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LEARNING TO QUESTION: CATEGORIES OF QUESTIONING USED BY PRESERVICE TEACHERS DURING DIAGNOSTIC MATHEMATICS INTERVIEWS

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ABSTRACT

Developing appropriate questioning techniques is an important part of mathematics teaching and assessment. This study examined the questioning strategies used by 48 preservice teachers during one-on-one diagnostic mathematics interviews with children. Each participant conducted an audiotaped interview with one child, followed by an analysis and reflection of the interview. Data were analyzed to develop general categories of questions used by the preservice teachers. These categories included: 1) checklisting, 2) instructing rather than assessing, and 3) probing and follow-up questions. The analyses and reflections completed by preservice teachers indicated that using the diagnostic interview format allowed them to recognize and reflect on effective questioning techniques. Through an examination of these categories of questions, we offer suggestions for teaching the skill of mathematics questioning in preservice teacher education courses.

KEY WORDS

Questioning Techniques

Interviewing

Preservice Teacher Education

Mathematics Questions

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The kinds of knowledge children construct and communicate during a mathematics lesson may be prompted by teachers' questions. Teachers who can question effectively at various levels within the cognitive domain, such as knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom, 1956), are better able to discern the range and depth of children's thinking. A good question may mean the difference between constraining thinking and encouraging new ideas, and between recalling trivial facts and constructing meaning (Kamii & DeVries, 1978; Kamii & Warrington, 1999; Schwartz, 1996; Stone, 1993). Some researchers argue that a teacher's verbal behavior is a strong indicator of their total teaching behavior (Adams, 1994). Recent focus on the use of questioning in teaching mathematics (Carpenter, Fennema, Franke, Levi, & Empson, 1999, 2000; Mewborn & Huberty, 1999) supports the idea that a teacher's questioning strategies are pivotal to the instructional process because questioning is the most frequently used instructional tool (Wassermann, 1991). Developing appropriate questioning techniques is an important part of teaching and assessing mathematics. Much of the research on questioning techniques provides evidence of the types of questions used by classroom teachers (Buschman, 2001; Carpenter et al., 1999, 2000; Mewborn & Huberty, 1999). Fewer research studies document ways to support the development of questioning skills at the preservice level (Ralph, 1999a).

Although research in recent years has seen a surge of interest in the relationship between teacher questioning and children's thinking (Baroody & Ginsburg, 1990; Buschman, 2001; Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Fennema, Carpenter, Franke, & Carey, 1993; Fennema, Franke, Carpenter, & Carey, 1993), more than just an understanding of the child's knowledge can be gained from using questioning as an assessment. The diagnostic interview of a child (combining questioning and observation) can also provide a record of how interviewers select questions that probe children's

mathematical thinking. We propose that preservice teachers can benefit from these types of interactions with children by scrutinizing their own performance and reflecting on the questions they use in these interviews. After the interview, preservice teachers can reflect on why they use particular questions and use this self-reflection process to develop better questioning strategies. Few studies address ways to cultivate this fundamental skill in preservice teachers, and no research has categorized the types of questions that might be expected of these beginning teachers.

The purpose of this project was to (1) examine the questioning strategies used by preservice teachers during one-on-one diagnostic mathematics interviews with children and (2) engage the preservice teachers in an analysis of and reflection on their own questioning. We believed the preservice teachers would use a variety of questions during the interviews, ranging from basic factual questions to those questions that more deeply probed students' mathematical thinking. We also believed that guiding preservice teachers through an analysis of the questions they asked and the responses they received from children would enable them to recognize both effective and ineffective questioning throughout the interviews. In this paper we categorize and label the types of questions used by the preservice teachers during their mathematics interviews with the children. We propose that the use of these categories for discussion is an effective strategy for teaching the skill of mathematics questioning in preservice teacher education courses.

THEORETICAL PERSPECTIVE

The Interview

The use of alternative forms of assessment in mathematics, such as interviewing (a combination of questioning and observing), has grown in popularity as a result of the Standards movement and other calls for reform in mathematics education (Huinker, 1993; NCTM, 1991, 1995, 2000; Stenmark, 1991). Classroom teachers have used student interviews to guide and inform their own instruction in mathematics (Buschman, 2001). Teachers are encouraged to ask children questions in mathematics that help them to work together and make sense of mathematics; to learn to reason mathematically; to learn to

conjecture, invent, and solve problems; and to connect mathematics, its ideas and its applications (NCTM, 1991). Verbal interactions and performance-based assessments are seen as an important part of the mathematics teaching and learning process.

Historically, one-on-one diagnostic interviews are derived primarily from the clinical method of interviewing developed and perfected by Swiss psychologist Jean Piaget (1926, 1929) who used the interview technique to investigate the nature and extent of children's knowledge on a variety of topics, including mathematics. Interviews have also been used as an important means of diagnosing children's misconceptions and error patterns in computation (Ashlock, 2002). Posner and Gertzog (1982) identify the interview's chief goal as ascertaining "the nature and extent of an individual's knowledge about a particular domain by identifying the relevant conceptions he or she holds and the perceived relationships among those conceptions" (p. 195). As face-to-face meetings or conversations, interviews, by definition, rely on verbal communication as the primary means for eliciting this information from the interviewee.

Developing Effective Questioning Strategies

Typical interactions between teachers and students in mathematics classrooms in America are characterized by Stigler and Hiebert (1999) in their book The Teaching Gap. Their analysis of the cross-cultural Third International Mathematics and Science Study (TIMSS) research reveals that the "script" for teaching mathematics in the United States involves acquiring isolated skills through repeated practice (Stigler & Hiebert, 1999). The TIMSS videos also demonstrate teachers' rapid-fire questions that require one-word responses and the way in which "the nature and tone of teachers' questions often give away the answer…" (Stigler & Hiebert, 1999, p. 45). Developing effective questioning skills in mathematics classrooms requires shifting the practices and beliefs of the individuals engaged in those interactions. For that reason, some classroom teachers and university researchers are working collaboratively in action research projects studying how effective questioning techniques help teachers understand student thinking and guide classroom instruction (Buschman, 2001) and ways to develop these techniques in mathematics classrooms (Mewborn & Huberty, 1999).

Although seemingly a basic activity that requires little expertise, effective questioning in mathematics actually requires well-developed oral-questioning skills – in many cases, the same skills teachers must use during classroom interactions. Based on a synthesis of questioning research, Ralph (1999a, 1999b) proposes that these basic oral-questioning skills should include (among others) preparing important questions ahead of time, delivering questions clearly and concisely, posing questions to children that stimulate thought, and giving children enough time to think about and prepare an answer. As Mewborn & Huberty conclude from their classroom research on questioning, "Allowing children to explain their thinking takes more time than simply asking for one-word answers and telling children whether or not they are correct" (Mewborn & Huberty, 1999, p.245).

Research has shown that using the interactive structure of dialogue in teaching mathematics is difficult for preservice teachers (Nilssen, Gudmundsdottir, & Wangsmo-Cappelen, 1995). When open-ended questioning is used and there are many right answers, the learning environment becomes complex and less predictable as teachers attempt to interpret and understand children's responses. To do this effectively requires principled knowledge of mathematical concepts and an understanding of how students think and reason mathematically (Ball, 1991; Lampert, 1986; Leinhardt & Greeno, 1986; Ma, 1999). Whereas experienced teachers have a repertoire of easily accessible strategies and pedagogical content knowledge preservice teachers have difficulty interpreting and responding to unexpected answers from children (Nilssen et al., 1995).

Developing questioning skills can be an integral focus of preservice mathematics education coursework. The one-on-one diagnostic interview of a child offers an alternative staging area for practicing these skills, one that simultaneously duplicates the uncertainty of classroom interactions, focuses on the child's thinking, and forces preservice teachers to use questioning to get at that thinking. Just as providing a scripted lesson does not guarantee competent teaching, providing an interview protocol does not guarantee competence in questioning. While the interview protocol and the goal of the interview may be clear, preservice teachers cannot plan what the children will say. In the process of

interpreting and responding to unexpected answers, preservice teachers practice developing questions that take into account children's thinking.

Shifting Beliefs

Teacher education and professional development programs alike generally agree that underlying beliefs guide a teacher's adoption and use of instructional techniques. The CGI (Cognitively Guided Instruction) (Carpenter et al., 1999) Professional Development Program attempts to shift teachers' beliefs about children's mathematical thinking by demonstrating how children think mathematically and by encouraging teachers to invite, listen to, consider, and incorporate children's divergent solutions (Carpenter et al., 2000). Teachers in CGI classrooms who have not previously attended to their students' invented strategies "are often surprised at what students say and do," suggesting that these interactions impact teachers' underlying beliefs (Bowman, Bright, & Vacc, 1998).

A number of studies indicate that when mathematics teachers listen to and comprehend their students' thinking, they expand their understanding of mathematics, shift their beliefs about how it should be taught, and modify their teaching practices (Fennema & Carpenter, 1996). One study in particular determined that "a focus on children's thinking" and "considerable reflection on both one's beliefs and behavior" were instrumental in shifting preservice teachers' beliefs about mathematics instruction (Bright & Vacc, 1994, p. 10). Other research (Moyer & Moody, 1998) conducted on the use of preservice teacher-conducted interviews found the one-on-one interactions to be a useful strategy in understanding what children were thinking and shifting preservice teachers' beliefs about mathematics assessment in general.

Action research projects in classrooms have demonstrated that individual interviews with children make teachers more aware of what children know, help teachers understand how children learn mathematics, and influence teachers' instructional practices (Buschman, 2001). Although much of the research on questioning focuses on the inservice teacher, fewer studies document the questioning skills of the preservice teacher. We believe that the types of questions preservice teachers chose to use during

mathematics interviews are worthy of inquiry, and that these categories of questions can guide discussions on the development of questioning techniques. Having preservice teachers focus on the skill of questioning in a one-on-one diagnostic interview may be an effective starting point for developing the mathematics questioning skills they will use as future classroom teachers.

METHODOLOGY

Participants

This study occurred during the fall of one academic year. Participants were 48 elementary preservice teachers enrolled in a mathematics methods course in their senior year as undergraduates, prior to their final internship placement for teacher certification. The participants were both male (3) and female (45). Participants were told they would be audiotaped and that these audiotapes would be transcribed and used in a self-reflection of their questioning during the mathematics interviews.

Procedures

The preservice teachers conducted mathematics interviews with elementary children from local elementary schools. Rational numbers were chosen as the topic for the assessment interview assignment. The instructor selected a variety of fraction tasks developmentally appropriate for elementary children, and an interview protocol was developed using these tasks. The interview protocol included the following tasks: (1) use a region and a set model to show ½, 1/3, ¼, and ¾; (2) use a pictorial model (shapes and sets) to shade or draw ½, 1/3, ¼, and ¾; (3) express what you know about fractions in symbolic form; (4) examine different models of ½ and explain why all of the models are called "one-half"; and (5) use a drawing to show how to share a pizza. The region model uses a *region* (such as a circle, square, or rectangle) as the whole, and the parts of the region are congruent (same shape and size). The set model uses a *set of objects* as the whole, and the parts of the set are the individual objects (such as counters, buttons, or coins). The interview protocols included several suggested follow-up questions; however, preservice teachers were told that the main focus during the self-reflections would be on the types of questions they developed and used themselves during the interviews.

During one 3-hour class session, preservice teachers watched a video in which the instructor interviewed two second-grade children. During the video, follow-up questions used by the interviewer with the children were highlighted as specific examples of questions that would be appropriate for the responses given by the children. Following the viewing of the video, preservice teachers and the instructor discussed examples of questions that elicited the children's thinking and conceptual understanding about the tasks. The video was used to identify questions that probed children's thinking in several categories: 1) questions that helped children to make sense of mathematics (i.e., Can you explain to me why that makes sense?), 2) questions that helped children rely more on themselves to determine whether something was mathematically correct (i.e., How did you reach that conclusion?), 3) questions that helped children learn to reason mathematically (i.e., How could you prove that to me?), 4) questions that helped children to conjecture, invent and solve problems (i.e., What would happen if...?), and 5) questions that helped children to connect mathematics, its ideas, and its applications (i.e., Have we solved any problems like this one before?) (Reys, Suydam, Lindquist, & Smith, 1998, p. 45; Stenmark, 1991, pp. 31-32). These question categories were used by the preservice teachers when they conducted analyses of their own interviews. There was also discussion about ways to address a child's potential anxieties regarding the interview process (i.e., nervousness about being taped, fear of being graded, etc.) so that preservice teachers could hopefully prevent these anxieties from interfering with the interview. Each preservice teacher was assigned to a classroom placement during the time they were enrolled in the course and specific questions about children at different grade levels were also addressed during the class discussion.

Preservice teachers were given protocols, including specific tasks and sample questions, and were asked to select a child from their school placement with whom to conduct the interview. Some materials for the interview were provided (reproducible sheets of region models) but preservice teachers were required to obtain some additional materials on their own (e.g. counters). The children selected by the preservice teachers to participate in the mathematics assessment interviews were generally average to

above average students in terms of academics, as defined by the classroom teachers. There were 48 children ranging in age from 5 to 12, distributed among grades K-6 as follows: Kindergarten (6), Grade 1 (8), Grade 2 (10), Grade 3 (10), Grade 4 (5), Grade 5 (6), and Grade 6 (3).

The interviews were designed so that the number of tasks completed with follow-up questions would take approximately 20-30 minutes, depending on the responses of each child. The actual interviews varied in length from 10-60 minutes, with the age level of the child having no consistent effect on interview length. That is, one child in Kindergarten may have been interviewed for 10 minutes, while another was interviewed for 30 minutes, and yet another was interviewed for 50 minutes. The length of each interview was determined by the individual interviewers, regardless of the age of the child being interviewed.

Preservice teachers were encouraged to conduct several practice interviews before submitting their final interview for reflection. For the final interview, they audiotaped their interviews, recorded behaviors during the interviews, and collected student writings and drawings completed during the interviews. These materials were used to provide a holistic picture of the interactions that occurred between each preservice teacher and child during the interviews. Following the interviews, preservice teachers fully transcribed their audiotapes, conducted guided analyses of their own interviews and completed written reflections based on their questioning and interactions with the children during the interviews.

The procedures used in this research were those of a descriptive case study, which is useful in describing the details of an innovative practice (Merriam, 1988). This method of qualitative research was used to collect detailed information on a single phenomenon using a variety of sources for the purpose of explaining and evaluating the experience. It was important to the researchers to collect these data in a natural context and to include preservice teachers' verbatim comments and points of view.

The study used three sources of data: complete transcriptions of the audiotaped interviews, preservice teachers' written reflections of the interview process, and descriptive data on non-verbal

behaviors that occurred during the interview. The interview transcripts and the written reflections were read and coded separately by two independent readers using an interpretational analysis to examine the data for constructs, themes, and patterns that may be used to explain the questioning strategies of the preservice teachers during the interviews (Gall, Borg, & Gall, 1996). The researchers coded the themes using a modified constant comparative method (Strauss, 1987) that included an iterative process of reading and re-reading to identify categories and tagging preservice teachers' written reflections and interview transcripts. Analyses of the transcripts focused on preservice teachers' questions that were not a part of the interview protocol. Following the first phase of coding we clustered data segments around the most salient and recurring themes. These themes were organized into predominant categories of questioning strategies commonly used across the 48 interviews, and data were re-analyzed against these categories.

RESULTS: CATEGORIES OF QUESTIONS

Several patterns emerged in the interviewing verbalizations that seemed indicative of differences in questioning techniques. We categorized these verbalization patterns as (1) checklisting, where the interviewer proceeds from one question to the next with little regard for the child's response, which included (a) no follow-up questions, and (b) questions with verbal checkmarks; (2) instructing rather than assessing, which included (a) leading questions that direct the child's response, and (b) abandoning questioning and teaching the concept; and (3) probing and follow-up, where different types of questions were used to invite or further investigate the child's answer, which included (a) questioning only the incorrect response, (b) non-specific questioning, and (c) competent questioning. We acknowledge that there is a great deal of overlap among these categories and that interviewers frequently use more than one technique simultaneously within the same interview. In the following sections, we discuss examples and descriptions of these categories using verbatim quotes from transcripts of the audiotaped interviews (where "T" stands for the preservice teacher interviewer and "C" stands for the child interviewee) and preservice teachers' written reflection comments.

Checklisting

A common behavior of preservice teachers during interviews was "checklisting." The "checklisting" interviewer reads the questions on the interview protocol one after the other, relying on the script to direct the interview rather than acknowledging the responses of the child. No matter what answer the child gives, the interviewer simply moves on to the next question. In essence the interviewer appears to be listening, not to the child's thinking, but for a response which then allows the interview to continue. The resulting interview is often fast-paced, marked by a lack of follow-up questions, and frequently accompanied by verbal "checkmarks." Interviewer who used this questioning technique repeatedly often completed their interviews rapidly (in 10-15 minutes).

No follow-up questions. "Checklisting" interviews are characterized by the degree to which their strategy precludes the child from expounding on an answer. When interviewers ask no follow-up questions they risk obtaining no information about the child's mathematical thinking by not specifically inviting it. Several interviewers asked no follow-up questions of the children they interviewed. They simply read through the list of questions on the protocol, obtained an answer from the child, and moved on without probing the child's thinking, as in the following example.

T: What part is shaded and what part is not?

C: The left.

T: How much of it is shaded?

C: The whole.

T: How much is shaded in the circle?

C: Uh, half. (Grade 2, Interview 2, p. 1)

During one portion of the assessment interview, the interviewer presents a half square piece and a half circle piece and asks the child to explain why both are called half when they don't look alike. The purpose of this question is to assess the child's informal understanding of the concept of "half" even in the face of empirical evidence that seems to suggest that the two models are different. This idea requires

a generalization of the concept of half and requires children to explain their thinking. The interviewer should force the child to examine and defend his explanation. Here is how one interviewer handles the question:

T: If you have a circle and you halved it, how many pieces would you have?

C: Two.

T: What about the square?

C: Two.

T: Does it matter about the shape?

C: No.

T: Good. (Grade 6, Interview 1, p. 5)

Verbal checkmarks. In addition to its pace, checklisting may be distinguished by the interviewer's specific and repetitive use of verbal "checkmarks." These one- or two-word verbalizations, such as "OK," "Right," and "Good," indicate to the child that it is no longer necessary to continue thinking about the question because the question is completed, and therefore "checked off" the list. In essence a word or phrase becomes a verbal checkmark ending one task to begin another. The written reflections indicate that interviewers often recognized their use of these verbal checkmarks; as one preservice teacher commented, "I used the word OK to make transitions from question to question" (Grade 2, Interview 5, Reflection).

In the following exchange, "Good" becomes the verbal checkmark that ends a task and begins a new one. This example also shows how interviewers who are checklisting move rapidly from one question to the next, allowing little time for a complete response from the child. Notice how the child's responses are brief and how the interviewer gives the verbal signal before moving on to the next question.

T: You made how many pieces?

C: Two.

T: Good, good job. I have given you six counters. I want you to give me half and you keep half. [child moves counters] Good, how many counters are half?....

C: Three.

T: Good, because three plus three equals six, right? [child nods "yes"] Good job. (Grade 6, Interview 1, p. 5)

In the previous example, the verbal checkmark "good" signals that the interviewer is moving on to the next question. One preservice teacher recognized her checklisting behavior in her reflection, stating, "After listening to the interview, I noticed that I rewarded the student's correct responses by saying 'Good' or 'Very good'.... I feel I did this out of instinct for praise" (Grade 2, Interview 7, Reflection). These signal words end discussion of the question by indicating to the child that the interviewer is not waiting for any additional information.

During the questioning process, this child appears to recognize the rapid pace of the interview. At one point, when the interviewer proceeds too quickly, the child attempts to slow down the interview by asking the interviewer to "wait" for him.

T: OK, now with these squares can you show me 1/2 on this square right here? [child begins coloring the square] OK—

C: Wait, wait! [child is still working]

T: OK, on that second square right there…. (Grade 5, Interview 3, p. 2)

After a brief pause, the interviewer resumes the checklisting of tasks. Later, the child again asks the interviewer to slow down.

T: OK, now I am going to take these twelve counters right here and I want you to show me half, what would be half. [child moves counters] OK—

C: Wait! [child is still working] (Grade 5, Interview 3, p. 2)

For the child in this interview, the word "OK" has become a verbal checkmark—an indicator that the interviewer is moving to the next task and does not expect the child to think about or respond to the

previous question anymore. In this exchange, the word "OK" has specific meaning to the child: the child does not ask the interviewer to "Wait" because he has heard the next question; he asks the interviewer to wait as soon as he hears the interviewer's signal word, "OK." The interviewer proceeded through all the questions at this rapid pace, consistently saying "OK" after she finished one question and moved on to the next, for a total of 25 "OK"s in this brief 10-minute interview. Reflecting on this interview, the preservice teacher wrote, "The student may have felt a little rushed…. When I ask questions to students or anybody, I need to give them time to think and then respond. If I were to assess another student, I would slow down the pace of the interview a little bit" (Grade 5, Interview 3, pp. 4-5).

Instructing Rather than Assessing

Some preservice teachers attempted to instruct children during interviews instead of assessing their mathematical knowledge. In a variety of instances they used leading questions that directed the child's response or provided hints about the answer, or they simply abandoned the strategy of questioning and attempted to teach the concept by explaining or telling the solution.

Leading questions. The following preservice teachers use questioning strategies that are leading and in essence attempt to guide and prompt the child to the correct answer. This strategy results in a guessing game in which the child concentrates more on puzzling out what the interviewer is thinking rather than on explaining his/her own thinking. In one example, when the problem is to divide a square in half, the interviewer asks, "What were you trying to do? Give me *what* and you keep *what*?"; the child fills in the blanks: "I give you one and I take one" (Kindergarten, Interview 1, p. 11). Reflecting on her interview experience, this preservice teacher observed that "with the right questions… [the student] showed some knowledge of fractions"; she also noted that "to be an effective interviewer…you have to be ready to ask questions to prompt students" (Kindergarten, Interview 1, Reflection).

After coaching one child to the correct answer, this interviewer asks the child to explain his thinking: "So what did you have to think about to know that? You had to think about it as having *what*?" (Grade 1, Interview 4, p. 7). The interviewer then supplies an answer for the child, delivered in the form of a

question: “You had to think about that whole thing, the whole set, you had to think about it kind of being in four different groups and then you could take one of them...?” The child agrees— “Yes”—and the interviewer goes on to the next problem (Grade 1, Interview 4, p. 7). Some interviewers acknowledged their leading behaviors: “After hearing myself in the tape, I feel I may have spoon-fed a few answers to [the child] without realizing it” (Grade 2, Interview 3, Reflection).

Interviewers often presented answers as “yes or no” questions, cueing children by ending their questions with “right?” During an interview with a first-grader, this preservice teacher offers an elaborate leading explanation with which the child is encouraged to agree.

T: Okay, since we had these divided, I had them in three different rows and you knew that you had to have an equal amount in all three groups, right?

C: Yes, ma’am.

T: So is that what you were thinking?

C: Yes, ma’am. (Grade 1, Interview 4, p. 6)

Rather than persisting with questioning to extricate the child’s answer, interviewers who lead assume they know what the child is thinking, and in essence, attempt to verbalize this thinking *for* the child.

Teaching and telling. About one-fourth of the interviewers moved from questioning children to teaching the concepts rather than assessing the child’s level of knowledge on the topic, adopting a more directive and explanatory method of interacting with the child. Often “leading questions” and “teaching” worked together to provide answers for children rather than encouraging children to think or elaborate on a response.

Here is an example of an interviewer who leaves the role of questioner and takes over the role of problem-solver. When the child is unable to divide a drawing of a pizza equally among five people, the interviewer steps in. Confronted with the child’s confusion about how to solve the problem, the interviewer presents the solution for the child:

T: What if we didn't draw a line all the way down the middle. What if we just drew it to the half and made some equal pieces this way. Do you think that might work? See we could get more equal pieces if we didn't have to draw all the lines. We didn't have to draw straight down.... What if we did that? (Grade 4, Interview 4, p. 6)

Another interviewer asks the child to write, in numbers, what one-fourth looks like; when the child responds that the number would be "Five," the interviewer replies, "No. I just said to write one-fourth..." (Grade 1, Interview 8, p. 5). When the child writes "three plus four" for three-fourths, the interviewer stops questioning and begins teaching the child how to write fractions as numerals:

T: Ok, let me show you. Let me show you what I can write. I could write this—write right here—one over two and that would stand for one-half. I could one over three [sic] and that would stand for one-third, one over four and that would be one-fourth, and three over four, so it's a little bit different. (Grade 1, Interview 8, p. 5)

When asked to divide up two pizzas for five people so that each person will get the same amount, a sixth-grader divides one pizza into five pieces and the other pizza into six. After questioning the amount of pieces the child made for each pizza, the interviewer says, "Well, there are five people so you forgot that the two pizzas are going to have to be divide [sic] the same way. You have to distribute the pizza to all five people. Each person has to get the same amount" (Grade 6, Interview 1, p. 6). Having offered this reasoning to the child, the interviewer then returns to questioning the child's thinking about the solution. The child basically reiterates what the interviewer has told him was incorrect about his answer, supplying the explanation that the interviewer already gave.

Probing and Follow-up Questions

In contrast to the checklisting and instructing strategies, the use of probing and follow-up questions during an interview demonstrates the interviewer's greater attention to the child's thinking. While the checklister often asks no follow-up questions at all, the probing interviewer responds to the child's answer with another relevant question in an attempt to get the child to expound on the answer or think

about it further. Rather than signaling the end of the task, this strategy communicates to the child that the answer is still open for discussion. Yet not all probing and follow-up questions adequately or appropriately assess what the child is thinking. Follow-up and probing questioning in the mathematical interviews with children in this study included (1) questioning of only incorrect responses, (2) non-specific questioning, and (3) competent questioning that specifically and consistently probed a child's answer.

Questioning only the incorrect response. There were several instances where preservice teachers only questioned children when they gave an incorrect response; many did not use follow-up when a child's response was correct. This practice works with the assumption that because the child produced the correct answer, the child must understand the concept. In the following interaction, the interviewer probes only the child's incorrect response.

T: Where is the fraction circle that shows 1/3?

C: There. [child points to 1/3]

T: Good, what about 1/4?

C: [child points to 1/4]

T: Good, what about 3/4? Can you show me 3/4?

C: [child points to 1/8]

T: Is this 3/4? Eight pieces out of one?... If I give you this circle [fraction circle divided in fourths], can you show me 3/4 of it? (Grade 3, Interview 4, p. 1)

Using a probing question only when an incorrect response has been given limits the child to explaining only wrong answers, thus bypassing an opportunity for the child to articulate and defend accurate solution routes.

In another example, the interviewer moves rapidly through the questions until the child gives an incorrect response to the interviewer's question to show 1/3 of 12 counters:

T: Show me 3/4.

C: [child uses fraction circles to show 3/4]

T: Good, good job. Now with these 12 counters show me 1/2 of the counters.

C: [child shows 6 counters]

T: Show me 1/3.

C: Three? [child shows 3 counters]

T: You sure? Think about it. If you want to rearrange them, you can. (Grade 3, Interview 3, p. 1)

As in the previous exchange, the progression stops when the child gives an incorrect answer, and only then does the interviewer begin to question the child's thinking. As one interviewer reflected, "I learned that it sometimes helps to keep questioning to get an answer that you are looking for" (Grade 5, Interview 1, Reflection). For this preservice teacher, questioning was merely a means of getting the "right answer."

Non-specific questioning. Even those interviewers who consistently followed up children's answers often did so with questions that lacked specificity. Often questioning did not acknowledge the child's specific response, resorting instead to general follow-up questions such as "What were you thinking?" As part of the preparation for interviewing children, preservice teachers were given some general open-ended sample questions one might ask children in order to encourage them to explain their thinking. In many cases, the interviewers simply used one or more of the suggested questions repeatedly rather than tailoring the questions to fit individual children's responses. Upon reflection several preservice teachers recognized the lack of specificity in their questioning: "I think that I could have used better questions to get at what [the child] was thinking" (Grade 2, Interview 1, Reflection) and "If I were to give this interview again, I would make sure that my questions were clearer" (Grade 2, Interview 4, Reflection).

For instance, some neutral questions provided by the instructor were "How did you figure out the answer?", "Can you explain to me what you were thinking when you were trying to figure out the answer?", and "Can you give me another example to explain what you mean?" It is evident from the following excerpts of different transcripts that these four different preservice teachers were simply using one of the sample questions rather than creating questions tailored to individual children's responses.

T: Can you explain to me what you were thinking when you tried to figure that out? (Kindergarten, Interview 5, p. 1)

T: Can you explain to me what you were thinking when you were trying to figure out the answer? (Grade 1, Interview 1, p. 1)

T: What were you thinking when you tried to figure out the answer? (Grade 5, Interview 4, p. 1)

T: Can you explain to me what you were thinking when you tried to figure out these answers? (Grade 3, Interview 5, p. 4)

Several children gave interesting or unusual responses to interview questions. For example, one child described the concept of fourths as "knowing a window" and as a "lion's cage" (Grade 4, Interview 5, p. 1 & 4) and two other students described fractions as parts of a moon (Grade 3, Interview 6, p. 7; Kindergarten, Interview 6, p. 1). These responses seem to warrant follow-up by the interviewers to explicitly determine what the children were thinking when they used these analogies in their answers. Unfortunately some of the interviewers did not use a specific follow-up question to explore the response and the children's analogies were lost. Several preservice teachers recognized this in their reflections: "I also discovered after listening to myself, that there were plenty of opportunities to add something or ask more thought-provoking questions about something the student said...." (Grade 2, Interview 9, Reflection); "I realized interviewing students is much more difficult then [sic] I had expected, especially when the student gives answers I did not expect to hear" (Grade 2, Interview 3, Reflection).

Competent questioning. In contrast there were interviewers who listened to children and used their responses to construct a specific probe for more information about children's answers. For example, this interviewer uses information from the child's accurate drawing of one-third in a square to ask a specific probing question: "How did you figure that out? How did you know you had to put two lines to make three parts?" (Grade 5, Interview 5, p. 2). In the following conversation with a second grader, the interviewer probes a correct answer by using the child's response as part of the question.

T: Which is larger, 1/3 or 1/4?

C: 1/3.

T: How did you figure out that answer?

C: I looked at the pieces.

T: How did the pieces show you that 1/3 was larger than 1/4? (Grade 2, Interview 6, p. 1)

Whereas other interviewers might have stopped questioning the child after the child's correct response ("1/3"), this interviewer continues with two additional questions to probe the child's initial response. This interviewer is not looking for a correct answer or simply listening for a response. The specifically tailored follow-up questioning reflects the child's answer and stimulates relevant discussion about the child's thinking.

In this last example, the interviewer uses several skills of competent questioning. She specifically probes for more information and follows up persistently on an intriguing response from the child with questioning that demonstrates she has listened to the child's response.

T: Can you explain to me what you were thinking about the half-circle piece and the half-square piece? What were you thinking?

C: Um...well, I knew that half would be half the circle and, um, it looked like a half moon.

T: Oh, that's interesting. Can you tell me more about that?

C: Um... no.

T: About the moon and its shape, it does look like the moon, doesn't it?

C: Uh-huh. The moon can sometimes look like a half, but it changes shape a lot. (Grade 3, Interview 6, p. 7)

In this interaction, the child attempts to terminate discussion with the words "um…no." Even though the child seems to be finished explaining, the interviewer persists with an additional question specific to the child's response and consequently gains greater insight into what the child is thinking.

DISCUSSION

The interview as a medium relies heavily on verbal language, especially questioning, to carry information between the interviewer and the interviewee. Although an interview (with a set of guiding questions and tasks) is quite different from the teaching and learning processes in a classroom setting, the skill of interacting with children through questioning is an important component of both processes. For example, the use of questions in a "checklisting" style, as exhibited by the preservice teachers, is often observed during whole-group mathematics instruction when teachers are asking students brief factual questions. Knowing when different types of questions are appropriate to use is an important skill for preservice teachers to develop.

We expected that the preservice teachers conducted these interviews with little or no prior experiences in interviewing children or using questioning skills in a mathematics classroom and that their underlying beliefs would guide the adoption and use of questioning techniques. The rapid pace of the questioning during several of the interviews may have mirrored the experiences of some preservice teachers in previous mathematics classes. Because their experiences in this area were limited, the behaviors of the children often dictated their actions, prompting them to speed up an interview when a child seemed bored. The level of questioning skill of the preservice teachers in this study is reflective of their status as novices. We would not expect that these beginning teachers would have well-developed questioning skills; many classroom teachers are themselves working on developing their skills in asking effective questions in mathematics (Buschman, 2001; Mewborn & Huberty, 1999).

Yet, we do want preservice teachers to recognize that there are various types of questioning that can be used to assess and understand children's thinking in mathematics and that it is important to use different types of questions in different mathematical situations. On the basis of the data presented above, these preservice elementary teachers brought a variety of questioning techniques to their interviews with the children. Although preservice teachers generally don't use competent questioning techniques (Ralph 1999a; 1999b), these data demonstrate that the preservice teachers who participated in this project did exhibit some important beginning characteristics of competent questioning. For example,

asking appropriate follow-up questions is an important skill to develop for teaching mathematics, and many of the preservice teachers did attempt to use follow-up questions. Although some used follow-up questions that were non-specific or questioned only incorrect responses, others did specifically target children's thinking and used follow-up questions to probe that thinking. These preservice teachers were able to recognize the various patterns of questioning strategies they used when reviewing their own transcripts. Logical next steps would be to examine how to develop better questioning skills and when different types of questioning in mathematics might be more appropriate.

Reflecting on the Interview to Develop Questioning Competence

Questioning interactions are a significant part of mathematics teaching and learning, both in structured interview settings and in the classroom, and preservice teachers need opportunities to practice their questioning techniques. As a staging area for developing questioning skills and using those questioning skills with a child, the interview may serve as an important vehicle for developing preservice teachers' questioning techniques. By recording the questions they select, preservice teachers may use the one-on-one interview to reflect on their own questioning. This realistic, yet controlled, interaction with a child allows preservice teachers to examine their own patterns of verbal interaction with children prior to using those verbal patterns in the classroom.

Structured opportunities that engage preservice teachers in learning appropriate questioning strategies in mathematics and provide direction in analysis and reflection can be valuable experiences in preparing for future classroom situations. Through discussion about vague or general follow-up questions and examples of specific questioning techniques, preservice teachers have opportunities to devise better questioning strategies. For example, if a child has just said that a half circle is like the moon, asking her "How is a half circle like the moon?" acknowledges her answer and directs her toward a specific elaboration, helping to keep her focused on the mathematical question at hand without compromising her thinking. As one interviewer stated, "With practice, I feel like I will be better able to think on my feet and guide without telling the answer" (Grade 2, Interview 9, Reflection). When

preservice teachers have questioning "practice" with children and a chance to reflect on those interactions, the experience may lead to the recognition of those questioning strategies that are more effective in certain situations.

The effectiveness of the one-on-one interview lies in its ability to document preservice teachers' reactions to children's unpredictable responses in a mathematics interaction. Many of the preservice teachers reflections' expressed the lack of opportunity for explaining mathematical concepts during their own school experiences. Therefore, when a child gave an unexpected response they were unsure what questions to ask. Using the one-on-one interview may provide opportunities to interpret and understand unusual or unexpected solutions presented by children. For prospective teachers who will soon be required to "think on their feet," the interview is a place to interpret and respond to various solution routes in a controlled setting with one child. Because it provides a controlled, yet realistic, interaction with a child, it gives preservice teachers a chance to reflect on their own questioning during that interaction. Learning to respond to children's unexpected answers in a one-on-one structured interview is a first step towards developing the questioning strategies that will be used in the multi-dimensional, simultaneous, unpredictable environment of the classroom.

Implications for Teacher Education

These question categories provide an important contribution to the literature on questioning techniques used by the beginner. The findings may serve as a framework for beginning levels of questioning skills. Identifying and labeling typical questioning patterns allows educators to have a shared discussion about the kinds of questions to expect of the beginner and strategies for developing higher level questioning skills for classroom use. The examples from the data can be used to discuss forms of questioning in mathematics and the types of responses these questions typically elicit from children.

Preservice teacher-conducted assessment interviews can be effective performance-based assessment tools for teacher educators. Documenting the types of questions a preservice teacher uses during an

initial interview with a child at the beginning of a course and comparing these questions with interview questions used later in the semester are one way to document growth in developing questioning techniques. The course instructor can use this documentation as an assessment that shows evidence of growth by the preservice teacher. In these analyses, the preservice teacher might be asked to identify and reflect on specific questioning strategies that would support student learning.

The categories identified in this project can be used during a self-analysis of one's own interview. Interviewers could document the frequency with which they use "checklisting" or "specific follow-up" questioning strategies. The categories and names for question types with examples make it easier for educators to discuss the variety of question types that might be used during an interview. This provides the opportunity for a shared discussion about the kinds of questioning preservice teachers are using in mathematical situations with children. Subsequent class sessions might be used to identify the different kinds of responses elicited from children when different types of questions are asked.

Real experiences with a single child can provide a valuable learning context for a preservice teacher. One of the ways educators and preservice teachers might use these questioning categories is as a framework for coding mathematics interviews with children. Preservice teachers could code their own transcripts of an interview with a child as a self-reflection on the types of questioning they used during the interview. The preservice teacher might audio- or videotape herself and then engage in conversation with an experienced educator for an examination of the questions the interviewer used with the child.

Additional research on the types of questioning categories preservice teachers and inservice teachers use during teaching and learning interactions in typical classrooms would also contribute to our knowledge base on the types of questions used and their appropriateness in different mathematical situations. These examinations would lead to a better understanding of the types of questioning skills that could be developed in preservice teacher education courses to support questioning skills for the classroom. We believe it is important to examine how to better prepare preservice teachers in the skill of

questioning and hope this study brings focus to this issue for preservice teacher mathematics education coursework.

REFERENCES

Adams, N. H. (1994, March). Ask, don't tell: The value of asking young children questions. Paper presented at the annual conference of the Association for Childhood Education International.

Ashlock, R. B. (2002). Error patterns in computation: Using error patterns to improve instruction. Upper Saddle River, NJ: Merrill Prentice Hall.

Ball, D. (1991). Research on teaching mathematics: Making subject matter knowledge part of the equation. In J. Brophy (Ed.), Advances in Research on Teaching (Vol. 2, pp. 1-41). Greenwich: JAI Press.

Baroody, A. J., & Ginsburg, H. P. (1990). Children's mathematical learning: A cognitive view. In R. B. Davis, C. A. Maher, & N. Noddings (Eds.), Constructivist views on the teaching and learning of mathematics (pp. 51-64). Reston, VA: NCTM.

Bloom, B. S. (1956). Taxonomy of educational objectives: The classification of educational goals (Handbook I: Cognitive domain). New York: David McKay Company, Inc.

Bowman, A. H., Bright, G. W., & Vacc, N. N. (1998, April). Teachers' beliefs across the first two years of implementation of cognitively guided instruction. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Bright, G. W., & Vacc, N. N. (1994, April). Changes in undergraduate preservice teachers' beliefs during an elementary teacher-certification program. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Buschman, L. (2001). Using student interviews to guide classroom instruction: An action research project. Teaching Children Mathematics, 8(4), 222-227.

Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L., & Empson, S. B. (1999). Children's mathematics: Cognitively guided instruction. Portsmouth, N.H.: Heinemann.

Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L., & Empson, S. B. (2000, September). Cognitively guided instruction: A research-based teacher professional development program for

elementary school mathematics. National Center for Improving Student Learning and Achievement in Mathematics and Science, Report No. 003. Madison, WI: Wisconsin Center for Education Research, The University of Wisconsin-Madison. <http://www.wcer.wisc.edu/ncisla/publications>

Carpenter, T. P., Fennema, E., Peterson, P. L., Chiang, C., & Loef, M. (1989). Using children's mathematics thinking in classroom teaching: An experimental study. American Educational Research Journal, 26, 499-531.

Fennema, E., Carpenter, T.P. (1996). A longitudinal study of learning to use children's thinking in mathematics instruction. Journal for Research in Mathematics Education, 27(4), 403-434.

Fennema, E., Carpenter, T.P., Franke, M. L., & Carey, D. A. (1993). Learning to use children's mathematics thinking: A case study. In C. Maher & R. Davis (Eds.), Schools, mathematics, and the world of reality (pp.93-118). Needham Heights, MA: Allyn Bacon.

Fennema, E., Franke, M. L., Carpenter, T. P., & Carey, D. A. (1993). Using children's mathematical knowledge in instruction. American Educational Research Journal, 30, 555-585.

Gall, M. D., Borg, W. R., & Gall, J. P. (1996). Educational research: An introduction. White Plains, NY: Longman.

Huinker, D. M. (1993). Interview: A window to students' conceptual knowledge of the operations. In N. L. Webb (Ed.), Assessment in the mathematics classroom, (pp. 80-86). Reston, VA: NCTM.

Kamii, C., & DeVries, R. (1978). Physical knowledge in preschool education: Implications of Piaget's theory. Englewood Cliffs, NJ: Prentice Hall.

Kamii, C., & Warrington, M. A. (1999). Teaching fractions: Fostering children's own reasoning. In L. V. Stiff, & F. R. Curcio (Eds.), Developing mathematical reasoning grades K-12: 1999 Yearbook (pp. 82-92). Reston, VA: NCTM.

Lampert, M. (1986). Knowing, doing and teaching multiplication. Cognition and Instruction, 3(4), 305-342.

Leinhardt, G., & Greeno, J. (1986). The cognitive skill of teaching. Journal of Educational Psychology, 78(2), 75-95.

Ma, L. (1999). Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States. Hillsdale, NJ: Lawrence Erlbaum Associates.

Merriam, S. B. (1988). Case study research in education: A qualitative approach. San Francisco: Jossey-Bass Publishers.

Mewborn, D. S., & Huberty, P. D. (1999). Questioning your way to the standards. Teaching Children Mathematics, 6(4), 226-227, 243-246.

Moyer, P. S., & Moody, V. R. (1998). Shifting beliefs: Preservice teacher's reflections on assessing students' mathematical ideas. In S. B. Berenson & K. R. Dawkins (Eds.), Proceedings of the Twentieth Annual Meeting of the North American Chapter of the International Group of the Psychology of Mathematics Education (Vol. 2, pp. 613-619). Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

National Council of Teacher of Mathematics. (1991). Professional standards for teaching mathematics. Reston, VA: Author.

National Council of Teacher of Mathematics. (1995). Assessment standards for school mathematics. Reston, VA: Author.

National Council of Teacher of Mathematics. (2000). Principles and standards for school mathematics. Reston, VA: Author.

Nilssen, V., Gudmundsdottir, S., & Wangsmo-Cappelen, V. (1995, April). Unexpected answers: Case study of a student teacher derailing in a math lesson. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Piaget, J. (1926). The language and thought of the child (Preface by E. Claparede; translated by Marjorie and Ruth Gabain). London: Routledge and Kegan Paul.

Piaget, J. (1929). The child's conception of the world (translated by Joan and Andrew Tomlinson). London: Kegan Paul, Trench, Taubner, & Company.

Posner, G. J., & Gertzog, W. A. (1982). The clinical interview and the measurement of conceptual change. Science Education, 66(2), 195-209.

Ralph, E. G. (1999a). Developing novice teachers' oral-questioning skills. McGill Journal of Education, 34(1), 29-47.

Ralph, E. G. (1999b). Oral-questioning skills of novice teachers: …Any questions? Journal of Instructional Psychology, 26(4), 286-296.

Reys, R. E., Suydam, M. N., Lindquist, M. M., & Smith, N. L. (1998). Helping children learn mathematics. Needham Heights, MA: Allyn and Bacon.

Schwartz, S. L. (1996). Hidden messages in teacher talk: Praise and empowerment. Teaching Children Mathematics, 2(7), 396-401.

Stenmark, J. K. (1991). Mathematics assessment: Myths, models, good questions, and practical suggestions. Reston, VA: NCTM.

Stigler, J. W., & Hiebert, J. (1999). The teaching gap. New York: The Free Press.

Stone, J. (1993). Caregiver and teacher language: Responsive or restrictive? Young Children, 48(4), 12-18.

Strauss, A. (1987). Qualitative analysis for social scientists. New York: Cambridge University Press.

Wassermann, S. (1991). The art of the question. Childhood Education, 67(4), 257-259.