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TEACHER EDUCATION & DEVELOPMENT | RESEARCH ARTICLE

The development of case studies to evaluate the usefulness of teaching interactions in one-to-one teaching of early number

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Abstract: This research paper reports on phase two of an Australian study that examined video-recorded intensive one-to-one teaching interactions with 6–7-year-old students who were in their second year of schooling and identified by their class teacher as low attaining in early number. The two-phased study from which this paper emerges was originally conducted in 1998 as part of my Bachelor of Teaching Honours (Research) program at Southern Cross University Lismore, New South Wales. That study identified teaching interactions particularly suited to one-to-one teaching in the Maths Recovery Program, a program designed for these students who were at risk of failure in early number. A great deal has not changed since that time with limited literature available that comprehensively reports on teaching interactions in intensive one-to-one settings. Revisiting the original study is considered timely because of the increasing number of withdrawal and intensive programs now funded and adopted by schools and yet, rarely reported on in terms of the effectiveness of the teaching interactions that occur in such settings. This paper then builds on from the first research paper, The identification of teaching interactions used in one-to-one teaching of number in the early years of schooling to present a series of case studies of teaching interactions that were identified as positively influencing intensive one-to-one teaching and learning settings.

Subjects: Childhood; Continuing Professional Development; Curriculum Studies; Early Years; Teaching & Learning

Keywords: one-to-one teaching; early childhood; mathematics intervention; low-attainers; scaffolding; mathematics education; post question wait-time; questioning; prompting



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Bronwyn Ewing is a senior lecturer in the School of Curriculum at QUT. In her research role, Bronwyn works with industry partners, government and private sectors and community groups in a range of collaborative research and commercial projects with a specific focus on mathematics education, multi-sensory/modal pedagogy and social theory of learning to enhance the mathematical learning of a range of equity groups, including students who are Indigenous, with special needs and ESL. This paper contributes to further understandings of working with such groups to improve their mathematics achievement. It also works to inform undergraduate and postgraduate primary mathematics students that I teach in my academic role.

PUBLIC INTEREST STATEMENT

Low-attainment in mathematics in the second year of schooling in Australia has been identified as a strong predictor of later achievement in numeracy and literacy. Low attainment necessitates intervention through intensive one-to-one mathematics teaching programs in the early years to prevent low levels of academic performance in mathematics in the later years. This research study provides insights into phase two of a study that focused on the development of case studies. The two case studies demonstrate positive teaching interactions that are influential to one-to-one teaching. In doing so, they provide the evidence in support of the premise that positive interactions between teacher and student in a one-to-one setting positively influence student achievement.

1. Introduction

Education is an anti-poverty strategy to protect children from later disadvantage. Its purpose is to bring about success and create educational and social advantages for students. Social advantage and disadvantage and education success and failure are linked to the Australian education system (Kenway, 2013). Currently, economic and social advantage equates with education success whilst economic and social disadvantage equates with educational failure.

Success in mathematics is becoming increasingly important to today's teachers, students, parents and employment providers in Australia. Mathematics is viewed as high status and essential for a range of employment opportunities. In Australia, children are at risk of failure in this subject in the early years of schooling if they are not identified as low attaining by their classroom teachers.

Low-attainment refers to students who are 6–7 years of age and in their second year of schooling in Australia. In the context of this paper, if they are at risk of failure in early number learning and identified by their teacher and the Maths Recovery Teacher using an interview-based assessment *Schedule for Early Number Assessment* (Wright, Martland, & Stafford, 2006), they are placed in individualised teaching cycles of length 12 to 15 weeks. The purpose of the cycles is to advance children's early number learning to a level at which they are likely to learn successfully in a regular classroom.

Children who were low attaining in early number provided the focus for phase two of the study: to identify positive teaching interactions used in one-to-one teaching settings with a view to understanding a teacher's practice when interacting intensively with students. The following questions guided the process:

- (1) What research understandings of one-to-one teaching provide the basis for the development of the case studies? and
- (2) How do these understandings compare with the empirical data observed from one-to-one video-recorded teaching sessions?

To address these questions, a brief discussion of the research literature is provided to identify one-to-one teaching interactions that positively influenced the intensive teaching and learning setting. A discussion of the methodology used to investigate the research questions follows. Similar to phase one of the study, a pragmatic approach is adopted, to puzzle out and problem solve to identify positive interactions observed in empirical data. To do this necessitates a brief summary of the Maths Recovery program.

1.1. Maths recovery program

The Mathematics Recovery (MR) Program is an early intervention program for students who are 6 to 7 years of age and in their second year of schooling. Developed by Robert Wright over a three-year period (1992–1995) (Wright, 1989, 1991a, 1991b, 1993) in Australia and more recently with Wright et al. (2006), the program is used in classrooms in the United Kingdom, Ireland and the United States of America. It was used as the foundation for the Count Me in Too Program in New South Wales, Australia (Gould, 2001). The MR program was funded by the Australian Research Council (1992–1995) (AM9180064). The program draws extensively on the constructivist teaching experiment work of Steffe (1990, 1991), von Glasersfeld (1990, 1991) and Cobb, Wood, and Yackel (1991). This work was designed to investigate children's mathematical knowledge and learning in instructional classrooms and individualised settings. The teaching experiments of Steffe and others involved selecting students who were considered to be low-attainers in their class and withdrawing them several times per week for individual teaching sessions over extended periods.

2. Review of theoretical ideas

The understanding that students can construct their mathematical knowledge has been at the centre of debates for over 30 years (cf. Cobb & McClain, 2001; Kyriacou & Goulding, 2006; Kyriacou & Issitt, 2007; Roth, 2014). This is so because two cognate approaches, constructivism and social constructivism began to influence mathematics education over that time. Constructivism has its origins in cognitive theory and the work of Piaget (1936) whilst social constructivism is influenced by the work of Vygotsky (1930, 1934). Both are claimed to have significantly influenced the way mathematics has been taught and learned in classrooms and continues to do so (Cobb & Steffe, 2011; Cobb & Yackel, 1998; Ernest, 1996; von Glasersfeld, 1995; Waschescio, 1998).

There are two major premises to constructivism. First, the child's knowledge, knowledge, attitudes and experiences brought to a learning context provide the starting point for learning. Second, as the interplay of that knowledge, and the attitudes and experiences, students begin to construct new knowledge based on previous learning. This knowledge is grounded in and develops further from previous experiences. Thus, when something is said to make sense and or is meaningful, it is this association of knowledge that is addressed.

In the 1990s, some researchers (see, e.g. von Glasersfeld, 1991, 1995) explored the application of Piaget's (1977) theory of assimilation and accommodation to the mathematics classrooms to further understand how students construct their mathematical understanding. What was found was that learners constantly strove for equilibrium, that is, the cognitive stability that occurs through the process of assimilation and accommodation. Assimilation occurs when new information meshes with existing understanding. Through this meshing a learner is said to be accommodating this new information to fit with their cognitive schemata and schemes. Equilibrium occurs because of these two processes and is crucial to a student's cognitive development. Knowledge then is not a commodity that rests outside the knower, where it is simply passed from the teacher to the child, but rather it is an individual's constructive activity.

The study draws on two important theoretical ideas identified as underpinning mathematics teaching in the early years of schooling in Australia, namely, (1) social constructivism and (2) socio-cultural theory. These ideas allow for a better understanding of children's number knowledge and the advancement of that knowledge.

2.1. Social constructivism

The early work of Cobb et al. (1991) with American teachers in the 1990s was instrumental in supporting them in renegotiating classroom social norms so that they and their students together constituted a community of active and engaged learners—a forecast perhaps of the rise of social constructivism. This meant classroom learning involved small-group collaborative activities and whole-class discussions of students' interpretations and solutions (Cobb & Yackel, 1998). They found that the interplay between students' thinking and mathematical concepts was increasingly important and therefore required the teacher to make instructional decisions and changes to their teaching practices in order to accommodate this interplay (Cobb & Yackel, 1998; Fennema, Sowder, & Carpenter, 1999).

Social constructivism builds on the constructivist position and rests on the premise that what children can do with assistance is more indicative of their cognitive development than what they can do alone (Brown, Metz, & Campione, 1996; Marti, 1996). Moreover, the focus is on the interplay between language and thought (Sierpinska, 1998) and cognitive development and culture (Lave & Wenger, 1991; Saxe, 1991). Researchers who claim that priority should be given to social and cultural processes (Engestrom, 1996; Forman & McPhail, 1993; Levine, 1996; Minick, 1996; Voigt, 1994) draw mainly from Vygotsky's (1930) contention that social interaction and culture are constitutive of an individual's cognitive development.

2.2. Sociocultural theory

According to Vygotsky's sociocultural theory (Renshaw, 1992, p. 5), learning is a communal activity. That is: culture is not an overlay on basic substrata of individual development, but is a constitutive element of individual development. That is, learning for any individual is a process of appropriating "tools for thinking" that are made available by social agents who initially act as interpreters and guides in the individual's cultural apprenticeship.

Using qualitative methodologies such as ethnographic research, researchers applied Vygotsky's sociocultural theory to investigate the significance of culture and social interaction with students in mathematics classrooms (Engestrom, 1996; Forman & McPhail, 1993; Levine, 1996; Minick, 1996; Voigt, 1994). Minick (1996), for example, suggests that there is much to learn from exploring the connections between social practice and cognition through the face-to-face encounters of teachers and students in the classroom. One way of doing this is to explore the influences of curriculum and teaching materials on teachers and learners. Similarly, Voigt (1994) found that negotiation of meanings is a necessary condition for mathematics learning. He pointed out that this was the case when "students' understandings differed from the understanding the teacher wants the students to gain" (p. 215). Such differences are seen to be crucial to negotiations of meanings in the classroom. Hence, communication between students and teacher and individual expertise should be supported in classrooms, including one-to-one teaching contexts.

Both theoretical ideas highlight several important points about children's learning. First, children bring to a learning context their knowledge, attitudes and experiences which provide the entry point into building on from what they bring to a context. Second, it was proposed that children are capable of constructing mathematical ideas with the support from a teacher who is able to guide and build on a student's cognitive constructions. Here, the interplay between the student's mathematical development and a teacher's practice has a critical role because both are active participants in the teaching and learning context. The task of the teacher is to micro-adjust or change their practice to accommodate a child's active learning and to negotiate mathematical meaning as part of this process. A brief overview of the conduct of the study now follows.

3. Methodology

In this study, three methodological principles were used. They formed the basis of Vygotsky's approach to the analysis of higher psychological functions. The first involved studying the processes, i.e. "process analysis as opposed to object analysis" (p. 65). The second was explanation versus description, i.e. "analysis that reveals real, causal or dynamic relations as opposed to enumeration of a process's outer features, that is, explanatory, not descriptive" (p. 65). And the third was "developmental analysis that returns to the source and reconstructs all the points in the development of a given structure" (p. 65).

This process of abductive reasoning (Walton, 2004) allowed for the development of an initial series of teaching interactions from video observations, progressing to more likely possible explanations which provided the basis for constructing the case studies in phase two. These interactions were compared and contrasted with the research literature until a fit was obtained and possible explanations of the observations could be made. Tasks and settings observed during the study are described as they arise.

3.1. Research context

The current study focuses on the teaching interactions of one-to-one teaching sessions. The study was conducted in New South Wales, Australia. The data for the study consisted of videotaped recordings of one-to-one Maths Recovery teaching sessions conducted by four teachers. The video-recorded sessions were part of a larger trial study of the implementation of Maths Recovery into primary schools (Wright, 1989, 1991a, 1991b, 1993). Analysis of these recordings focused on teaching and specifically, on the interactions between teacher and student.

3.2. Ethics

As the study focused on a small aspect of the much larger trial study in the 1990s and discussed previously, it was encapsulated in the ethics for that study. The conduct of the study was part of my Bachelor of Teaching honours program. Permission to use the data was granted by the project Chief Investigator Professor Robert Wright in 1995. All observable data were de-identified by the project team prior to the commencement of this study.

3.3. Sampling: selection of video recordings of teachers

Purposeful sampling was suited to the investigation because it provided representative samples of teaching interactions from four teachers in a range of intensive teaching settings which could then be compared with the research literature (Patton, 1990; Silverman, 2007). This sampling allowed for “information-rich cases” that could be study in depth to provide opportunities for learning about the purpose of the study (Patton, 1990, p. 169).

3.4. Construction of case studies

In this study, I adopted a method of analysis that was informed by Cobb and Whitenack’s (1996) approach to longitudinal analysis of data on teaching in the form of video recordings and transcripts. In that work, they emphasised “that the development of theoretical constructs should occur simultaneously with data collection and analysis” (p. 224). They identified that this approach was found to be consistent with Glaser and Strauss (1967) constant comparative method. That is, theory development occurs simultaneously with data collection and analysis.

As described in the first paper, the research process involved two phases. Phase one involved a process of abductive reasoning that allowed for the development of the initial series of teaching interactions. Phase two built on this process. Drawing on Cobb and Whitenack’s (1996) approach, I used three critical steps to analysis in phase two to develop theory about teaching interactions that positively influenced intensive one-to-one settings. Step one involved 12 hours of video-recorded teaching sessions from phase one. They were re-observed with notes of four kinds—descriptions, protocols and explanations. The descriptions focus on the teaching interactions and settings. The protocols illustrate the interactions and the explanations provide an elaboration of the interactions.

Summaries about case studies are provided at the conclusion of each interaction to evaluate their effectiveness for one-to-one teaching. As the data were previously de-identified by the project team from the larger study, each of the descriptions, explanations, protocols and summaries was re-coded by interaction, teacher pseudonym, child pseudonym and task.

4. The development of case studies: analysis of interactions in one-to-one teaching

Two case studies (John and Julie) which focused on the interactions of one-to-one teaching are presented and include scaffolding, post question wait-time and questioning and prompting. Each interaction is described on several different tasks, for example, forward number word sequence, numeral identification using a number chart to 50, counting by two using counters, addition using hundreds chart, addition using screened counters, subtraction using screened counters, counting by tens using tens strips, counting using bundling sticks, determining numerosity using bundling sticks.

The two case studies demonstrate teaching interactions seen to be influential to one-to-one teaching. They provide evidence in support of the premise that understanding the interactions serves as a guide to understanding a teacher’s role when interacting with students who are low-attainers in early number and which enable positive student achievement.

4.1. Scaffolding

Bruner’s (1996) notion of scaffolding referred to the gradual release of teacher control and support as a consequence of children’s increasing mastery. Effective scaffolders focus children’s attention on the task and keep them motivated and working throughout the session (Wood, 1990, p. 140). Wood

(1990) divides the learning task into accessible components and directs the child's attention to the essential and relevant features. According to Díaz, Neal, and Amaya-Williams (1990), "the teacher who scaffolds, demonstrates and models successful performance while keeping the task at a proper level of difficulty, avoiding unnecessary frustration and encouraging children's independent learning" (p. 40).

Clay and Cazden (1990) assert that within the zone of proximal development, the child is not a passive recipient of the adult's teaching, nor is the adult simply a model of expert, successful behaviour. Rather the adult and child engage in joint problem-solving activities, where both share knowledge and responsibility for the task (p. 218). The Maths Recovery teacher performs the crucial function of scaffolding the task to make it possible for the child to reflect on the strategies and thinking involved and gain confidence in their own solutions, reducing the need to continually refer to the teacher for approval.

4.1.1. *John and Ben—forward number word sequence*

In the following protocol John supported the child, Ben, who was identified as experiencing difficulty counting from "30" and recognising particular numerals. John commenced with a forward number word task but based on his observations micro-adjusted this task when the child was unable to count from "39" to "40".

- T: All right Ben, will you count for me please? We'll see how far you can go.
- C: (Rests chin on hands which are on the table) one, two, three, ... thirty-nine, fifty, fifty-one, fifty-two, ... fifty-nine, thirty, thirty-one, thirty-two, thirty-three.
- T: (Looks at child and with an upward inflection) stop there Ben. All right, this time start at number thirty, thirty, thirty-one.
- C: (Rests on hands as before) thirty-two, thirty-three, thirty-four... thirty-nine, fifty.
- T: (Looks at child and with an upward inflection) stop there. (Changes the task to see if the child recognises the numerals he is counting.) All right, can you tell me what that number is?
- C: Thirty (pauses) thirty-three.
- T: (Points to numeral card which has "31" on it and looks at child) thirty?
- C: (Looks at teacher) thirty.
- T: (Points to "1" on card) one.

Evident in this protocol was John's awareness that Ben was unable to identify the numeral "31". He then scaffolded and adjusted the task to see if Ben recognised the numerals he was counting. Here, the skill of the teacher is critical to the student's learning. The protocol demonstrated the teacher's monitoring and observation in order to take account of the child's learning progression. In this case, the task posed, micro-adjusted and scaffolded by John is informed by his observations and reflections of the child's prior activity, forward counting (Wright et al., 2006). This can be seen in the next protocol using cards with numerals written on them.

4.1.2. *John and Ben—numeral identification—number chart to 50*

In this protocol, Ben experienced difficulty with counting on from "39" to "40". John invited Ben to count with him as he demonstrated and modelled successful counting. This was identified as a strategy to avoid unnecessary frustration for Ben. Ben counted with John. Soon after, John withdrew the scaffold allowing him to proceed unaided.

- T: (Places chart numbered up to "50" in front of child). Use this Ben and this time when you're counting point to the number for me. Right, head up now. (Points to chart to demonstrate pointing to numbers.) I want you to use your finger to point to the numbers as you count.

- C: (Immediately begins to count and point to each numeral). One, two, three ... twenty-nine, thirty (pauses on “30”) thirty-three (places head on table).
- T: (Points to “30” and speaks with an upward inflection) thirty.
- C: (Points to “30”) thirty, thirty-one, thirty-two, thirty-three.
- T: All right, stop there. (Points to chart) we went twenty-seven, twenty-eight, twenty-nine (pauses to wait for child to count) thirty.
- C: (Counts with teacher) twenty-nine (pauses and counts after teacher) thirty.
- T: (Invites child to count and points to each numeral) you count along with me. Thirty-one (points to chart).
- C: Thirty-two, thirty-three, thirty-four,...thirty-nine, fifty.
- T: Thirty-nine. Let’s start here again (points to “37” to indicate where to start) thirty-seven, thirty-eight, thirty-nine, forty.
- C: (Counts with teacher) thirty-eight, thirty-nine, forty, ... fifty.
- T: Fifty! Good boy, well done Ben.

John supported Ben and was willing to be involved in meaningful communication. Ben responded to this interaction. After he was invited to count with the teacher, he responded and achieved success with minimal frustration. Once again John micro-adjusted the task as he observed Ben’s difficulty with counting on from “30” and “39”. John encouraged Ben whilst keeping the task at a reasonable level of difficulty. In the next protocol, Julie (case study 2) also demonstrates this interaction with Alex.

4.1.3. Julie and Alex—counting by two—counters

Alex was asked by Julie to count by twos as the teacher arranged counters by twos on the table. Alex grappled with the complexity of explaining his thinking when solving a mathematical problem. Initially, he stated that he did not know what he was thinking. At this point, the teacher questioned Alex to gain some insight into the strategies he was using. In light of the child’s participation in this task, the teacher was able to move in and out of the scaffold, supporting him when he needed it and at other times allowing him to gain more control of his mathematical learning. T: Let’s see if you can count by twos for me again today.

- C: (Immediately) two, four, six ... ten (pauses to think) twelve ... eighteen.
- T: (Arranges blue counters by twos up to ten on the table). And two more?
- C: Twenty.
- T: That’s right. You really had to think about those last ones didn’t you? What were you doing while you were thinking so hard? (Arranges red counters as before to indicate counting by twos up to twenty.)
- C: Um, I don’t know.
- T: What were you doing in your mind to help you get the answer?
- C: (Immediately) I was counting by twos and I went all the way back to two then I counted on from two.
- T: Did you? (Touches two counters and moves them slightly to indicate counting by twos.) Let’s do it a little bit quicker with our counters.
- C: (Immediately) two.
- T: (Touches counters as before to indicate counting by twos) two.
- C: Four, six ... ten (begins to count slowly from “12”) twelve ... twenty.
- T: Good boy. Why is it faster like that?

- C: Because you can see two, you can see a two pattern and then you can see sev ... a four pattern, then you can see eight, and then you can see all the other patterns.
- T: So when you are doing it, you can see some patterns can you? (Places a card over “18” counters and leaves “2” counters exposed.) What can you see there?
- C: Two.
- T: (Moves card along counters as child begins counting by twos).
- C: Four, six, ... twelve (begins to count slowly) fourteen, sixteen, (pauses) eighteen, twenty.
- T: How come you were so quick on that one? (Indicates “14” with card.)
- C: Because I saw a four pattern there (points to four blue counters).
- T: So you just went four (points to four blue counters) teen.
- C: (At the same time as the teacher) teen.
- T: (Moves card as before to indicate counting by twos).
- C: Sixteen, eighteen, twenty.

With the support of Julie, Alex appeared to have gained confidence with his counting by twos. In this task there appeared to be little frustration for Alex. He had opportunities to verbalise his solutions and contribute what he could. Julie questioned and encouraged Alex to discuss his solutions. This assisted him to better understand the problem and gain some control of his learning, all the while, keeping him at the cutting edge of his learning. This interaction can be seen in the next protocol.

4.1.4. Julie and Alex—addition—hundred chart

In the following protocol, Julie scaffolded Alex’s working through the problem by having the hundreds chart in front of him if he needed to use it. The problem involved addition of “73” and “10”. Alex used the hundreds chart to identify and find a useful strategy for solving the problem. Julie allowed Alex to mutter to himself and work through the problem so that he could develop his strategy for finding a solution.

- T: (Points to “73” on hundred chart) you were on seventy-three and you added on ten more, and where did you go?
- C: (Pauses for six seconds and appears to be thinking, mutters to himself).
- T: (Speaks softly) seventy-three and ten is?
- C: (Reflects for fourteen seconds, appears to be thinking as before, points to hundred chart and seems to be counting to himself) seventy.
- T: (Points to hundreds chart and with an upward inflection) seventy-three not sixty-three, it’s seventy-three and ten.
- C: (Mutters) seventy-three.
- T: That’s where we’re starting. Seventy-three and ten is?
- C: (Immediately) eighty-three.
- T: Yes, so what row were you going down there?
- C: Thirties.

In this protocol, Julie questioned Alex and gave him time to reflect on the question and his thinking. Alex solved the problem “73 + 10”. When Julie questioned him about which row he was going down to solve “73 + 10” he answered thirties. From this response it does appear he was referring to the “3” in “73” and “83” as thirties. Further understanding of place value is needed to assist Alex with knowing the value of each numeral.

4.1.5. Summary of case studies—scaffolding

John and Julie were similar in the way they provided scaffolding when the students, Ben and Alex, seemed to be experiencing difficulty. This served to minimise frustration on the part of the students and kept them focused and working on tasks which were nevertheless at a reasonable level of difficulty. Evident in the protocols of John and Julie were demonstrations of how they micro-adjusted their teaching depending on students' success on the tasks. When the student was not succeeding, John and Julie adjusted the task to one closely related to the original task. This kept them at the cutting edge of their competencies, in their continually changing zone of proximal development.

On several occasions, John invited Ben to count with him and withdrew when he had some control of his counting. Julie allowed opportunities for Alex to discuss his solutions. Evident in the teaching of both John and Julie is the strategy of building on the each of the students' intuitive, verbally based strategies which serves as a base for the development of written forms of arithmetic.

The notion of scaffolding affirms Vygotsky's (1930) theory of a zone of proximal development. Every child can do more with assistance than they can by themselves but only within the limits of their development (p. 103). Significant in John and Julie's teaching was their confident approach to one-to-one teaching, which, in turn, seemed to engender motivation and confidence in their students. Both teachers provided instructional support based on continual monitoring and observations of students. During the analyses of videotaped teaching sessions, the students' abilities to become independent learners were observed.

4.2. Post question wait-time

Post question wait-time is the length of time that a student has to respond to a question (Brophy & Good, 2009). "The length of pause following questions should vary directly with their difficulty level" (p. 362). In Reading Recovery teaching, Clay and Cazden (1990) assert that students, when they read texts at an instructional level, "use a set of mental operations, strategies in their heads that are just adequate for the more difficult bits of the text" (p. 207). During this process, the student engages in deliberate attempts to solve new problems with familiar tasks.

4.2.1. John and Chris—addition—covered counters

In the following protocol, Chris was asked to solve the addition problem "5 + 2". John supported Chris by allowing time for him to reflect and think about how he was going to solve the addition problem.

- T: There's six under there. Six counters are under cover. I'm going to take one of those out and put it in here (places counter under a second cover which already has "1" counter under it).
- C: (After thinking for six seconds and with an upward inflection) six!
- T: There was six but I took one out.
- C: Four! (Thinks for twenty seconds looks at teacher) five!
- T: (Takes cover from counters to show "5").
- C: (Writes and says) five plus two equals (looks at covered counters) six!
- T: How did you work that out?
- C: Five (points to written "5" and covered "5" then points to covered "2") two, no one.
- T: Two.
- C: Two.
- T: Then how many is it?
- C: Five, six, seven (writes "7" to complete addition).

John supported Chris by giving him time to reflect and solve this problem independently. John asked Chris how he solved the problem and Chris was able to respond. He carefully guided John through his strategy linking the unseen counters with the written numerals. Once again if John did not give that reflection time or asked questions and wait for a response, he would not have gained valuable insights into Chris' knowledge used to solve the problem. This interaction is further identified in the next protocol.

4.2.2. *John and Chris—subtraction—covered counters*

The wait-time in this protocol was minimal. Chris had to solve the missing subtrahend problem “7” to “5”. Chris paused on two occasions but was able to respond to the problem in his own time. T: Seven and now you've got five left (removes two counters and covers them).

- C: (Pauses, touches and counts visible counters) one, two, three, four, five.
T: How many did I take out?
C: (Pauses and places hand on cover) twice.
T: (With an upward inflection) seven?
C: Two.
T: Good.

John waited for Chris' response to the problem. This was not a difficult problem for Chris because he had developed an appropriate strategy for subtraction, therefore the wait-time was reduced.

4.2.3. *Julie and Alex—counting by tens—tens strips*

Julie had been working with Alex on incrementing by tens. She questioned him about what happened to the known number and amount each time a row of 10 counters were placed on the table. Alex was able to count on by tens from “30”. Julie increased the complexity of the task by changing directly from six rows of ten to nine rows of ten. With appropriate questioning and wait-time, Alex was able to work through the problem and use appropriate strategies.

- T: (With an upward inflection to indicate a question) what have we got to do to make nine rows often?
C: (Indicates across counters with hand) put another lot up here and that makes ninety.
T: I don't think so.
C: Seventy.
T: That's right. So what have we got to do to make it sixty to ninety? (Points to counters.)
C: (Pauses and reflects for fourteen seconds, points to counters). Just put three more rows (indicates with hand to show rows).
T: Good boy. Three more rows. That's exactly right!

In this task, Alex used hand movements to help with clarifying the problem and finding a possible solution. By observing this Julie was able to gain insight into the strategies he uses to solve problems. Alex's confidence with solving problems seemed to be increasing. Julie provided the opportunity for Alex to think about the task and work through it in his own time.

4.2.4. *Julie and Sara—subtraction—covered counters*

Julie had been working with Sara on solving subtraction problems. Sara was experiencing difficulty with solving “21–2” using covered counters. Julie micro-adjusted the task using a numeral track which allowed Sara to work through the problem and find a solution. T: Twenty-one take two is twenty? (With an upward inflection to indicate child's error.)

- C: (Mutters).

- T: If I had twenty-one and took two away, I wouldn't have twenty. That's a bigger number isn't it?
- C: (Looks at teacher then looks away appears to be thinking, reflects for twenty-one seconds).
- T: What numbers did you say?
- C: (Reflects for nine seconds).
- T: (Reaches for numeral track) let's have a look on here. There's twenty-one (lifts flap covering "21") and we're trying to take two away (points to two flaps before "21").
- C: (Places fingers on same flap as teacher).
- T: There's twenty-nine (points and lifts flap covering "29"). It's not twenty-nine is it? Something else with a nine.
- C: (Reflects for six seconds) nineteen.
- T: Nine? (With an upward inflection to indicate for child to repeat.)
- C: Teen.
- T: (Lifts cover from "19" to indicate that child was correct).

In this protocol, Sara was given adequate time to reflect and think about this problem. Julie provided scaffolding for Sara during this problem, supporting her only when necessary. Sara appeared to be focused on finding a solution.

4.2.5. Summary of case studies—post question wait-time

John and Julie were similar on the interaction of post question wait-time. They provided sufficient time after questions and during the task for each child to reflect and respond to the problem. As a general rule, length of wait-time depended on the level of difficulty of the question. A question requiring more abstract thinking would need and was accorded a longer wait-time than a factual question. Both teachers appeared to use their professional judgement well in deciding when to intervene and scaffold the task. Their skill and ability to observe closely what the students were doing was evident. They displayed remarkable patience with their students. Similarly, they did not speak unnecessarily but allowed periods of sustained silence for the students to reflect on their thinking. This appears to be consistent with the underlying principles of Maths Recovery and Vygotsky's socio-cultural theory (1934). As John and Julie interacted with their students, each child appeared to internalise and transform that social interaction and move from the social plane of functioning (intermental) to the individual and internal plane of functioning (intramental). Both teachers waited for a response to questions asked. This helped the students to clarify problems. Clay and Cazden (1990) assert that as students work at an instructional level in reading they "use a set of mental operations, strategies in their heads that are just adequate for the more difficult bits of the text" (p. 207). John and Julie's teaching was consistently at an instructional level as the student worked at solving problems.

Post question wait-time is crucial to a child as he or she engages in deliberate attempts to solve challenging problems. The student has time to respond to a question and use strategies in their head that are adequate for solving the difficult pieces of a problem. Wait-time varies with level of difficulty of question. During wait-time, students think hard about solving new problems with familiar information and reflect on their thinking.

4.3. Questioning and prompting

According to Lyons, Pinnell, and DeFord (1993, p. 157) questioning and prompting takes much practice and experience. They state that Reading Recovery teachers develop the skill to observe closely what the student is doing, decide what kind of information the student needs to attend to and then select the prompt or question that will help the student become a more independent problem solver. Lyons et al. assert that a Reading Recovery teacher "learns when, why, how, and under what conditions questions can and should be asked and how to tailor questions to fit the demands of the text and specific student needs" (p. 159).

4.3.1. *John and Ben—addition—covered counters*

In this protocol, Ben was unable to solve the covered addition problem “7 + 5”. John realised Ben’s difficulty in solving the problem and micro-adjusted the task so that Ben could achieve some success. He prompted Ben by asking questions and by placing counters one at a time for Ben to count.

- T: (Places seven red counters under cover). There are seven there (places five green counters under another cover) and there are five here. How many altogether Ben?
- C: (Reflects and appears to think for twenty seconds) eight.
- T: Let’s have a look at those Ben (uncovers green counters). How many are under there? (Places hand on covered counters).
- C: (Pauses) seven.
- T: Seven (with an upward inflection to indicate he is correct, places one green counter beside cover so that child can see it). Now how many?
- C: (Reflects for ten seconds) eight.
- T: (Places another green counter as before to make two).
- C: (Pauses) nine.
- T: (Places another green counter as before to make three).
- C: (Immediately) ten.
- T: (Places green counter as before to make four).
- C: Eleven.
- T: (Places green counter as before to make five).
- C: Twelve.
- T: There are twelve counters.

Apparently, Ben was able to count on from seven but could not use a strategy involving counting on five from seven. John continually challenged Ben and kept him motivated and involved in solving the problem.

4.3.2. *John and Ben—subtraction—covered counters*

Ben reflected for some time on the problem “12–1”. When he responded with “9” and was unable to explain how he got that answer John once again micro-adjusted the task to prompt Ben into finding a strategy to solve the problem. The importance of allowing Ben the opportunity to reflect and try to explain how he arrived at his answer was crucial. John would have some understanding into how Ben solved subtraction problems.

- T: There are twelve (covers counters) and I’ll take one away (leaves uncovered).
- C: (Reflects for twenty-two seconds appears to be thinking) nine.
- T: (Pauses) how did you work that one out?
- C: (Plays with hands, mutters indistinctly) I don’t know, nine.
- T: What made you say nine? (with an upward inflection) how did you think about working out nine?
- C: (Plays with fingers) I forgot.
- T: Okay (uncovers counters and places them in two rows of six). Count them for me Ben.
- C: (Points and counts) one, two, three, ... twelve.
- T: (Looks at child) we’ll take this one away. How many are left there now?
- C: (Points and counts quietly from one) eleven.
- T: (Slides another counter away) there are ten there Ben, and I’ll take this one away (covers nine counters). How many are left under there?
- C: Nine.

4.3.3. *Julie and Alex—counting task—bundling sticks*

In this protocol, Julie had been working with Alex on counting by tens. Three bundles of sticks were on the table from a previous problem. Alex showed that he was developing strategies for incrementing by tens. Julie prompted Alex to check his solution. Instead of saying to Alex to check his answer, she reworded the question so that he heard, “How many bundles in seventy?” Alex responded in time with the answer. T: Can you change that to a seventy?

C: (Places three more bundles with three already on table. Counts and touches each bundle, gets one more bundle to make seventy).

T: How many bundles in seventy?

C: (Reflects and appears to be thinking for nineteen seconds, touches and counts bundles) seven.

T: (With an upward inflection to indicate the child is right) Right, seven bundles.

Through questioning Julie provided Alex with the opportunity to focus on the visible bundling sticks. The question was specific to the task and focused Alex’s attention on using the counting strategy of counting by tens to solve the task.

4.3.4. *Julie and Alex—determining numerosity—bundling sticks*

Julie observed closely what Alex was doing. He worked through the problem of showing “47” using bundling sticks. Alex did this confidently and with little assistance from Julie. She prompted only when she felt he needed to focus on the displayed bundles of tens.

T: Can you change that into forty-seven? (Places hand on seven bundles of sticks to represent “70”.)

C: (Reflects for thirty seconds gathers more sticks from bucket. Counts bundles takes three away).

T: Forty-seven (speaks softly).

C: (Places single sticks out) forty-seven.

T: (Looks at child) just better count those and check I think.

C: (Counts sticks) six (gets one more) there!

T: Okay, what number did you make?

C: Forty-seven.

T: That’s right and how do you write forty-seven? What two numbers do you need to write?

C: Four.

T: (Places plastic digit “4” below four bundles often).

C: Seven.

T: (Places plastic digit “7” below seven sticks). Forty-seven, that’s it isn’t it?

Julie asked questions which helped Alex accomplish the task. Following the first question, Alex was given time to reflect and work through the problem using bundling sticks.

4.3.5. *Summary of case studies—questioning and prompting*

Inherent in questioning and prompting were scaffolding, post question wait-time and effective communication. These interactions were apparent when observing John and Julie as they questioned and prompted their students. John and Julie seemed very aware of their students’ learning and previous knowledge and experiences and took account of these with appropriate micro-adjusting of tasks. To this observer, their timing of questioning and prompting seemed particularly appropriate. They seemed to know when, why and how questions should be asked. They tailored questions and prompts to fit the task and the students’ needs. As well, prompting was not always communicated

verbally. Hand gestures and eye contact seemed to influence the students and keep them focused on the task.

Questioning and prompting seem to be consistent with Cole and Chan's (1987) assertion about skilled communicators. The use of gesture with the expression of meaning holds the attention of students and helps facilitate communication between a teacher and student. The teacher observes what the student is doing, decides what kind of information the student needs to attend to and then selects the question or prompt that will help the student solve the problem. Questioning and prompting can be useful for understanding the zone of proximal development. The teacher needs to be aware of the student's previous experience and should micro-adjust their teaching according to this zone.

5. Discussion of the teachers in the case studies

The premise is supported in this study: the teaching interactions serve as a guide to understanding a teacher's role when interacting with students who are low-attainers in mathematics and which enable positive student achievement. The approach to analysing the interactions of one-to-one teaching provides explanations of teacher practice that will serve as a guide to understanding a teacher's role when interacting with a student. Reasons for John and Julie's inclusion in the case studies are now given.

In phases one (Ewing, 2016) and two of the study, John consistently demonstrated teaching interactions suitable to one-to-one teaching. He continually micro-adjusted his teaching and the task based on ongoing observations. John's observational skills appeared to be of a high level as he observed each child as they constructed, reflected and solved problems. His timing of questioning and prompting seemed to be particularly apt. John guided the students very well as they built on their current knowledge.

Like John, Julie consistently demonstrated teaching interactions suitable to one-to-one teaching. She micro-adjusted her teaching and the tasks so that the child was challenged to think hard in order to find a solution to a problem. Julie allowed periods of sustained silence so that the child could reflect on the problem and spoke only when necessary. She tailored questions to suit the task and the student's needs. Julie exhibited a commitment to meaningful interactions with each student.

The case studies consistently used teaching interactions seen to be particularly suitable to one-to-one teaching. Both teachers provided scaffolding as the students were working on tasks. They appeared to micro-adjust their teaching based on their observations of the students. This helped to prevent unnecessary frustration and kept the students working at finding a solution. Throughout their teaching, John and Julie allowed sufficient time for the students to respond to a question. The length of time varied depending on the type of question asked. During wait-time the students reflected on the problem, asked the teachers questions and discussed their solutions.

The teachers were effective with directing the students to the necessary bits of information needed to solve the problems without reducing the difficulty of the task. John and Julie questioned and prompted, as they observed the students. Both teachers appeared to choose the most appropriate question or prompt which helped the students solve the problem.

6. Findings and concluding comments

The development of the case studies emerged from the initial series of interactions in phase one and discussed previously and the research literature which focused mainly on interactions of teaching in a whole class and small group setting. This initial series was then tested *via* the construction of case studies. The research literature was consistent with the view that interactions could be identified as either appropriate or inappropriate to one-to-one teaching.

The following specific findings are based on the discussions and explanations from phase two of the study.

- (1) The research literature which refers to the classroom setting remains a suitable guide to analysing one-to-one teaching.
- (2) In phase two of the study, teachers displayed suitable interactions for one-to-one teaching which were consistent with research literature.
- (3) Scaffolding, post question wait-time and questioning and prompting positively influences intensive one-to-one teaching of 6–7 year olds who are low attainers in early number.

The conclusion of the study is that the research literature of teaching interactions was appropriate for developing an initial series of interactions and the case studies for understanding the interactions of one-to-one teaching. However, to determine the effectiveness of intensive teaching in one-to-one settings, more studies with the focus on the teacher are needed to document changes in interactions of one-to-one teaching.

There are two limitations to this study. There was minimal research literature available which specifically focused on one-to-one teaching. However, the literature studied was suitable for the current study. Another limitation of the study was the inability to communicate with the teachers involved. Video-recorded protocols proved valuable to the study but communicating with the teachers would have provided further information about one-to-one teaching.

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