailed description of mathematics teaching and learning in two teachers' classrooms, particularly focussed on the experiences of four low-attaining students. Case studies offer teachers "real world" examples of teaching and learning. Though the findings of a case study are particularistic they can be recognised in other situations (Stake, 1995). The experiences of the teachers and students in this case study offer teachers the chance to reflect on their own practice. Examining a particular case can also prompt reflection on general areas of complexity in teaching mathematics such as responding to scaffolding opportunities.

Participants

The first teacher, Ms B, had five years of teaching experience, with two years experience in teaching Year 5. Two students in Ms B's Year 5 class were targeted for data collection. These students, Carl and David, were operating about 12 to 18 months below expected levels in mathematics according to the *Victorian Essential Learning Standards* (Victorian Curriculum and Assessment Authority, 2006). Data regarding David are not discussed in this paper.

The second teacher in this study, Ms L, had eleven years teaching experience. The two target students from Ms L's class were Sophie, a Year 5 girl and Riley, a Year 5 boy, both operating at about 12 months below expected levels in mathematics according to the relevant curriculum at the time, *Victorian Essential Learning Standards* (Victorian Curriculum and Assessment Authority, 2006).

Data Collection and Analysis

Six sequential mathematics lessons were observed in each class. Each lesson was 80 to 90 minutes long. Data collection included interviews before and after observed lessons with the teachers and audio recordings of each lesson via a mobile recording device worn by the teachers. Data regarding the target students were gathered via lesson observations and a one-to-one interview after each lesson. There were two parts to these interviews. Firstly the interview focussed on the student's feelings about the tasks and their teachers' actions. Secondly a short assessment piece designed by the researcher was given to assess understanding of the concept of major focus within the lesson.

Interviews and lessons were transcribed and detailed lesson observation notes written for each observed lesson. These data were analysed using the NVivo program (QSR International, 2005). Data from a variety of sources such as interviews, observations, and work samples, built up a "rich, thick description" (Merriam, 1998, p. 38) of the teachers' and target students' experiences of their mathematics classrooms. I then "searched for patterns" (Stake, 1995, p. 44), seeking common themes but also recognising instances that differed from such themes in an effort to "come to know the case well" (Stake, 1995, p. 8).

Results and Discussion

The scaffolding opportunities that arose in this study were just some of the many decisions faced by the teachers in the busy world of the classroom. The teachers were dedicated and thorough but responding effectively to scaffolding opportunities was challenging. Some common factors that impacted on the teachers' response to scaffolding opportunities emerged in both classrooms (Ferguson, 2012). In this paper I will discuss two of these factors: knowledge and use of appropriate tools or representations, and responding to student prior knowledge. For each factor I examine instances of both opportunities missed and opportunities taken in both the research classrooms.

Knowledge and Use of Appropriate Tools or Representations

Ms L taught multi-digit multiplication during all six of the observed lessons. Although she talked about the potential positive effect of using manipulative materials or representations, Ms L did not deviate from her lessons emphasising written processes, to use such materials. Ms L was not familiar with how to use squared grid paper to shade regions in a way that could illustrate the distributive properties of multi-digit multiplication. The squared grid paper was a suggestion I made after Ms L asked me about possible representations.

However Ms L shied away from using grid paper by suggesting that using these visual representations could confuse students and in fact, may have confused her. She said:

> I might actually show them the other one, drawing the grid ... I was going to show that but I thought that might be too confusing. I think with a lot of kids the visual can confuse them more. I looked at it and thought "Oh I don't know how that's helping me" but kids are different I suppose.

There was evidence from a post-lesson assessment task that using the squared grid paper representation potentially supported Riley's understanding of multi-digit multiplication. This assessment task asked Riley to "Find an answer to 14 × 16 using a written method and then use the grid paper to draw an array". Riley quickly grasped the idea of using grid paper to show a multiplication expression as an array. He was then able to divide up the larger array into manageable pieces in order to find a total. After showing the outline of the array "14 × 16", Riley said "It would be much easier if it was 14 times 10 'cause I can go 10, 20, 30, 40 … I could break it down again ‘cause I’m not well [*sic*] at my 6 times tables. I can break it down again. 1, 2, 3, 4, 5 I can go 5, 10, 15, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75 and then I go down so then I can go, then I know that is 14 so I’ve got the answer”. (See Figure 1) Though he made an error in counting by fives by omitting 20, this strategy was effective and showed a distributive strategy for multi-digit multiplication.

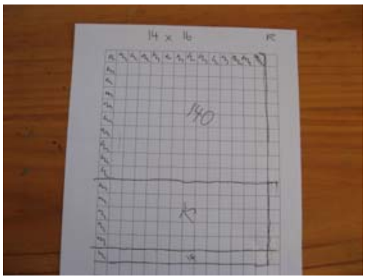

Figure 1. Riley’s solution on square grid paper.

I believe Riley’s ease at using the grid paper showed that this was potentially a useful representation for him and an effective way to scaffold his learning. If Ms L used representations that, as Boulton-Lewis and Halford (1992) suggested, illustrated the underlying concepts behind these processes, such as the squared grid paper, Riley’s understanding could have been scaffolded more effectively. This was a scaffolding opportunity missed as the conditions that Sowell (1989) described as essential for the successful use of materials and representations were missing in that the teacher did not have sound knowledge of the representation and had not experienced long term use of it. This points to the need for teachers of upper primary students to have knowledge of and experience in using the most appropriate representations or materials for complex concepts such as multi-digit multiplication in order to scaffold more effectively.

In the classroom of Ms B the use of representations provided an example of a scaffolding opportunity taken. During all lessons observed, Ms B focussed on fractions and decimal numbers and how they relate to each other. In the same way as Ms L, Ms B asked me what kinds of representations she could use to illustrate decimal numbers. I suggested the decimat, a rectangle divided into a grid of one thousand equal parts with bold lines showing the tenths and the hundredths of the rectangle.

The data from previous lessons and post-lesson interviews revealed that Carl could not name the decimal number that was the same as one half. The day before using the decimat the following exchange was recorded.

Ms B: What’s a half as a decimal?
Carl: Zero point two, zero point oh two?
Ms B: How many is half of the tenths? In a whole, how many tenths?
Carl: Ten.
Ms B: What’s half that?
Carl: Five.
Ms B: Five tenths as a decimal? Zero point? …
Carl: Zero point zero one?

It was clear from Carl’s responses that he really did not know how half could be expressed as a decimal. He also demonstrated a common misconception by offering that “point two or point zero two” might be equivalent to half, seemingly taking the number two from the denominator of one half and applying this to decimal numbers. Carl needed a vehicle to link one half and five tenths for him so that he could see how they are equivalent.

After Ms B introduced the decimat by creating one together on the board, the students began to play a game using this representation. As they were playing, I observed that both

Carl and David were able to link the notation of decimal numbers with the amount they had coloured on their decimat. This was noteworthy progress given their performance during previous lessons. In addition, Carl appeared to be developing his understanding of the decimal equivalent to half.

Carl : [Calling out] Ms B! I've coloured in a half!
Ms B : Good! How many tenths is that?
Carl : Five.
Ms B: Five tenths, yeah, half the tenths.

I am not claiming that Carl now understood how five tenths and one half relate to each other but I believe he was now "on the way" to developing this understanding. This was the first time Carl had used the decimat but this representation appeared to have scaffolded his learning. The decimat representation is an example of a "concrete embodiment" (Boulton-Lewis & Halford, 1992) where the concept is directly represented. Such representations were found in the large study to be beneficial for scaffolding (Ferguson, 2012). By using the decimat representation, Ms B was able to maximise a scaffolding opportunity for Carl.

Responding to Student Prior Knowledge

The decimat task occurred on the final day of lesson observations but during the previous two weeks, Ms B struggled on many occasions to scaffold Carl's learning. The cognitive demand of six out of the eight tasks observed in Ms B's classroom was too high for Carl based on lesson observation and post-lesson interview data about Carl's level of understanding for fractions and decimal numbers. One example is Carl's response to improper fractions. In the first assessment task I asked Carl to draw "three halves". He hesitated and said "Like three equal bits?" and I said "Mmm. Whatever you think." Carl drew a circle and divided it into three roughly equal parts. He did not shade any of the parts. He then wrote "3 halfs" [*sic*] beside it. Clearly Carl did not understand improper fractions.

The following day Ms B assigned the class a task called "Fraction Rods" which compared the size of Cuisenaire rods to find the fractional relationships between them. This example is one of the exchanges between Carl and Ms B was recorded during this lesson.

Ms B:	If the blue is one and a half, what each of these green ones worth?
Carl:	A third
Ms B:	A third *of the blue rod* because the blue rod is worth one and a half. How many halves in one and a half?
Carl:	Three
Ms B:	Yes why?
Carl:	Cause … we just did it then. [Carl's voice is quiet and sulky]
Ms B:	No but I'm asking you. How many halves in one and a half?
Carl:	I don't know.
Ms B:	How many halves in a whole?
Carl:	Four
Ms B:	How many *halves* in whole?
Carl:	Two
Ms B:	Have you switched off?
Carl:	Yes
Ms B:	Switch back on please. How many halves in a whole?
Carl:	Two

It is clear from Carl's responses and tone of voice that he was confused about the task. As was shown during the assessment task about improper fractions, asking Carl to determine one third of three halves was out of Carl's zone of proximal development. Ms B did not act on Carl's obvious confusion by adjusting the task so that it was within his grasp but persisted. This appeared to cause Carl frustration and disengagement, "have you switched off?" "Yes". The task was beyond Carl's current understanding so it is likely that no amount of explanation from Ms B would have been sufficient for Carl to have understood this task. The opportunity to scaffold Carl's learning was missed as Ms B did not respond to his prior understanding or knowledge.

Turning again to Ms L's class, Ms L's conversation with Sophie (Ferguson & McDonough, 2010) revealed responsiveness to Sophie's prior understanding that resulted in a scaffolding opportunity taken.

Ms L: So now, how can you tell me what 9 times 87 is? What can we keep doing here?
Sophie: Keep adding on 87
Ms L: Until you've added it?
Sophie: Until we've got 9.
Ms L: Okay that will give you the right answer so that's one strategy because addition, multiplication is when we keep adding the same number over and over and over again. So keep adding on for that please.

Ms L invited Sophie to use her preferred strategy, evident from previous lessons, of repeated addition. Ms L responded to the strategy that Sophie had decided to use herself, and responded to Sophie's prior knowledge of multiplication as repeated addition. However, repeated addition is an inefficient strategy when multiplying with larger numbers and it would be desirable for Sophie to develop a more efficient strategy. Ms L scaffolded this development when she returned in a few minutes for the final part to this conversation.

Ms L: How are we going here Sophie? Okay if you think, this is pretty time consuming isn't it? So let's look at, if it's 9 times 87 do you think perhaps we could use our knowledge, how do we multiply by 10? So 10 times 87 which would be what?
Sophie: 870
Ms L: Okay, spot on. But we only want to multiply 9 times so what do we have to take away from 870 to make it correct?
Sophie: Ahhh… 87?
Ms L: Because we've multiplied one extra. So you do 870 take away 87. See if that will help you. That will be a quicker … if that's going to help you because that's a quicker way of doing it, isn't it?

Now Ms L offered Sophie an alternative strategy that would be more efficient. Importantly she did so after allowing Sophie to use her preferred strategy, recognising this prior learning. Experiencing an inefficient strategy perhaps added to Sophie's motivation for finding a quicker way. Sophie appreciated the efficiency of the "multiply by ten and take one set" strategy for multiplying by nine, commenting in the post-lesson,

> I was confused with trying to find the answers. I got confused trying to find the answer to 87 times 9. Then I used subtraction. If you do 10 times 87 it will make 870. If you minus 87, it gets to 783. If I kept adding 87 to my answer it would've taken a long time. It was Ms L's idea.

Ms L responded in this episode to Sophie's prior knowledge before scaffolding a more sophisticated strategy. The task made it reasonably difficult for Sophie to use her repeated addition strategy but not too difficult in that her initial strategy could still be attempted. In moving from what Sophie knew to something just beyond, Ms L was able to make the most of this scaffolding opportunity.

Practical Implications

This paper has illustrated the challenges for teachers in assisting the learning of low-attaining students by responding effectively to scaffolding opportunities. The two factors addressed here that impacted on the teachers' ability to make the most of scaffolding opportunities can be examined to draw out the implications of these findings for mathematics classrooms.

The first implication is that upper primary teachers need access to high quality materials and representations and that these materials need to be readily available in classrooms. More important than simply having materials available, teachers also need professional learning in using representations and materials to effectively illustrate particular concepts. The teachers in this study asked me about representations for multi-digit multiplication and decimal numbers. This implies that on-going professional development should be provided on appropriate representations and materials for the more complex concepts encountered in upper primary school such as multi-digit multiplication and decimal numbers. As Sowell (1989) suggested, effective use of materials and representations relies on the teacher, both the teacher's familiarity and persistence with the materials and their knowledge of how to use them to effectively scaffold learning. The present study, for example, found that materials and representations that illustrated concepts (Boulton-Lewis & Halford, 1992) were more effective than others when scaffolding the learning of the low-attaining target students (Ferguson & McDonough, 2010). Information is needed for teachers regarding the kinds of materials and representations that illustrate particular concepts.

This study found that missed opportunities for scaffolding where the teacher did not recognise or respond to the students' prior knowledge were crucial. Without tasks that fell within the students' Zone of Proximal Development (Vygotsky, 1978), scaffolding could not take place. Without the task being adjusted in some way, students struggled unproductively.

An initial implication for teachers is to find out what the students' prior knowledge is for the concept to be taught. Armed with this knowledge, tasks can then be adjusted depending on student needs (Sullivan et al., 2006). In the case of the Fraction Rods task described previously, Ms B could have created alternative sets of questions that explored more about proper fractions for students such as Carl who needed consolidation in this area. The task remains essentially the same, comparing rods to find fractional relationships, but is adjusted to provide an "enabling prompt". Examining the use of enabling and extending prompts (Sullivan et al., 2006) might support teachers in planning task adjustments to more effectively respond to students' prior knowledge.

In any lesson there are many decision points for teachers, one of which is when and how to respond to scaffolding opportunities. Responding effectively during a lesson "depends very much on a combination of the teacher's knowledge, beliefs and professional judgement" (Muir, 2008, p. 366). Addressing key factors such as appropriate materials and representations and student prior knowledge before the lesson might assist teachers in responding more effectively to scaffolding opportunities as they arise. This paper illustrated some examples of both scaffolding opportunities missed and opportunities taken. It is hoped that teachers can use these examples to reflect on these issues in their own classrooms.

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