An Exploration of Prospective Teachers' Learning of Clinical Interview Techniques[1]

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Received: 31 July 2015 Accepted: 20 July 2016

The present study followed four prospective teachers through the process of learning to interview during an undergraduate research project experience. Participants conducted and video recorded a series of interviews with children. They also carried out guided analyses of the videos and written artefacts from the interviews to formulate conjectures about how to improve their questioning techniques. Communicating the purpose of the interview to children and formulating probes spontaneously were particularly difficult for participants. However, the experience helped participants realise when they were providing too much guidance and also when they missed opportunities to have children further explain their thinking.

Keywords · clinical interviews · mathematics teacher education · undergraduate research · teacher reflection · qualitative research

Piaget's (1976) clinical interview methodology has made a lasting mark on the landscape of educational research. A clinical interview generally consists of open-ended tasks for a student to solve. The interviewer hypothesises how the student will respond, but often maintains a flexible questioning structure to explore alternative hypotheses about the student's thinking (Heng & Sudarshan, 2013). Follow-up questions are posed with the intent of ascertaining the student's underlying thought process (Goldin, 2000). The ability to probe students' thinking in such a manner sets the clinical interview apart from other forms of assessment, such as observation and testing, in which the assessor plays a more passive role (Ginsburg, 2009). Because they allow researchers to actively investigate students' reasoning and problem-solving strategies, clinical interviews have become indispensable tools for mathematics education researchers (Schoenfeld, 2002; Koichu & Harel, 2007).

[1] This material is based upon work supported by the National Science Foundation under Grant Number DRL-1356001. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Purpose of the Study

Clinical interviews have value beyond their use in formal research. Mathematics educators have begun to explore clinical interviewing as a means of teacher education. The purpose of the present study is to provide empirical accounts of prospective teachers' learning of clinical interview techniques. Such empirical descriptions are valuable because of their potential to facilitate the formation of inferences about strategies for helping individuals become skilled interviewers. The empirical accounts were constructed by addressing two guiding research questions: (1) What changes do prospective teachers make in their interview techniques after watching and reflecting on interviews they have conducted?; (2) Which types of interview techniques are resistant to change?

Empirical Support for Clinical Interviews as Mathematics Teacher Education Experiences

Several studies have reported benefits of using clinical interviews as mathematics teacher education experiences. Some of these studies have involved prospective teachers (e.g., Dunphy, 2010; McDonough, Clarke, & Clarke, 2002), and others have involved practicing teachers (e.g., Heng & Sudarshan, 2013; Hunting & Doig, 1997). Studies indicating the usefulness of interviewing in mathematics teacher education span the pre-school years (Dunphy, 2010), early school years (Heng & Sudarshan, 2013; Hunting, 1997; McDonough et al., 2002), and adolescence (Fernandes, 2012; Jenkins, 2010). Conducting clinical interviews to explore children's mathematical thinking has yielded benefits across these populations.

Clinical interviewing has helped some individuals learn to ask questions that are more effective in eliciting children's mathematical thinking. Jenkins (2010) found that doing clinical interviews helped prospective teachers ask questions to prompt children to clarify their thinking. Prospective teachers in the Jenkins study also learned to ask mathematical questions requiring inference and interpretation. Heng and Sudarshan (2013) found that practicing teachers learned to help students explain, justify, and communicate their mathematical ideas as a result of conducting clinical interviews. Hence, it appears that the questioning techniques used during a clinical interview transfer to a degree to the context of teaching.

Another benefit of conducting clinical interviews is that it can lead to better understanding of children's mathematical thinking, learning, and problem-solving (McDonough et al., 2002; Heng & Sudarshan, 2013). Many adults initially believe that children's mathematical thinking will mirror their own. As a result, they are sometimes surprised at the mathematics that children find difficult (Dunphy, 2010). Or, they may observe children exhibit mathematical thinking initially believed to be beyond their abilities (McDonough et al., 2002). Interviews also afford unique opportunities to elicit the thinking of children who are ordinarily silent in classrooms (McDonough et al., 2002). As prospective and practicing teachers develop more comprehensive understandings of children's thinking, they tend to shift their classroom stance toward a position of respectful and interpretive listening (Heng & Sudarshan, 2013; Jacobs, Ambrose, Clement, & Brown, 2006; Jenkins, 2010; McDonough et al., 2002).

Shifts in classroom stance lay groundwork for shifts in assessment. As teachers learn about children's thinking during clinical interviews, they appreciate the importance of having classroom instruction guided by children's mathematical thinking (Jacobs et al., 2006). Lesson planning then becomes more focused on addressing children's mathematical needs (Heng & Sudarshan, 2013). Clinical interviews help make teachers aware that they need to elicit children's informal mathematical ideas and help connect them to formal mathematics (Heng & Sudarshan,

2013). Clinical interviewing can thus prompt a shift away from instruction guided strictly by a priori mathematical and pedagogical expectations toward instruction guided by continuous formative assessment.

As teachers design instruction that is responsive to children's thinking, they may also begin to set aside less-productive pedagogical strategies. Heng and Sudarshan (2013) reported that teachers who conducted clinical interviews began to see the harmful effects of encouraging "key-word" approaches to word problems and teaching with manipulatives in a rote manner. Teachers in their study witnessed how children who had experienced such teaching strategies were limited in their abilities to think deeply about mathematical tasks. Hence, clinical interviews can facilitate not only the development of new teaching and assessment techniques, but also the elimination of less-effective strategies.

Helping Teachers Develop Fundamental Clinical Interview Techniques

Although clinical interviews have potential for teacher education, teaching interview techniques can be difficult. Labinowicz (1985) remarked,

> It takes considerable sensitivity, experience, and skill to become a good interviewer. A raw beginner might not uncover any more information than a standardized achievement test could. This might be due to either a failure to probe or an overbearing manner that inhibits the child (p. 28).

Researchers have identified several specific challenges inherent in helping teachers become skilled clinical interviewers. Below, four challenging aspects are summarised: building a relationship with the child within the context of the interview, posing interview tasks, asking appropriate probing questions, and maintaining a stance of inquiry into the child's thinking.

Building Relationships

Novice interviewers must approach the interview setting as unfamiliar territory for both the interviewer and the interviewee. Throughout the interview, teacher-interviewers must bear in mind that their primary function is to pose tasks rather than to teach children how to do them (McDonough et al., 2002). Many children are not accustomed to explaining their reasoning after giving a correct response in a classroom (Hunting, 1997). Interviewers need to convince interviewees that the goal is to understand the interviewee's thinking, and not to produce a response that satisfies the interviewer (Hunting, 1997).

A teacher-student interaction like a clinical interview also has an inherent power imbalance that interviewers must recognise and navigate (Alexander, 2003). An interview is largely driven by the interviewer's agenda rather than the child's. This can make it difficult to establish dialogue. In some cases the child may even express a desire to stop the interview (Dunphy, 2010). Interviewers who anticipate this power imbalance can take steps to address it. It is important to establish a relaxed atmosphere, particularly if the interviewer has not previously met the child (Hunting, 1997). Furthermore, it is essential to establish mutual trust and respect if the interview is to attain its full potential (Hunting, 1997).

Posing Interview Tasks

Adults sometimes struggle to pose interview questions in a manner that is understandable to children (Dunphy, 2010). In such cases, the interviewer might change or simplify the original task (Hunting & Doig, 1997). Although changing interview tasks to make them understandable can

be productive, some changes lower the cognitive demand of the original task (Jenkins, 2010). Lowering the cognitive demand can turn tasks that provide opportunities for students to do mathematics into little more than exercises in recalling or applying procedures (Henningsen & Stein, 1997). When such modifications are made to interview tasks, interviewers lose opportunities to elicit authentic mathematical problem-solving. Modifications should ideally preserve the cognitive demand of the original task.

Asking Probing Questions

Once a child has responded to an interview task, the interviewer must formulate appropriate follow-up probing questions. Teachers learning to conduct clinical interviews may have trouble navigating situations where children give unexpected responses or their responses do not reflect the most sophisticated strategy they are able to use (Ellemor-Collins & Wright, 2008; Weiland, Hudson, & Amador, 2014). Some of the difficulties in reacting to students' responses can be traced to weaknesses in mathematics content knowledge. Formulating probing questions spontaneously requires deep knowledge of mathematical concepts and their connections (Ginsburg & Seo, 1999; Heng & Sudarshan, 2013; Hunting, 1997). Strengthening one's mathematical content knowledge can help improve the quality of probing questions.

Some difficulties asking probing questions can be traced to sources other than mathematics content knowledge. For instance, Dunphy (2010) found that some teachers asked too many follow-up questions during interviews. In such cases, interviewees become overwhelmed with the interview demands. Teacher-interviewers also sometimes allow too little time for students to think and respond before posing follow-up questions (Dunphy, 2010; Ellemor-Collins & Wright, 2008). When this occurs, children cannot fully exhibit their thinking about the task at hand. Fernandes (2012) found that allowing too little wait-time during interviews sometimes stems from the belief that if a child is not responding, he or she lacks understanding of the task. Therefore, in order to become skilled in formulating probing questions, teachers may need to reflect on and refine pedagogical skills and beliefs.

Maintaining a Stance of Inquiry

Prospective and practicing teachers who conduct clinical interviews enter territory that differs from conventional classroom settings. The interviewer's role is to maintain a neutral stance toward children's responses (Hunting, 1997) rather than to guide their mathematical thinking. Doing so can be quite difficult. Teachers often have a strong impulse to quickly validate children's responses or to correct errors they have made (Dunphy, 2010; Heng & Sudarshan, 2013; Labinowicz, 1985). This may lead them to give non-verbal and verbal cues when they sense a child is struggling with a task (Ellemor-Collins & Wright, 2008; Weiland et al., 2014), and children are prone to look for such cues because they occur frequently in classroom contexts (Hunting, 1997; Koichu & Harel, 2007). Heavy use of cues and guiding questions tend to funnel children's thinking toward "correct" responses (Fernandes, 2012; Wood, 1998). Funnelling lowers the cognitive demand of the task (Henningsen & Stein, 1997) and diminishes opportunities to fully understand children's thinking.

Process Reflection in Learning to Interview

In order to help prospective and practicing teachers overcome challenges in developing clinical interview techniques, we propose the use of a process reflection framework. Ricks (2011) characterised process reflection as "an active form of reflection that extends and links together

separate reflective incidents into cohesive mental continuums as ideas through action" (p. 252). Ricks contrasted this with incident reflection, which involves reflecting on the past but not connecting reflections with future action. Ricks' process reflection framework incorporates views of reflection held by Dewey (1933) and Schön (1983), who portrayed reflection as a cycle of hypothesis formulation and testing. From this perspective, creating a hypothesis about the nature of a problematic situation is not an end in itself, but instead the basis for formulating actions to address the problem. Observing the effect of the actions may lead to new hypotheses about addressing the transformed problem situation.

Ricks (2011) described specific steps within process reflection. The first step is an experiential event that initiates a reflective cycle, i.e., an unsettling event that sends a practitioner searching for resolution. The second step is idea suspension and problem creation, which involves avoiding quick and simplistic resolutions in favour of careful analysis. The third step, idea formation, consists of creating possible solutions to the problematic event. During idea formation, several alternate solutions may be considered, and the ultimate choice of strategy can be based upon data, past experience, and other factors that afford thoughtful problem solving. In the fourth step, idea testing, ideas formed during the third step are tested empirically. Empirical testing of ideas may then become an experiential event that triggers another reflective cycle.

One well-known application of process reflection to teacher education is Japanese Lesson Study (JLS) (Lewis, 2002; Ricks, 2011; Stigler & Hiebert, 1999). A typical JLS cycle begins with an instructional dilemma that teachers wish to resolve. Rather than acting impulsively to resolve it, teachers deliberatively analyse the problem within the context of a lesson study group. In the group, teachers use available data and relevant past experiences to write a lesson plan that addresses the instructional dilemma. One of the teachers from the group then tests the ideas in the lesson plan by teaching the lesson to a group of students. Group members observe the lesson, making the lesson itself an experiential event capable of motivating another JLS cycle.

Some elements of Hunting and Doig's (1997) approach to preparing teachers to conduct clinical interviews resonated with the process reflection framework. Their approach involved having teachers observe interviews to identify critical moments and key interviewer decisions. These initial analyses of interviews were done to encourage conjectures about how clinical interviews should be conducted. The conjectures were then empirically tested by carrying out an interview with a child. Although Hunting and Doig's model incorporated some elements of process reflection to help teachers learn to conduct clinical interviews, empirical accounts of teachers' learning in the context of the model were not provided. Such accounts are important if researchers are to understand the dynamics of how individuals learn interviewing techniques. Understanding the dynamics at play can help researchers refine process reflection approaches to be maximally responsive to novice clinical interviewers' learning needs.

Method

Participants

Four prospective teachers were involved in the study. They are referred to with the pseudonyms Veronica, Linda, Rachel, and Shantel. Veronica and Linda were pursuing elementary certification (grades K-6). Rachel and Shantel were pursuing secondary mathematics certification (grades 7-12). The four participants were selected from among those involved in a National Science Foundation (NSF) Research Experiences for Undergraduates (REU) project. To be eligible for the project, applicants were required to have a grade point average of 3.0 or above and be enrolled in an undergraduate program leading to teaching certification. Applicants were also required to

submit two letters of reference from instructors who had taught them in a mathematics or education course. All participants met these application requirements. NSF REU projects are designed to provide pre-graduate experiences with formal research. In doing so, they aim to encourage the pursuit of graduate studies.

Veronica and Rachel were undergraduates at the authors' home institution, Shantel was from a neighbouring four-year undergraduate institution, and Linda was from a local community college. Participants from the authors' home institution were further along in their certification programs in that they each had completed a mathematics teaching methods course. Participants from the other institutions had completed an education course at their home institution but had not yet completed a mathematics teaching methods course. Veronica was paired with Linda to study third-grade students' learning of fractions. Rachel and Shantel studied fifth-grade students' learning of statistics. Each pair was assigned a group of four children (two male and two female) to work with for nine weeks in the summer.

Procedure

During the first week of the REU project, participants conducted individual pre-assessment interviews with children. The interview scripts consisted of open-ended tasks from various sources, including the National Assessment of Educational Progress (http://nces.ed.gov/nationsreportcard/), the Illustrative Mathematics website (http://www.illustrativemathematics.org), and the University of Arizona Learning Progressions documents (http://ime.math.arizona.edu/progressions/). Participants were provided the scripts to help ensure the inclusion of open-ended questions and coverage of the learning standards to be investigated during the project. Participants did not write their own interview scripts. It is an open question, perhaps worthy of future research, if interview techniques differ among participants who construct their own interview scripts.

Each participant interviewed two children from the group they were assigned, and all interviews were video recorded. Participants then used what they learned during the interviews to design instruction for their group. During the final week of the experience, they conducted post-assessment interviews to assess the extent of student learning during the project and again video recorded the interviews. Participants generated transcripts of all videos. An overview of the process and its connection to the process reflection framework is provided in Figure 1 and described in detail below.

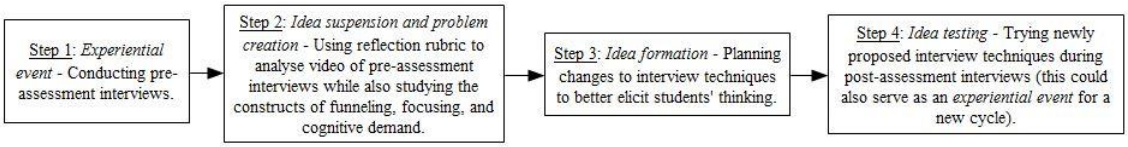

Figure 1. A process reflection framework for learning to conduct clinical interviews.

Step 1: Pre-assessment interviews

The pre-assessment interview experience provided an experiential event to initiate a process reflection cycle. To prepare to conduct the pre-assessment interviews, participants completed an online instructional module. In the first portion of the module, participants read an article explaining how clinical interviews support problem-based mathematics learning (Learn NC & Wheatley, 2001). The article included video clips of an experienced researcher interviewing

children. After reading the article and viewing the videos, participants responded to the writing prompt, "How can clinical interviews support problem-centred mathematics instruction?" In the next portion of the module, participants were given an article on the logistics of conducting video-based clinical interviews (Ellemor-Collins & Wright, 2008). After reading the article, they were to participate in an online discussion about it. The first post to the discussion board was to be a summary of the article, and subsequent posts were to raise questions about the article and respond to questions posted by others. In the final portion of the module, they were given the interview scripts to be used as pre- and post-assessments. Upon completing the online modules, pairs of participants did mock interviews with the scripts, with one acting as the interviewer and the other as the child being interviewed. The mock interviews were to help participants anticipate any potential difficulties in administering the script.

Once the pre-assessment interviews had been completed, each of the authors viewed a subset of the video recordings. While viewing the recordings, we looked for and made note of techniques that were effective for eliciting children's thinking (Hunting, 1997), and also looked for and noted less-effective and counterproductive techniques. We then compared observations with one another to compile the observed techniques and to construct a self-reflection rubric the participants could use in evaluating the videos of interviews they and their partners conducted (Appendix). We included elements in the rubric if they were observed by more than one of the authors as they conducted video analysis. As elements for the rubric were identified, we collaboratively refined the language to describe each element so that it would be broad enough to describe multiple cases, yet specific enough to draw readers' attention toward the particular issue or technique at stake. We organised the rubric into four categories, which were reflective of the four earlier-described types of challenges teachers often have in learning to conduct clinical interviews: building relationships, posing interview tasks, asking probing questions, and maintaining a stance of inquiry. Although we remained open to identifying challenges not fitting these four categories as we analysed interview videos, we did not find any that fell outside the four that would require us to add to the categories.

Step 2: Reflecting on pre-assessment interviews

Before conducting post-assessment interviews, each participant used the rubric we constructed to evaluate the videos of her pre-assessment interviews as well as those of her partner. This was done to help engage participants in idea suspension and problem creation, which involves conducting a careful analysis of the initial experiential event. The rubric prompted them to identify productive and unproductive techniques they observed by time-stamping occurrences in the videos. The rubric incorporated the constructs of funnelling and focusing discourse (Wood, 1998) and cognitive demand (Henningsen & Stein, 1997) because in some instances we observed participants use highly leading questions or alter tasks in a manner that minimised students' opportunities to exhibit mathematical thinking. To help participants understand the difference between questioning patterns that funnel students toward a pre-determined response and those that probe students' thinking, we had them act out one classroom situation involving a funnelling pattern of discourse and a parallel situation in which the teacher genuinely elicited student thinking (Herbel-Eisenmann & Breyfogle, 2005). To help them understand varying levels of cognitive demand reflected in tasks, we had them complete a task-sorting activity in which they classified tasks into levels and compared their classifications with one another (Smith & Stein, 1998). Both activities were completed before participants used the rubric to analyse video from the first round of interviews.

Step 3: Planning changes

Two writing prompts were posed to help participants reflect on the techniques they observed while watching pre-assessment interview videos:

- After watching this interview, I believe that the interviewer should adopt the following techniques to improve the second round of interviews. Address techniques from each of the four aspects above and explain your reasoning.
- After watching this interview, I believe that the interviewer should avoid the following techniques in order to improve the second round of interviews. Address techniques from each of the four aspects above and explain your reasoning.

In accord with the notion of process reflection, the two prompts required participants to reflect not just for the sake of thinking about what they had done, but also to make conjectures about how to improve their interviewing techniques (i.e., to engage in idea formation). After completing the rubrics and accompanying writing prompts for their own interviews and for their partners' interviews, partners had a debriefing session during which they shared their observations and conjectured improvements with one another.

Step 4: Post-assessment interviews

Next, participants engaged in idea testing by conducting and video recording the post-assessment interviews. This provided an opportunity to refine their techniques from the pre-assessment interviews and observe the effectiveness of the techniques for eliciting children's thinking. After conducting the post-assessment interviews, participants were given two additional writing prompts:

- In what ways do you believe you improved the most in your clinical interviewing techniques from the first round of interviews to the second round of interviews? Please explain.
- In what ways do you believe you can still improve in your clinical interviewing techniques? What would you do differently in terms of interviewing techniques next time you conduct a clinical interview? Please explain.

These two prompts framed the post-assessment interviews as experiential events for the beginning of a new cycle of process reflection. Although time was not available to engage in an additional cycle of process reflection, the prompts helped portray the development of effective interview techniques as an ongoing process rather than one with a set endpoint.

Data Gathering and Analysis

In all, 16 interviews were conducted and video recorded (8 pre-assessments and 8 post-assessments). To complement the videos, we gathered data from various sources to facilitate cross-checking (Bogdan & Bicklen, 2007; Patton, 2002) during data analysis: participants' written work and discussion comments from the initial online interview preparation activities, interview transcripts generated by participants, interviewer written notes, children's written work from interviews, participants' responses to writing prompts on the constructs of funnelling and focusing, peer and self-assessments of pre-assessment interview videos, and participants' responses to the writing prompts completed after the post-assessment interviews.

Each interview was re-constructed by using the video while simultaneously attending to the child's written work, the interviewer notes, and the interview transcript. The rubric we constructed and refined during our initial viewings of the interviews was used to identify and document significant interviewer behaviours observed. A time-ordered matrix (Miles & Huberman, 1994) was then used to summarise interviewer behaviours observed during each

participant's first pre-assessment interview, second pre-assessment interview, first post-assessment interview, and second post-assessment interview (Figure 2). The time-ordered matrix for each participant also contained columns to summarise conjectures for the underlying causes of interviewer behaviours observed during the pre-assessment and post-assessment phases. The cells in these two columns were populated by looking to participants' self-evaluations and peer evaluations of interviews, their work during the initial online interview preparation activities, responses to writing prompts about funnelling and focusing, and responses to writing prompts completed after the post-assessment interviews. Drawing upon these data sources allowed us to generate empirically grounded conjectures (Corbin & Strauss, 2008) about the underlying reasons for participants' selection and implementation of observed interview techniques. The time-ordered matrices were used to generate outlines for individual narratives (Bernard & Ryan, 2010; Yin, 2003) explaining how and why each participant improved in her clinical interview techniques, regressed, or stayed the same. These individual narratives are presented in the next section.

	Pre-assessment interview 1 behaviours	Pre-assessment interview 2 behaviours	Possible causes of pre-assessment interview behaviours	Post-assessment interview 1 behaviours	Post-assessment interview 2 behaviours	Possible causes of post-assessment interview behaviours
Relationship-building moves						
Modifications to initial interview script						
Interviewer's probing questions						
Interviewer stance						
Other						

Figure 2. Time-ordered matrix used to construct outlines for participant narratives.

Results

The following narratives illustrate changes participants were able to make in their clinical interview techniques as well as techniques that were resistant to change. All of the claims and examples provided in each narrative are drawn from the video and written data gathered during the study and summarised in the earlier-described time-ordered matrix (Figure 2). In the following narratives, commonalities and differences among participants' experiences are described alongside salient learning themes for each individual. These individual themes are learning to: press for explanations, relinquish control, improve quantity and quality of probing questions, and deviate from script.

Veronica: Learning to Press for Explanations

At the outset of each pre- and post-interview, Veronica attended to making students comfortable by engaging in informal conversations about students' personal interests, backgrounds and things they had done over the summer. As each interview progressed, she interjected acknowledgements of student effort such as "you are doing a great job" and "I think you are working really hard." Veronica also believed it to be important to help students understand the purpose of the interview at the outset. During her pre-assessment interviews, she explained to

one student that the purpose of the interview was to "see what you know so that I can help." When she failed to give the same explanation at the outset of her second pre-interview, she noted it in her self-reflection and subsequently provided an explanation of the purpose to each student at the outset of each post-assessment interview.

As each pre-assessment interview progressed, Veronica used probing questions inconsistently. On one occasion, when she asked a student why two fractions were equivalent, the student responded, "Because they are the same." The interviewer and child both laughed at that point (regarding "equivalent" and "the same" as synonyms), and Veronica followed up by asking "How do you know they are they the same?" When the child was not able to clarify further, Veronica responded by saying, "Let's move on" rather than trying to understand the underlying reasons for the difficulty. In some cases when children failed to make progress on a task, Veronica used probes in a manner that funnelled them toward a desired response. For example, one interview question showed a large rectangle partitioned into six equal-size squares. Three of the squares where shaded in. One student claimed that the fraction represented three-sixths. As part of the interview protocol, Veronica followed up by asking if the fraction could be written in another way. When the child responded that it could only be written as three-sixths, Veronica asked, "Could you also call it one-half?" The child responded "yes," and Veronica moved on to the next item. For another interview item, students were asked if it would be fair to charge the same amount of money for slices of cake depicted in four cake diagrams. In some of the cakes, the pieces were the same size, and in others they were not. In both of the pre-interviews she conducted, Veronica settled for "yes" or "no" responses and did not ask students to explain.

Veronica' use of probing questions changed during the second round of interviews. In analysing her performance during the pre-assessment interviews, she wrote that she needed to avoid accepting "because" as an explanation from students and that she needed to ask students how they obtained their answers, whether correct or incorrect. Veronica also recognised cases where she had funnelled students toward desired responses and wrote that she wanted to avoid doing so in the future. In conducting the post-assessment interviews, she was able to act on these reflections. She asked students to explain their responses to the cake problem on which she accepted simple "yes" or "no" answers during pre-assessment interviews. Additionally, the following exchange with a student is indicative of how she began to probe in a manner that flowed naturally from a conversation about a task:

Veronica: What other way could you write that (pointing to a rectangle diagram the student has already labelled "one-sixth")
Monique: You can write it as…uh, I don't know
Veronica: You don't know? How could we figure it out?
Monique: By counting it?
Veronica: Counting it? How would you count it? What do you mean?

Monique then counted the unshaded squares in the diagram and considered re-writing the fraction as five-sixths before deciding against the idea. Veronica' probes in this case helped focus Monique on the task without funnelling her toward a desired response. On two occasions during post-interviews that Veronica did begin to funnel students, she stopped herself. For instance, when a student struggled to represent a fraction, Veronica began to construct a representation for her, but then stopped in mid-course and re-directed the task to the student.

Although substantive changes were apparent in Veronica' use of probing questions during post-assessment interviews, on some occasions further questioning would have been desirable, as in the following exchange with Monique:

Veronica: What other way could you write that? (pointing to a rectangle diagram the student had already labelled to be three-sixths)
Monique: You could write it as two-fourths, six-eighths…not six-eighths, six-twelfths

Veronica: Six-twelfths?
Monique: You can write it as four-eighths, everything that's half.

From this exchange, it was not apparent if Monique was using conceptual or procedural reasoning to produce equivalent fractions. Further probing could have revealed if she was using a procedure to generate equivalent fractions or if she was reasoning visually from the diagram.

Linda: Learning to Relinquish Control

Linda began her pre-assessment interviews by giving students directions on how to complete the items and then immediately began asking the interview questions. No appreciable differences occurred as she set up the post-assessment interviews. At the outset of each post-assessment interview, the directions were slightly expanded because paper strips were made available for students to fold as they reasoned about fractions. Linda mentioned this new tool to students during the post-assessment interviews, but did not explain the purpose of the interview to the children at any point. The failure to address purpose was somewhat surprising in light of the fact that the need to do so came up in the reflections on her pre-assessment interviews. As each interview progressed, Linda maintained a friendly demeanour with students, encouraging them when they believed they answered tasks incorrectly.

Linda's questioning patterns differed appreciably from the first round of interviews to the second. During the pre-assessment interviews, she omitted some of the more difficult tasks in the script, despite having more than enough time to pose them (each of her first round interviews took approximately 10-12 minutes of the 30 minutes allocated). During the post-assessment interviews, she gave children the opportunity to respond to each task. After posing tasks during pre-assessment interviews, Linda did not ask for explanations of thinking beyond the generic probes built into the script (e.g., "how" and "why" questions). Linda did, however, begin to form some of her own probing questions to prompt children to clarify their thinking in post-assessment interviews, even though she did so inconsistently. The change in questioning patterns may have occurred because of the observed need to probe students' thinking more deeply when reflecting on the pre-interviews.

Linda's most noticeable changes between the first and second rounds of interviews were in the stance she took as an interviewer. During the first round of interviews, she engaged in dominant funnelling, immediately telling students when their answers were correct (not asking students to explain their thinking upon arriving at a correct response), and even explaining some of the interview tasks on her own rather than letting the student explain. The following pre-interview excerpt is illustrative, in which the interviewer was just to show the student a number line with the fraction three-fourths marked and ask the student to produce an equivalent fraction:

Linda: First of all, how many parts are in this number line? (pointing to each of the hash marks between zero and one)
Monique: Five…uh, I mean four
Linda: OK, so where is the dot located?
Monique: It's on the third one.
Linda: OK, so what would you make a fraction to show what this means? How do you think you would write it?
Monique: I would say one-third of it.
Linda: So, if we have one, two, three (pointing to hash marks while counting), the dot is at number three and there are four parts altogether…it would be…what do you think it would be?

Linda persisted in funnelling the student through the task, asking for a series of short responses until the correct answer was given. She noticed this behaviour while reflecting on her interviews,

stating, "It was extremely difficult for me to remain neutral in this process. I attempted to guide the students toward the correct answers without actually telling them what to write."

During the post-assessment interviews, Linda did not engage in overt funnelling. She did, however, on occasion do more subtle funnelling. For example, she suggested that students use the paper strips that were available to produce fractions for some of the tasks. She did refrain, however, from funnelling them in a desired direction with short, leading questions, as in the first round of interviews. Linda's reflections on the second round of interviews help explain her changes in behaviour. She wrote,

> Upon completing the program and administering the post-assessment, I realized that it was now much easier to permit the students to use the knowledge they had acquired over the summer, without actually steering them in the direction of the correct answers. Instead of asking these leading questions, I had learned to now offer neutral cues for the students to think back to what they had learned and in turn complete their work without assistance from a teacher.

Although she was able to relinquish leading questions during the second round of interviews, she still felt an obligation to offer "cues" to help students "think back." Her second-round cues were simply more subtle; in addition to the suggestion of using paper strips for fraction problems, she tended to ask for student explanations more consistently for wrong answers than for right ones (though in some cases she did begin to ask for explanations of correct answers as well).

Rachel: Learning to Improve Quantity and Quality of Probing Questions

Rachel's introductory remarks to children during each interview were brief and focused mainly on describing what was to happen during the interview. During the pre-assessment interviews, she told children to feel free to talk through anything that was confusing, to use the scrap paper provided, and to expect the interview to last about one-half hour. She alluded to the purpose of the interview only briefly during the first post-assessment interview she conducted, telling the child to recall what she had learned during the past several weeks so the interviewer could "see how she did." The introduction to her other post-assessment interview consisted only of a statement that the student's response would not be graded. Rachel's lack of attention to explaining the purpose of the post-assessment interviews was somewhat inconsistent with her reflections on the pre-assessment interviews, where she noted that she needed to "emphasise that the interview is geared more towards learning about student thinking." She did, however, act consistently with her belief that she should "make sure the student feels as comfortable as possible during the interview process" by trying to prevent anxiety about incorrect responses and by interjecting encouragements (e.g., "cool" and "awesome") after students' responses.

During both rounds of interviews, Rachel demonstrated the ability to respond to students' questions about tasks without lowering the level of cognitive demand. One example of this occurred on a task that asked students to compare data for heights of eight-year-olds to those of ten-year-olds. One of the questions in the interview script was, "What would you say is the typical number of inches of growth from age eight to age ten?" (Common Core State Standards Writing Team, 2011). When DuJuan said he did not understand the question, Rachel said, "From looking at this graph, how much would you say students grow from age 8 to age 10?" This slight re-phrasing kept the task intact and allowed the student to begin to formulate a response. However, Rachel was not consistent in maintaining level of task demand. In the pre-assessment interviews, she funnelled both students through a question requiring them to choose an appropriate graph to represent a problem situation. In the post-assessment interviews, she tended to funnel students on items requiring them to identify typical values in distributions. In one such item, students were to describe the centre of a distribution of puppy weights. When Shonice gave a range of values to capture the central cluster of data, Rachel suggested that she find a single

value to describe the centre. This prompted Shonice to estimate the median value of the distribution. This estimate set her up to respond quickly to the next question in the protocol, which asked for the typical value in the distribution. Hence, although Rachel avoided lowering the level of cognitive demand and funnelling on some occasions, leading students toward desired responses persisted as part of her agenda as an interviewer. This was also apparent in her final reflections, as she expressed a desire to improve as an interviewer by helping students "catch their own mistakes as well as develop greater understanding while solving the problem."

After reflecting on her first round of interviews, Rachel added to the types of probing questions she asked during the second round. During the pre-interviews, she did not ask students to explain the meanings of graphical representations they produced. During the post-interviews, she did so by asking one student to explain the meaning of the individual dots in a dot plot and by asking another to explain what the numbers on the scale of a bar graph represented. Rachel also consistently asked students to justify their responses during the second round of interviews; during the first round she had missed opportunities to do so. Another adjustment she made during the second round of interviews was to probe for multiple solutions after students had given just one. In one task, for example, students were asked to describe differences between two distributions represented with dot plots. In the second round of interviews, she asked students for additional thoughts after they described one difference between the two distributions.

Although the quantity of Rachel's probing questions increased during the second round of interviews, there were times that she did not probe to the fullest extent when engaging students in dialogue. In one such instance during the second round of interviews, the following exchange occurred:

Rachel: So, what do you think would be typical? (referring to an item that required identifying the typical birth weight for a group of puppies)
Joseph: (examining a dot plot he had produced) One.
Rachel: One what? The typical weight would be one?
Joseph: Yeah.
Rachel: OK, why do you think it would be one?
Joseph: Because most of the puppies are one…wait, 13, yeah, 13
Rachel: 13? So how many puppies are 13?
Joseph: 5
Rachel: 5? OK. Flip it over to the next question.

Joseph's choices of one and thirteen as typical values were puzzling, as neither value corresponded to the mean, median, or mode of the distribution. Instances like this, where student thinking remained unclear, occurred during both rounds of interviews Rachel conducted. Hence, improving the quality of her spontaneous probes proved to be more of a challenge than simply adding new types of probes to her repertoire.

Shantel: Learning to Deviate from the Script

At the outset of each pre-assessment interview Shantel conducted, she conversed informally with children about topics such as where they went to school and which sports they enjoyed. Immediately after doing so, she started reading tasks for students to solve without explaining the purpose of the interview itself. As students worked, she occasionally interjected encouragements such as "you are doing very well" after they provided a response to a task. Making students feel at ease appeared to be a high priority for her, as in her self-reflections she noted that she made attempts to get to know the students and to let them know that they were doing a "great job." Shantel did not realise that she had failed to help students understand the purpose of the interview. When asked to reflect on that aspect of the interviewing process, she noted that she

told students they would be doing an interview and that they should do their best on each question. She appeared to confuse the giving of directions (what students should do during the interview) with establishing the purpose of the interview (to learn as much as possible about the children's mathematical thinking).

Shantel put a high priority on creating the appearance of objectivity during each pre-assessment interview. Her verbal and non-verbal language were largely neutral throughout the interviews, and she criticised herself during self-reflection on letting down her façade on one occasion by pronouncing the word "so" in a manner that seemed to suggest to a student that his answer was incorrect. Shantel took the pursuit of objectivity to such an extreme that it hampered her ability to probe students' thinking. She essentially read the questions as they stood on the interview protocol without injecting any of her own. As a result, she missed opportunities to elicit multiple solution strategies when appropriate, to ask students to explain their thinking further when it was unclear, and to get students to think aloud during long periods of silence. For example, Shantel had the following exchange with Shonice:

Shantel: (After asking the student to look at a graphical display of children's heights) What would you choose as the typical height of an eight-year-old?

Shonice: 53

Shantel: OK, and why do you say 53? (The protocol prompted the interviewer to ask "why" at this point).

Shonice: Because it's the one that's the farthest, and then I went down and it was in the middle. So I counted where it was in the middle, and their height was 53.

Shantel then went on to the next question in the script. Shonice's thinking was, however, still in need of clarification. She referred to 53 as being "in the middle," but it was actually the highest value in the data set. Spontaneous probing could have explored this seeming contradiction.

Several missed opportunities for spontaneous probing also occurred during post-assessment interviews, but the most striking difference in Shantel's behaviour during the post-assessment interviews was her willingness to deviate from the interview script. At times, her changes to the script resulted in lowering the quality of tasks. For example, one interview item asked students to produce a graph of their choosing and then describe its shape, centre, and variability. Shantel was satisfied after students had done the procedural step of producing a graph, and did not ask them to use their graphs to describe the characteristics of the distribution. Her primary concern in other items appeared to be related to students' procedural knowledge as well. When one student identified the most frequently occurring value as the typical value for the data set, Shantel asked, "Is there a name for that?" (trying to funnel the student toward saying "mode") rather than asking them why they chose that particular value to be typical. In other instances, Shantel's deviations from the interview script were more beneficial. For example, when reflecting on the first round of interviews, she noticed there were long periods of silence during which students were working and she could have asked them to think aloud. She took advantage of those opportunities during the second round to ask students what kinds of graphs they were producing as they worked. Although she missed the chance to prompt students to explain why they chose to make the graphs they did, Shantel at least began the process of asking spontaneous probes in response to students' observed behaviour.

Discussion

The accounts of Veronica, Linda, Rachel, and Shantel reveal interview techniques that were amenable to change as well as those that were resistant. These techniques can be discussed in terms of four categories: (i) preparing children cognitively and affectively for an interview, (ii)

transitioning from teacher to interviewer, (iii) transitioning from objective researcher to active participant, (iii) increasing quantity and quality of probing questions. Interview techniques related to each category are discussed in turn below. Each category elaborates upon specific aspects of the four general challenges in developing interview techniques described earlier: building relationships, posing interview tasks, asking probing questions, and maintaining a stance of inquiry.

Techniques that were resistant to change are of special interest in the following discussion because they suggest points at which the process reflection model used for the study (Figure 1) might be refined and strengthened. Hence, potential revisions to the process reflection model employed are considered as well, as these may be useful to others seeking to use elements of the model or extend it for use in other settings.

Cognitive and Affective Preparation

Cognitive and affective preparations are both important in establishing a relationship with a child in the context of a clinical interview (Dunphy, 2010; Hunting, 1997). In some cases, participants made efforts along both fronts, but in others one or both aspects were neglected. Veronica, for example, was conscious of informing children of the purpose of the interview (cognitive preparation) and putting them at ease (affective preparation). She was aware of the importance of both types of preparation during both pre-assessment and post-assessment interviews. Linda, on the other hand, plunged directly into the interview script during both rounds of interviews without attempting to prepare children in either regard. Shantel and Rachel made attempts at affective preparation but seemed to confuse the activity of giving directions with helping children understand the purpose of the interview. Appreciable differences in cognitive and affective preparation efforts between pre-assessment and post-assessment interviews were difficult to detect for each of the four prospective teachers.

The participants' experiences setting up interviews indicate a need to attend more explicitly to helping interviewers set the stage. Although prospective teachers in this study were asked to reflect upon the effectiveness of their setup from the first round of interviews, additional measures appear to be necessary. It may be helpful, for instance, to have new interviewers watch videos illustrating effective and less effective techniques for starting interviews. They might be asked to comment on and discuss the affective and cognitive moves made by interviewers in the videos. Additional scaffolding of this nature appears to be necessary to help some interviewers develop skill in initiating interviews with children.

Teacher vs. Interviewer Stance

Results of the study confirm previous findings that it can be difficult for teachers to avoid guiding children rather than assessing their thinking during clinical interviews (Ellemor-Collins & Wright, 2008; Heng & Sudarshan, 2013; Moyer & Milewicz, 2002). All four participants at some point attempted to guide children in a desired direction. Such guidance sometimes consisted of subtle cues and other times overt leading questions. The tendency to want to guide children to produce correct answers was stronger in some participants than others, but was something all participants had to contend with to a degree.

The incorporation of the constructs of cognitive demand (Henningsen & Stein, 1997) and funnelling and focusing discourse (Wood, 1998) appeared to be helpful in moving participants toward the role of interviewer rather than teacher. Linda, in particular, showed noticeable growth in avoiding funnelling students toward desired answers. This growth occurred after she reflected on her first round of interviews in light of having studied the constructs of funnelling and focusing. Veronica also showed growth along this dimension after reflecting on her first round

of interviews, though her use of funnelling during the first round was not as pronounced as Linda's. Rachel's use of funnelling did not change appreciably from the first round to the second, though at the end of the second round she noted that she still needed to work on avoiding funnelling behaviours and lowering cognitive demand. Since she set these as goals for improvement, additional cycles of process reflection would likely be of value to her in continuing to refine her interviewer stance.

Refining one's stance during interviews is of particular importance because it can also carry over into one's teaching. Teachers' pedagogical approaches can be enhanced by incorporating questioning techniques used during clinical interviews (Hunting, 1997; Moyer & Milewicz, 2002). Adopting interview-like questions in the classroom can encourage a shift in focus from determining if students' thinking is "right" or "wrong" to probing the limits of student understanding and exploring underlying causes of "incorrect" answers (Ellemor-Collins & Wright, 2008; Goldin, 2000). As teachers become skilled in using such questioning techniques, they develop a pedagogy of listening (Rinaldi, 2005), which entails continuously eliciting students' mathematical thinking and using what is learned to advise instruction (Dunphy, 2010). Using classroom questions to inform teaching in this manner is at the heart of formative assessment, which is essential for fostering students' mathematical learning (Wiliam, 2007).

Objective Researcher vs. Active Participant

Clinical interviews are of little more value than written assessments if interviewers do not take advantage of emergent opportunities to probe children's thinking (Labinowicz, 1985). Shantel's case most clearly illustrates dynamics involved in moving from an objective, detached stance to an active one. During the first round of interviews she conducted, she read the interview script almost verbatim. During the second round, she made fairly substantive changes to the script. In some cases, the changes were productive, such as her introduction of questions to ask students to explain their thinking during periods of silence. In other cases, Shantel's changes limited what could be learned about children's thinking, as when she omitted questions that pressed students to explain their thinking or to engage in higher levels of cognitive demand.

Shantel's experience suggests the importance of helping interviewers explicitly attend to both beneficial and harmful changes to an interview protocol. From the first round of interviews to the second, she learned of the need to go "off-script" at times, but was still working to understand how and when such moves should occur. Certainly, additional cycles of process reflection may be helpful in sorting through such issues. Additional cycles of reflection may be of no use, however, if reflection and analysis during these cycles is not grounded in appropriate guiding principles. Shantel, for example, still seemingly needed to realise that alterations from the script should serve to reveal students' conceptual understanding rather than just procedural skill. Establishing this principle more firmly may help additional cycles of process reflection yield more robust results.

Quantity and Quality of Probes

Although having guiding principles in place for what one wishes to accomplish as an interviewer is essential, it does not automatically furnish the ability to act on the principles in the interview environment. In particular, interviewers must develop the ability to formulate skilful probing questions (Moyer & Milewicz, 2002) aligned with their guiding principles in response to unexpected or unclear responses from children. The process reflection model described in this report helped participants recognise the need to probe students' thinking and increase the quantity of probing questions asked during interviews. However, developing the ability to

formulate quality spontaneous probes to deeply probe children's thinking about unexpected responses proved to be more elusive.

Cognitive processes involved in developing effective spontaneous probes are worthy of more careful, focused study. It seems likely that knowledge of content and students (KCS) (Ball, Thames, & Phelps, 2008) plays a role in the formulation of spontaneous probes. Well-developed KCS provides a means for formulating conjectures about why a child responded to a task in a given manner. However, this is not to say that KCS is necessarily a pre-requisite for engaging in the sort of process reflection described in this manuscript. Conducting interviews can be a productive platform for developing KCS because of the firsthand opportunities it furnishes to observe children's thinking (Jenkins, 2010). Rather than making a certain level of KCS a pre-requisite for conducting interviews, teacher educators might instead view video of interviews alongside novice interviewers, pausing the video when necessary to offer suggestions about specific spontaneous questions that could have been asked to gain better understanding of children's thinking. Such an arrangement allows for the development of KCS and interviewing techniques in tandem, and hence appears to be a viable refinement to test within the process reflection framework.

The potential for prospective and practicing teachers to develop KCS during clinical interviews is perhaps the most compelling reason to continue the investigation of ways to improve their clinical interviewing techniques. Jenkins (2010) observed that clinical interviews provide unique settings for firsthand acquisition of KCS, since they afford opportunities to explore students' mathematical thinking in real-time. Opportunities to develop KCS in this manner are powerful, as teachers may value firsthand experiences with children more than learning about children's mathematical thinking in the context of a traditional academic course (McDonough et al., 2002). As teachers develop more sophisticated KCS, they begin to realise that children's thinking often differs from their own and hence overcome egocentrism (Ginsburg, 2009). This ability to "de-centre" and view mathematics from children's perspectives facilitates the development of pedagogically powerful ideas (Silverman & Thompson, 2008).

Conclusion

A great deal of literature suggests that conducting clinical interviews is a valuable activity for prospective and practicing teachers. However, researchers are still in the process of learning about the intricacies of learning clinical interview techniques. The present study describes how such learning may occur for prospective teachers within the context of a process reflection framework. The framework offers tools and strategies to scaffold beginning interviewers' techniques. The empirical accounts of individuals' learning within the framework suggest potential areas for its improvement. Further testing of the framework can help contribute to its refinement and our understanding of the acquisition of clinical interviewing techniques. Such testing can also illuminate principles that are generalisable beyond the four participants in this study. As we become more familiar with teachers' learning in this area, we can better support their endeavours to develop KCS during firsthand interactions with children.

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Appendix: A Guide for Reflecting on Clinical Interviewing Techniques

Instructions: Use the tables below to evaluate the clinical interviews that you conducted as well as the interviews your partner conducted. The tables guide you to examine four aspects of the clinical interviewing process. For each example of a productive or unproductive move you find, provide a time stamp that gives the corresponding beginning and end time in the interview video.

Name of interviewer: _____

Name of child being interviewed: _____

Aspect 1: Relationship-Building Moves

Productive Moves	Examples from Interview (provide time stamps)	Unproductive Moves	Examples from Interview (provide time stamps)
The interviewer attempts to put the student at ease about the interview.		The interviewer jumps immediately into asking mathematical tasks.	
The interviewer explains that the purpose of the interview is to learn as much as possible about the student's thinking.		The interviewer sets the student up to get the right answer to the task rather than respectfully listening to student thinking.	
The interviewer verbally acknowledges student effort during the interview.		The interviewer conveys negative messages about mathematics to students.	

Aspect 2: Modifications to Initial Interview Script

Productive Moves	Examples from Interview (provide time stamps)	Unproductive Moves	Examples from Interview (provide time stamps)
The interviewer keeps the *cognitive demand* of the task intact when responding to students' questions about the interview items.		The interviewer re-words a question to lower the level of *cognitive demand* at the outset.	
The interviewer adapts a question in the script to be responsive to student thinking and keeps the objective of the question intact.		The interviewer re-words a question in an awkward, confusing, or inaccurate way.	

Aspect 3: Interviewer's Probing Questions

Productive Moves	Examples from Interview (provide time stamps)	Unproductive Moves	Examples from Interview (provide time stamps)
The interviewer's probing questions are understandable to the student.		The interviewer's probing questions are awkward or confusing.	
The interviewer probes further when a student's reasoning about a task is not completely clear.		The interviewer fails to probe further when a student's response is in need of explanation.	
The interviewer asks students to explain the meanings of representations they have produced.		The interviewer misses chances to elicit multiple solution strategies when multiple solution strategies are possible.	
The interviewer's probing questions keep students focused on the task.		The interviewer's probing questions lead student away from the purpose of the task.	
The interviewer's probing questions prompt students to make their thinking explicit.		The student is silent for extended periods and the interviewer does not probe thinking.	

Aspect 4: Interviewer Stance

Productive Moves	Examples from Interview (provide time stamps)	Unproductive Moves	Examples from Interview (provide time stamps)
The interviewer adopts the stance of learning from the student, eliciting the student's thought process.		The interviewer imposes a way of thinking on the student rather than trying to elicit the student's thinking. This might involve funneling questions.	
The interviewer allows sufficient wait-time for students to think about tasks.		The interviewer allows insufficient wait-time, prematurely ending a student's time to think.	
The interviewer's voice inflection, body language, verbal language, or non-verbal communication is neutral and encourages students to explain their mathematical thinking.		The interviewer's voice inflection, body language, verbal language, or non-verbal communication implies that a student's answer is correct or incorrect.	

Final Reflection Prompts – complete each of the following statements

1. After watching this interview, I believe that the interviewer should adopt the following techniques to improve the second round of interviews. Address techniques from each of the four aspects above and explain your reasoning.
2. After watching this interview, I believe that the interviewer should avoid the following techniques in order to improve the second round of interviews. Address techniques from each of the four aspects above and explain your reasoning.

Reflection to be completed after conducting second round of clinical interviews:

1. In what ways did you improve the most in your clinical interviewing techniques from the first round of interviews to the second round of interviews? Please explain.
2. In what ways do you believe you still can improve your clinical interviewing techniques? Please explain.

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