INVESTIGATING THE USE OF THE CLINICAL INTERVIEW METHOD IN AN ELEMENTARY MATHEMATICS METHODS COURSE

By

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ABSTRACT OF THE DISSERTATION

Investigating the Use of the Clinical Interview Method in an Elementary Mathematics Methods Course

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Increased focus on the preparation of early childhood educators (AMTE, 2010; NCTM, 2000; USDOE, 2002), underscores the importance of providing prospective teachers with experiences that will help them to become more aware of children's mathematical thinking. One type of experience, the focus of this study, involves using the clinical interview method (Piaget, 1952).

The six prospective teachers reported on here were enrolled in a mathematics methods course offered at Rutgers University - Newark, during Fall 2008. The prospective teachers utilized VITAL (Video Interactions for Teaching and Learning) software, designed by Columbia University's Center for New Media Teaching and Learning. VITAL is an online repository of clinical interview videos, along with other videos, of young children engaged in mathematical activities (Sorkin & Preston, 2010). As part of the course requirements, the prospective teachers provided weekly reflections about children's mathematical thinking using VITAL. In addition, they were required to plan, conduct, and reflect on their own clinical interviews with young children.

The following research questions guided this study: (1) in what ways did the prospective teachers' observations about young children's mathematical thinking change, if at all? (1a) How did their observations and reflections on children's errors, as seen in the VITAL videos, change

throughout the semester? (1b) How did their observations and reflection, as seen in their own clinical interviews, change throughout the semester? (2) What, if any, general observations and insights did the prospective teachers have about the use of the clinical interview method?

Results indicate that the prospective teachers were able to describe and provide explanations for children's mathematical thinking in VITAL and in their own clinical interviews with children. They noted instances where children made mathematical errors and tried to understand the errors by providing a variety of explanations: confusion with learned algorithms, children's reluctance to admit their errors, and child's developmental level, for example. Moreover, they documented when appropriate follow-up questions allowed children to consider their errors.

Results from this dissertation add to the research base documenting the use of the clinical interview method as a tool for helping prospective teachers reflect on young children's mathematical thinking.

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Dedication

To my Mom and Dad, who instilled in me the value of an education from an early age.

To my nieces and nephews—Kiara, Tiara, Gino, and Hugo—work hard and dream big.

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Chapter 1: Introduction

Recent attention has been paid at both the federal and state levels to the need for placing highly qualified mathematics teachers in all classrooms, including those at the early childhood level (AMTE, 2010; NCTM, 2000; USDOE, 2002). Similar attention has been placed on what constitutes early childhood mathematics education (ECME); this has been documented in the education research community (Ginsburg, 2009; Tsamir, Tirosh, & Levenson, 2011). In order to meet the demand for more and better-prepared mathematics teachers, many teacher education programs are seeking alternative ways to prepare prospective early childhood and elementary teachers to work with young children. One such approach involves helping future teachers to better recognize and understand the mathematical abilities of young children so that they can develop appropriate instructional practices that build upon children's concrete and intuitive ideas (Ginsburg, Jang, Preston, VanEsselstyn, & Appel, 2004; Ginsburg et al., 2006). A particularly useful vehicle for calling attention to children's mathematical thinking is the use of archived clinical interview videos. The clinical interview setting provides a unique opportunity to more closely observe a child working with mathematics and to consider their thinking process and implications of it for the teaching of mathematics. The clinical interview method stems from Piaget's (1929) early work with children on an alternative to standardized testing. Piaget criticized standardized testing of the time, pointing out its inability to provide information on children's thinking, particularly in the event of an incorrect response on a test.

Coupled with the practice of conducting one's own clinical interviews, the practice of viewing clinical interviews of children working on mathematics help prospective teachers see children's mathematical thinking as it happens in a one-to-one setting, consider what information

is contained in children's thinking, and reflect on the implications of children's thinking for instructional practice.

As prospective teachers engage in the practice of analyzing children's mathematical thinking, they may encounter situations in which the children think about the mathematics differently than they do. They may also encounter instances in which the children make errors or mistakes. Knowing and understanding children's mathematical errors is important for both in-service and prospective teachers. It is well documented in the research literature that for practicing teachers, it is often productive to view children's mathematical errors as teachable moments, fodder for mathematical discussion, and windows into children's mathematical thinking (Ball, 1991; Borasi, 1987, 1994; NCTM, 2000), rather than viewing errors as indications of children's inability to comprehend the mathematical content, or as "bugs" or misconceptions (Brown & Burton, 1978) about a topic. Ball (1991) calls for teachers to consider the information that can be obtained by attending to children's errors, including whether the errors stem from simple calculation inaccuracies or deep-rooted ways of thinking about a particular concept. This distinction between the types of errors can be difficult to make in the classroom as a lesson plays out. In fact, Santagata (2005) and Schleppenbach and colleagues (2007) describe some of the more typical ways in which in-the-moment decisions about responding to children's errors are made. These include the following: Teachers can opt to recognize errors and then choose to follow up with questions so that children work through their errors (via self-correcting or having other students or the teacher do the correcting), provide corrective statements (choosing the right or wrong answer for the child, or telling the child they have an incorrect solution), or ignore the error altogether. Some of these in-the-moment pedagogical decisions are often based on teachers' beliefs aligned with reform-oriented

mathematics instruction and teacher knowledge in four areas: knowledge of key mathematical concepts, student strategies, conceptually supportive teaching, and teachers' abilities to use mathematical knowledge to interpret student work (Bray, 2011; see also Thompson, 1984, for a discussion of the relationship between teachers' beliefs and mathematics instruction).

If prospective teachers can learn to view children's errors in the same way that is advocated for practicing teachers, they may enter their teaching experiences better prepared to interpret and respond to children's complex ways of thinking about and working on mathematics. This is important if we consider the role that past pedagogical experiences have on prospective teachers' formulation of their own teaching philosophies. For example, Feiman-Nemser (1983) points out that, "*studies of teacher socialization have long reported that prospective teachers' past classroom experiences, more often than not, help them develop implicit and imitative pedagogical tendencies, such as habits of correcting, telling, and supplying the answers*" (Feiman-Nemser, 1983, as cited in Crespo, 2002, p. 740; see also Thompson, 1984). Thus, one of the goals of teacher education programs should be to move prospective teachers away from *"habits of correcting, telling, and supplying the right answers"* (Crespo, 2002, p. 740) towards habits of fostering children's mathematical thinking and problem solving by highlighting misconceptions, as well as seeing children's errors as opportunities for rich mathematical discussions and learning to take place. That being said, it is important to provide opportunities for prospective teachers to examine children's mathematical thinking more closely (both correct and incorrect thinking), and provide space for them to consider the pedagogical implications of children's mathematical thinking. This will help them to become more aware of what to anticipate when they are working with children on mathematics, and how to use children's mathematical thinking as a way to inform their planning and practice.

This dissertation study was designed to focus on the use of clinical interview video cases as part of the teacher preparation process in order to provide such opportunities for prospective teachers. Video cases refer to multimedia case studies that employ video as a tool to illustrate a particular concept or message. In clinical interview case studies, videos of clinical interviews that have been conducted with a wide variety of subjects are utilized to invite prospective teachers to consider the mathematical thinking of these subjects. The age range of the interview subjects can range from the pre-Kindergarten child to adult learners. In this study, the archived clinical interview videos made available to the prospective teachers were of children spanning the grade levels of pre-Kindergarten to third grade.

While case studies have been a feature of professional development programs for in-service teachers (e.g., Miller, Moon, Elko, & Spencer, 2000; Stein, Smith, Henningsen, & Silver, 2000), more recent work has begun to highlight the use of *video* cases with both prospective and in-service teachers. Many studies illustrate the use of video cases in methods courses in content areas other than mathematics, such as developmental psychology or literacy (e.g., Abell & Cennamo, 2004; Boling, 2002; Derry & Hmelo-Silver, 2000; Ferdig et al., 2004; Hughes, Packard, & Pearson, 1999; Kinzer & Risko, 1998; Siegel et al., 2000; Steinkuehler, Derry, Hmelo-Silver, & Delmarcelle, 2002). More recently, studies have emerged that do take into consideration the use of video cases in mathematics teacher preparation (Dolk, den Hertog, & Gravemeijer, 2002; Friel & Carboni, 2000; Lee, Ginsburg, & Preston, 2009; Whitenack, Knipping, Novinger, Coutts, & Standifer, 2000). This research was initially[1] designed to add to the small, yet growing, body of literature on the use of video cases with prospective mathematics

[1] The proposal for this dissertation study focused on the use of video cases with prospective mathematics teachers; in analyzing the data collected for this study, and considering the types of video cases used, the new focus became the use of clinical interview video cases, and the clinical interview method in general.

teachers as an additional way to prepare them for the realities of classroom teaching. In Chapter 2, there will be a brief discussion on the literature surrounding video cases in teacher education to honor this initial focus. The completed study described herein investigated how the use of clinical interview (Piaget, 1952) video cases, as well as the actual practice of conducting their own interviews, may serve to prepare prospective teachers to better understand and tap into the mathematical abilities of their students. The clinical interview video cases and the interview assignments also provided an opportunity to examine how prospective teachers identify, interpret, and respond to children's mathematical errors. This was a result that came out of initial analysis of the data, and is elaborated on in Chapter 4 (Results).

Research Questions

The following research questions and sub-questions guided this study: (1) in what ways did the prospective teachers' observations about young children's mathematical thinking change, if at all? (1a) How did their observations and reflections on children's errors, as seen in the VITAL videos, change throughout the semester? (1b) How did their observations and reflection, as seen in their own clinical interviews, change throughout the semester? (2) What, if any, general observations and insights did prospective teachers have about the use of the clinical interview method?

Methods

To investigate the proposed research questions, data was collected during a semester-long mathematics methods course offered to elementary and secondary prospective teachers. From the months of September to December, while the students participated in various course activities, the activities that were used as primary sources of data for this study were: prospective teachers' observations and reflections of children's mathematical thinking as viewed in VITAL

videos, as well as their observations and reflections during their own clinical interview assignments (to address Research Question 1, 1a, and 1b); end-of-course reflections on their own growth as teacher professionals, including reflections on the clinical interview method and how that may have contributed to their growth (to address Research Question 2); and, results of a pre- and post-survey measuring attitudes towards mathematics and teaching mathematics. This last piece of data, the attitudes survey, helped to determine which of the 17 participating prospective teachers would be the focus of the more in-depth case studies (and reported on in Chapter 4). This was done to ensure a fairly representative sample of the course participants as a whole. Six of the 17 prospective teachers were chosen for further analysis.

Results/Conclusions

Early on in the semester, when prospective teachers were still new to the practice of interviewing and observing others conducting interviews, the reflections that they wrote were descriptions of the children's mathematical behaviors, as portrayed by the videos. Often, they described exactly what the video showed, and provided little analysis or explanation for what they were seeing. As the prospective teachers watched more VITAL videos, and had the experience of conducting their own interviews, they began to include possible explanations and hypotheses of the children's mathematical thinking. This is particularly true of the reflections for the VITAL videos that had instances where children made mathematical errors. The prospective teachers also began to show evidence that they were able to follow children's thinking carefully enough to formulate follow-up questions within their own interviews, or pose hypothetical follow-up questions for the VITAL videos. In addition, the prospective teachers began to analyze follow-up questions in terms of their effectiveness in getting the child to provide more detail about their thinking. This was, again, not a focus for all of the VITAL

assignments (the directions for only four of the eleven VITAL assignments mentioned follow-up questions), or of their own interviews, but the prospective teachers were able to engage in such an analysis where relevant.

In looking at each case study individually, it was noted that, while all prospective teachers showed some evidence of growth in sophistication of their reflections, this growth was not linear, nor did it follow the same path for each of them. Some prospective teachers appeared to revert back to offering purely descriptive reflections of the videos and of their own interviews as the semester neared an end, with very limited analysis of the children's mathematical thinking. One possible explanation for this finding is that some prospective teachers may have structured their written reflections only around what was asked of them in the directions for the assignment. If the directions did not specify reflecting on any one particular aspect of the assigned videos, then, there was no mention of anything extraneous or surprising in the reflection. Another possible explanation is the point in the semester at which these less-detailed reflections were noted. It is quite possible that, towards the end of the semester, the prospective teachers were more concerned with completing and handing in other assignments for the course, as well as completing assignments and final exams for other courses in which they were enrolled. Finally, it is important to consider that the practice of noticing and reflecting on children's mathematical behavior as seen in video records is difficult, but can improve over time (e.g., van Es & Sherin, 2008). For the prospective teachers in this study, this was their first experience watching and reflecting on clinical interview videos, as well as conducting their own interviews. It is unrealistic to expect that they would all become experts at noticing children's mathematical thinking in their first experience with viewing clinical interview videos and conducting their own interviews.

In addition, it was noted that the act of analyzing their own interviews was more difficult for the prospective teachers than analyzing the interviews of others. Perhaps having to reflect on one's own interview and be self-critical of the interview was new and difficult for the prospective teachers. They may have found it to be easier to be critical of an interview that was already completed, by someone they were not personally connected with. Also, the clinical interview video cases were not complete interviews; these video cases were, for the most part, excerpts from longer interviews. Therefore, the prospective teachers often commented on questions that were left unasked, based upon their viewing of the interview excerpt. This led them to, in some ways, criticize the interviewer for not asking those questions. In contrast, the prospective teachers had more control over their own interviews, determining the duration as well as the topics and questions to be discussed. Being more personally vested in their interviews, it may have been more difficult for the prospective teachers to discuss faults in their own work.

All six prospective teachers studied noted the utility of the clinical interview method in allowing them to examine more closely the mathematical thinking of young children. Some also noted the difficulty of having to prepare and conduct interviews, including the formulation of appropriate tasks as well as follow-up questions, and knowing how to really listen to a child as they explain their mathematical thinking. The interviews also helped to illustrate the complexity of children's thinking, and how it often differs from how adults or even older children might think about the same mathematical topics.

Limitations

When looking at changes in observations throughout a given time period, it is difficult to state whether these changes can be attributed to any one feature of the methods course the

prospective teachers were enrolled in. This dissertation report focuses in on one particular aspect of the methods course, which was that of the use of the clinical interview method (through archived video cases and through interview assignments). During this same time period, though, the prospective teachers completed other assignments that may have contributed to their understandings of children's mathematical thinking. These included: fieldwork assignments where the prospective teachers observed a classroom setting of their choice; lesson plans that were focused on a particular mathematical strand; and, course readings that were carefully selected to illustrate relevant issues in mathematics teaching and learning, among other things.

In addition, the structure and purpose of the VITAL videos and the clinical interview assignments was not to highlight children's errors, and so analysis of how the prospective teachers interpreted and responded to children's errors occurred only in those instances that were documented. It could be that other instances existed, but if they were not written about in the VITAL reflections or in their reports of their own interviews, it could not be captured and reported on here. It is quite possible that more carefully selected videos would have provided additional opportunities for the prospective teachers to delve more deeply into the mathematical thinking of children, particularly those instances when an error is observed. Similarly, the directions/writing prompts that the prospective teachers were given for the videos and for their interviews did not specify a need to reflect on errors. It is not a fair assumption to make that the absence of prospective teachers' reflections on errors indicates an inability to consider children's errors.

Finally, my dual role as the researcher and as one of the course instructors may have influenced prospective teachers' responses to course assignments (including VITAL and their interviews) because they were made aware of the purpose of the study, and my position as the

researcher, since the beginning of the semester. Similarly, when trying to document the prospective teachers' true feelings about the utility of clinical interviewing, it is possible that they assumed the course instructors wanted them to speak positively of the assignments, and so they complied. In addition, because the data collected was part of course assignments that were required, the feedback that was given to the prospective teachers as part of the dialogue between instructor and student may have influenced what prospective teachers reflected on in subsequent assignments, thereby giving a sense of improvement in terms of their capacity to reflect on children's thinking where it may not have existed.

Chapter 2: Conceptual Framework and Literature Review

While the argument has been made for using teaching cases and case methods in teacher education programs as a way to bridge theory and practice (Cranston-Gingras, Raines, Paul, Epanchin, & Roselli, 1996; Shulman, 1992; Smith & Friel, 2008), this dissertation seeks to elaborate on the specific situation of using clinical interview video cases with prospective mathematics teachers. Teaching cases and case methods, as defined above, are not to be confused with case studies in the qualitative research sense (see Hancock & Algozzine, 2011; Stake, 1995). To clarify, Cranston-Gingras and colleagues (1996) define cases as "true narrative accounts of actual teaching situations" (p. 158). Shulman (1992) defines cases and case methods as helping to teach about: "(1) principles or concepts of a theoretical nature, (2) precedents for practice, (3) morals or ethics, (4) strategies, dispositions, and habits of mind, (5) visions or images of the possible" (p. 2). Shulman further defines cases as: "(1) creating or increasing motivation for learning…(4) serving as the instructional material around which participants can form communities for discussion or discourse" (Shulman, 1992, pp. 2-3). This is not the same as Stake's (1995) definition, which regards case studies as "the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (p. xi). Furthermore, Hancock and Algozzine (2011) specify that case studies can focus "on an individual that is representative of a group" (p. 15). The children presented in the video cases the prospective teachers studied were not meant to represent all children and their mathematical thinking.

Video cases situated within the classroom/education domain differ from the more traditional types of cases used during field experiences in that they are not text-based cases, but rather, multimedia cases that include video of actual classroom teachers and students.

Furthermore, video cases differ from videotaped accounts of an event in that they are constructed so as to illustrate a particular point. For example, an interview conducted with a subject may be videotaped to provide a record that the interview actually took place. It need not be edited, because its primary purpose is to serve as proof of the interview occurring. In an interview video case, the videotaped record may be taken and edited, specifically to highlight a particular aspect or interesting segment of the interview. The same is true of videos taking place inside the classroom, be it an entire lesson that was videotaped, or a particular activity the students were engaged in for part of a lesson. Video cases may also include supplemental material relevant to the case, such as teacher lesson plans, student work, or expert commentary on the scenario captured in the video case, among other things. With respect to clinical interviewing, the video cases include one-on-one interviews with a subject about a given topic. Subjects can range in age and grade level, from the pre-Kindergarten student to the adult learner.

Video cases can provide an authentic depiction of the realities of classroom teaching and learning which can be viewed multiple times because of its digital form. Rather than reading a description of a classroom lesson or activity, the video case can show the lesson or activity in action. Behaviors or events that cannot be fully or accurately described in words may be better experienced via a video record. Furthermore, the use of video cases particularly with groups of prospective teachers creates a common ground on which they can discuss issues and insights arising from the video content (see Barron & Goldman, 1994; Lampert & Ball, 1998; Masingila & Doerr, 2002; Monroe-Baillargeon, 2002; Perry & Talley, 2001, for more detailed discussions on the affordances of video cases in teacher education programs).

Adult Learning

Research on adult learning supports the use of video cases as an instructional method in various ways. Bransford and colleagues (1999), Bruner (1996), and Lave (1996) write about the utility of real life situations in adult learning. In this particular case, the real life situations depicted in the video cases take place within an educational setting (real classrooms and real students). Furthermore, the use of these everyday educational cases can serve as the platform on which prospective teachers extend their learning and professional development (CTGV, 1993; Shulman, 1992).

To further make the case for the use of *clinical interview* video cases, the next section will look broadly at the use of video cases within teacher education. Then, clinical interviewing, as defined in this study, will be discussed, with particular attention to the clinical interview methods' utility in teacher education.

Video Cases

The video cases used in the studies mentioned earlier involve a broad range of structures for the cases, and it is important to note that the type and quality of these can influence the learning outcome of prospective teachers. In fact, Perry and Talley (2001) surveyed various experts to gain consensus on the features that are of importance when defining exemplary online video cases. Some of the features recommended by the survey participants included: cases should invoke discussion, have a clear purpose or objective, provide effective and ineffective models, and include dialogue between teachers and students (paraphrased from Perry & Talley, 2001, p. 28).

In much the same way that the structure of the cases can vary, the same is true when describing ways in which cases can be used in teacher education. Teacher educators may use

cases as illustrations of theories or concepts, examples of best practices, or as models of student thinking. In addition, prospective teachers can engage in watching ready-made video cases, or engage in the process of creating their own cases. Beck, King and Marshall (2002) discuss one way in which video cases can be used with future teachers. In their work, the authors used used an experimental design to test how video case construction affected prospective teachers' observations during their required classroom placements. A control group of prospective teachers was assigned to a traditional classroom placement for observations (i.e., they were assigned a teacher and classroom to observe for a specified length of time), while the experimental group engaged in video case construction and analysis in addition to their classroom placements. The video case construction and analysis consisted of choosing video clips of the classroom teacher being observed and subsequent analysis of the effective teaching practices depicted in the clips. Beck and colleagues (2002) showed that prospective teachers who had both the traditional classroom placement, as well as the video case construction and analysis experience, outperformed the control group on a written, online test given at the end of the quarter in the methods course. The electronic assessment, titled the Video Observation Test, was a performance-based assessment requiring the prospective teachers to view three videos in different instructional settings (i.e. whole-class and small-group instruction) and "identify, interpret, or analyze elements of effective teaching…" (p. 354). The prospective teachers submitted their written responses electronically, and the researchers/authors then coded the responses to see what features of the classrooms were focused on most often. Results of the tests, as interpreted by the authors, showed that the prospective teachers who were asked to construct their own video cases were better able to analyze the classroom observations for instances of effective teaching practices. While this study did have some limitations, including

the fact that familiarity with the technology may have helped the experimental group perform better on the Video Observation Test, further studies can be done to test this and other variables. The authors even suggest testing with a larger sample size, and with additional controls, such as providing prospective teachers with the video cases for analysis, rather than having them construct their own.

Similarly, Copeland and Decker (1996) explored the effects of video cases on the meaning-making teachers attributed to episodes (or 'vignettes', as the authors refer to it) of classroom teaching and learning. Differences in meaning making were measured by studying prospective teachers' responses to a video case prior to, during, and after a group discussion session in which a handful of prospective teachers collectively watched and discussed the video case. In this study, the authors sought to (1) look at the group discussion session as an intervention in the meaning-making process, and (2) provide some empirical evidence for the use of video cases in teacher education. The responses were coded and tracked to see whether topics mentioned by the prospective teachers prior to, during, and after the group discussion either (a) retained utility (i.e. the topic was mentioned before, during, and after the group discussion, and there was no change in how the topic was discussed), (b) adopted a new topic (thereby showing evidence for the influence of the intervention), (c) had little or reduced importance, (d) change in topic (and therefore, a change in meaning), or (e) creation (of a new topic). Based on this coding scheme, and the quantification of the number of instances that any one particular treatment of a topic was exhibited, the authors concluded that the group discussion intervention had an effect on the meaning making process of the prospective teachers, thereby making an argument for the use of this type of intervention in teacher education courses of a similar nature. As one might expect, the very nature of participating in the group discussions, where differing perspectives

from the other participants might cause you to reexamine your own ideas about a topic, may explain the effects of the intervention that the authors found.

A third context in which video cases were used with prospective teachers took place within a mathematics methods course designed for middle school and high school teachers in which the focus was teaching with technology. Hollebrands, Wilson and Lee (2007) sought to develop their prospective teachers' technological pedagogical content knowledge (TPCK[1]) through the use of video cases dealing with students' work with technologies related to the mathematical strands of data and probability. Like Copeland and Decker (1996), Hollebrands, Wilson and Lee coded their data for ways in which the prospective teachers made sense of the students' use of technologies through viewing the video cases. In this particular study, the authors characterized the prospective teachers' work based on the emphasis the prospective teachers placed on the student work provided, as well as the hypotheses they generated on how the student work related to student thinking. Four categories emerged from the data to describe the ways in which prospective teachers looked at student work in the video cases—the stances taken were either descriptive, comparative, analytical, or of a restructuring nature. In studying and describing the responses, the authors noted that the types of questions that the prospective teachers were asked to answer during the video case activities influenced the type of responses the prospective teachers gave. As an example, the authors described one such question, where prospective teachers were asked to describe a task they would assign students based on the what they saw in the video case, that would provide information as to what aspects of students' mathematical thinking the prospective teachers attended to as they analyzed the video case.

[1] Koehler and Mishra (2005) and Niess (2005) describe TPCK as the consideration that teachers need to have of the intersections of pedagogy, content, and technology when teaching their subject matters with technology.

They concluded that more opportunities should be given for prospective teachers "…to develop habits of attending to students' work in a way that fosters analysis and restructuring" (p. 974).

As described by the studies mentioned above, many of the video cases involved looking at classrooms or groups of students working on mathematics, with an end goal of gaining more understanding of various teaching practices or better understanding student reasoning. The research conducted in this study adds to the research literature by describing the use of *particular* video cases/situations (i.e., those of archived clinical interviews illustrating children's mathematical thinking) with the prospective mathematics teacher population. To give prospective teachers additional access to situations in which to consider children's mathematical thinking, the prospective teachers in this study also engaged in conducting their own interviews.

In the next section, the process of clinical interviewing is discussed in some detail, with emphasis placed on how the clinical interview method can be used to gain more information about children's mathematical thinking.

Clinical Interviewing

To build the case for this particular focus, it is necessary to draw on literature related to clinical interviewing, the development of mathematical ideas in young children, the importance of focusing on children's mathematical thinking, and what teachers can learn from analysis of children's mathematical thinking, and in particular, analysis of children's mathematical errors. This section focuses specifically on clinical interviewing.

The literature on clinical interviewing referenced for this study (Hunting, 1997; Ginsburg, 1997; Ginsburg, Jacobs & Lopez, 1998; Kaplan, King, Dickens, & Stanley, 2000) seeks to build on Piaget's (1929; 1952; 1976) initial notion of the clinical interview by looking closely at the applications of this method of assessment to the mathematics classroom. In

Piaget's early work, the use of the clinical interview method was seen as an alternative to standardized testing and its inability to get at the root of a child's misconception about a given topic. The structure of clinical interviewing (also referred to as "flexible interviewing"; see Ginsburg et al., 1998), as situated within literature on developmental psychology, can, however, provide teachers (both prospective and in-service) with an opportunity to gain insight into the mathematical thinking of a child. The interview is usually open-ended in nature, beginning with a set of questions on a given topic or topics, but often branching out in a certain direction based on the responses of the person being interviewed. The interview should not be used to point out right or wrong answers or to teach the interviewee something; rather, it is designed to elicit and expose the thinking of the interviewee to the person conducting the interview. In fact, Hunting (1997) refers to the role of the interviewer, be it a researcher or a teacher, in terms of becoming observers and learners of children's thinking; for the teacher, this may involve a reconceptualization of their role.

Ginsburg's (1997) book *Entering the Child's Mind: The Clinical Interview in Psychological Research and Practice*, juxtaposes the clinical interview with more standardized methods of assessment, explaining that the information we glean from standardized assessments may not give us a complete picture of what a child knows and understands. By using clinical interviews—and using them as described in many of the studies cited above—we can begin to expose how a child is thinking about a particular concept in a more in-depth way.

Teachers using clinical interview methods. While archived video cases of clinical interviews are a useful way for practicing and prospective teachers to learn about children's mathematical thinking, there is also great value in actually conducting clinical interviews. The

research literature includes examples of both practicing and prospective teachers using the clinical interview method to learn more about the students they are serving.

Practicing teachers using clinical interview methods. Buschman (2001) investigated how the insight teachers gain about children's mathematical thinking via clinical interviews influenced their teaching practice. As part of an action research project, elementary school teachers (grades K – 4) investigated how they could implement mathematical problem solving more successfully in their classrooms by utilizing information gained from clinical interviews with their students. For their interviews, teachers used task types identified by Cognitively Guided Instruction (Carpenter, Fennema, Franke, Levi, & Empson, 1999) and asked probing and leading questions (Buschman, 2001, figure 3, includes the list of questions). After each round of interviews was completed (two rounds total, once during the fall and once in the spring of a school year), the teachers would convene as a group and share what they were learning from the interviews. As the authors noted, an important component of successful implementation of mathematical problem solving involves the development of in-depth knowledge about individual children's mathematical thinking. Having gained this information about children's thinking teachers can then use the information to inform their practice. An additional component the study teachers were interested in learning about was the use of effective questioning to aid students as they engaged in mathematical problem solving. By conducting clinical interviews with their students, the participants in this study realized they were able to gain this type of knowledge. As a result of this action research project, participating teachers reported that their instructional practices were influenced by the knowledge they gained of individual students' mathematical thinking. Some of the ways that teachers reported change in their instructional practices were as follows: (a) increased awareness of which students were ready for more

cognitively challenging mathematics problems, and which students needed additional practice with developmentally appropriate tasks; (b) increased ability to write and select mathematics problems that focused on children's misconceptions revealed during the interviews; (c) increased awareness of children's different and complex ways of solving mathematics problems, and the need to give students time to develop their varied solutions and space to share these alternate strategies with their peers; and, (d) increased confidence in their students' mathematical problem solving capabilities.

How teachers choose to conduct interviews and what they learn from these appears to rely on a variety of factors. Heid and her colleagues (1999) identified some of these factors as they studied three secondary mathematics teachers learning to use interviews to gain information about a particular technology-rich algebra curriculum they were implementing. The three teachers learned the interview methodology, reviewed transcripts of interviews previously conducted, and then conducted and analyzed their own interviews with students. The authors found that the teachers' relationship with mathematics (their own understanding of it and their belief about what it means to know mathematics), their perceptions about their students' academic and emotional needs, and their beliefs about the purpose of the interviews, all influenced how they learned about and conducted their own interviews. For example, the teachers' own comfort level with the mathematics content had an impact on the types of tasks they used for the interviews, as well as what they attended to in the students' responses. The authors noted that if a teacher believed the mathematics task was to be solved in one prescribed way, he/she often expected the student to answer in the same way. In addition, what they chose to focus on in their analyses of their interviews was impacted by these factors as well.

There are many formats for teachers to use in conducting interviews. One involves

having teachers choose the mathematical topic of discussion, as well as the tasks. A second involves interviews that have been pre-designed for specific purposes, perhaps as part of a larger educational research project. Heirdsfield (2002) investigated teachers conducting pre-designed interviews related to mental computation. Because the interviews had been planned ahead of time, Heirdsfield posits that the teachers did not need to have in-depth pedagogical content knowledge about the topic (mental computations) and how students might respond to the activities. In fact Heirdsfield points out that Hunting (1997) also wrote about how the interview process itself can be used to help teach teachers learn more about children's thinking. This in turn, would then inform their pedagogical content knowledge. Anecdotal accounts from teachers participating in Heirdsfield's study confirmed this hypothesis. For example, teachers reported being better able to learn about their students' understanding and knowledge of mental computations through these interviews. Moreover, they reported that prior to the interviews, they had not considered the importance of questioning and listening to students. Heirdsfield conjectured that because the interviews were pre-designed, the teachers did not need to consider appropriate tasks and questions for the students during the interview. Despite the study results, an argument can also be made that teachers *do* need to have at least some ideas about how students may approach particular problems. This knowledge may come from research literature or prior experiences with children. In addition, this prior knowledge may help teachers better anticipate student responses and formulate potential follow-up questions. In fact, Ginsburg (1997) makes an important argument for what and how much a person should know prior to an interview:

> The goal [of the clinical interview] is to learn how the *child* [emphasis the author's own] thinks and how the child constructs a personal world. The danger is in imposing adult categories, in forcing the child's responses into a predetermined, adult mold… On the other hand, to discover something about the child's cognitive construction, the interviewer must

> have some ideas about what to look for, some notions about the forms children's thinking may take. Lacking concepts for interpreting the child's behavior and explanations, the interviewer is likely to overlook what is important and to focus on what is trivial (pp. 119-120).

The clinical interview method can be used to provide valuable information about all students. Hodges and his colleagues (2012) found that this is especially true for special education teachers working to implement Response to Intervention (RtI) to support struggling students in mathematics. As one particular teacher in this study learned, diagnostic interviews[2] helped her understand how four of her students understood multiplication and where they were having difficulties. Another layer of learning for the teacher involved how the interview protocol, which included the selection of tasks, served as a learning tool. Such tasks needed to be developmentally appropriate, and deliberately chosen to illustrate particular types of understanding (i.e., conceptual, computational, etc.). These tasks provided additional insights to the teacher. Generally speaking, as per the RtI model, the diagnostic interviews allow the teacher to identify the students who are in need of assistance, but also develop a plan of action for the student (and for classroom instruction, more generally) based on what is learned from the interview.

Encouraging teachers to use clinical interviews to obtain more information about their students' mathematical thinking has benefits for the students as well. As Kaplan and her colleagues (2000) discovered, children who were underperforming in mathematics were able to gain confidence in their abilities and see mathematics as something they could be "good at." This was due, in part, to their teachers' ability to listen to students explain their reasoning during a semi-structured clinical interview, identify areas where misconceptions were present, and then

[2] Hodges, Rose, and Hicks (2012) and Moyer and Milewicz (2002) use the phrase diagnostic interviews to describe clinical interviews that involve observation and questioning of one child, in a one-to-one setting, to find out more information about their thinking of a particular topic.

use this information to provide students with opportunities to reconstruct their learning in mathematically productive ways (during after-school tutoring sessions). Open-ended mathematical tasks were used in both the interview and the tutoring sessions to give students exposure to having to explain their reasoning, and having to use multiple representations to demonstrate their thinking processes. In effect, the students were participating in practices similar to those of a mathematician, with an end goal of having the students begin to think of themselves as capable mathematicians. One of the main components that Kaplan and her colleagues (2000) found contributed to the mathematical success of these students was that the reconstruction component of learning occurred in a fun and relaxing, yet conceptually challenging, environment. Teachers purposefully chose mathematical tasks that focused on students' strengths rather than weaknesses. The teachers were able to choose appropriate mathematical tasks based on what they learned about the students from their clinical interviews.

Prospective teachers using clinical interview methods. There is existing literature that examines prospective teachers conducting clinical interviews; this literature points to the learning potential that these interview experiences may have for prospective teachers. In particular, these studies note that clinical interviews may help prospective teachers to consider various aspects of children's mathematical thinking. In one such study, Jenkins (2010) had six prospective teachers enrolled in a mathematics methods course conduct their own structured interviews with students they were observing as part of a field experience. When analyzing the prospective teachers' interviews and analyses of their interviews, the researcher investigated three distinct types of listening (see Crespo, 2000; also Davis, 1996) the prospective teachers might have engaged in during their interviews: evaluative, interpretative, and hermeneutic. Davis (1996) describes evaluative listening as listening that only focuses in on whether a

student's thinking is correct or incorrect, and how to work on correcting any student misconceptions. Interpretative listening involves attending to students' strategies and ways of thinking, all the while trying to make sense of the information. Hermeneutic listening, described as a constant cycle (between a teacher and student) of listening to, interpreting, and reexamining mathematical understanding, can be considered the most sophisticated type of listening. In Jenkins' (2010) work, he found that his six prospective teachers were able to engage in interpretative listening of their students' understanding, with a few examples of evaluative listening that persisted through the three rounds of interviews the prospective teachers conducted. In fact, Jenkins' (2010) findings were similar to a study conducted by Crespo (2000) a few years earlier in which she, too, did not find any examples of hermeneutic listening amongst her prospective teachers. One difference in the two studies was that Crespo (2000) did not have her prospective teachers engage in interviews with students; instead, the prospective teachers engaged in a letter-writing activity with fourth-grade students. Yet both studies analyzed the data for evidence of the three types of listening described by Davis (1996). In reflecting on her results, Crespo (2000) wondered whether prospective teachers are even capable of engaging in hermeneutic listening. This question is an important one to consider when thinking about the types of experiences prospective teachers can engage with prior to entering a classroom, and what types of listening skills we hope to foster in future teachers.

McDonough and her colleagues (2002) described, more generally, several themes that emerged when prospective teachers conducted and reflected on interviews. Using protocols from a larger study, the prospective teachers interviewed elementary-aged children as part of their teacher preparation coursework. The goals of the study, as listed by the authors, were:

- To give them [prospective teachers] a sense of what young children know and can do in mathematics.

- To focus their attention on the variety possible in young children's mathematical thinking and strategies.
- To provide a model of kinds of *tasks* [emphasis their own] that can be used meaningfully with children in individual and group situations.
- To provide a model of kinds of *questions* [emphasis their own] that can be asked of young children that are likely to elicit their thinking and strategies (McDonough, Clarke, & Clarke, 2002, pp. 216 – 217).

The authors found that prospective teachers were able to recognize the power of the interview process in giving them information about their students. The individualized attention that the prospective teachers are able to give the children during an interview setting sends the message to the students that their ideas and thinking are valued, thereby increasing their confidence as mathematics learners. In addition, the interviews made the prospective teachers more aware of the various strategies children may draw upon when solving mathematics tasks. In terms of relating what they learn through the interviews and its relation to classroom practice, the prospective teachers were made aware of the different types of questions that can be asked to students to elicit their thinking and expose their understanding. Finally, the prospective teachers were able to relate what they learned from their interviews to their own conceptions about appropriate classroom experiences for children to engage meaningfully with mathematics, and what implications this had for their own teaching practice.

Similarly, Schorr (2001) identified three themes that emerged from prospective teachers using the clinical interview method with young children, and sometimes, with adults. Like McDonough and colleagues (2002), Schorr (2001) found that the prospective teachers in her study began to reexamine their views and beliefs about what constituted mathematics teaching, and how this was often different than previously held conceptions. In addition, the clinical interviews provided the prospective teachers with opportunities to consider children's (and adults') unique strategies when solving mathematics; this allowed the prospective teachers to

appreciate the variety of solutions that interviewees drew upon when engaging in mathematics, and that these solutions may not always match their own ways of thinking. A third theme that emerged from the prospective teachers' reflections of the interviews was that correct responses during an interview do not necessarily indicate understanding on the interviewees' part. As an example, respondents in the study noted instances where interviewees could successfully apply a procedure to obtain a correct solution, but could not explain the mechanics behind the procedure (i.e., why the procedure works for the given situation).

In sum, the act of conducting clinical interviews appears to provide prospective teachers with opportunities to consider how someone comes to know and understand mathematics, and how they think about particular mathematical topics. These insights into the mathematical thinking of young children, and even older students or adults, can then translate into teachers' instructional practices. Teachers can take the questioning techniques employed in the clinical interview and use them when questioning students during mathematics instruction. In addition, teachers can come to appreciate the complex ways in which someone internalizes mathematical concepts and tries to make sense of them, albeit in their own unique ways.

Mathematical Capabilities of Young Children

The video cases selected for use in this study were chosen to illustrate some of the mathematical concepts and ideas that students can master at an early age (Clements, Sarama & DiBiase, 2004; Copley, 1999; NCTM, 2000). Prospective elementary teachers often enter their teacher education programs with preconceived notions about what it means to "do" mathematics and the mathematical ability of young children. This is often reflective of their own mathematical experiences and abilities (Bullough, 1997; Pajares, 1992; Philipp, 2007; Thompson, 1992). It was therefore important that this dissertation study include video cases that

demonstrated the possible understanding/mastery of a mathematical concept at various early grades (primarily grades pre-Kindergarten – third grade). This allowed for the prospective teachers to (re)consider the mathematical ability of their future students, as well as give them models of what questions can be asked, or what activities can be given to their students to foster mathematical thinking and understanding. It also presented the prospective teachers with an opportunity to consider the complexity of the mathematical thinking of young children, and how it might be different than expected.

In making the case for teachers' knowledge and use of learning trajectories[3] in their planning and instruction, Sarama and Clements (2009) write:

> …even the youngest children possess powerful beginnings of mathematical ideas, and they use and develop these ideas to make sense of their everyday activities. However, their ideas and their interpretations of situations are particularly different from those of adults. Early childhood teachers must be particularly careful not to assume that children "see" situations, problems, or solutions as adults do. Therefore, teachers should interpret what the child is doing and thinking and attempt to see the situation from the child's point of view (p. 17).

For high quality mathematics instruction to take place, it is important for teachers to recognize the levels of thinking that children may progress through as they learn mathematical concepts, and learn to identify these levels as they happen in the classroom in order to be able to follow-up with appropriate questions or tasks to help the students progress further. Considering learning progressions in instruction also allows teachers to build upon the mathematics that children often bring with them to formal school settings, which are based upon out-of-school experiences (particularly in pre-school age children). In addition, as Sarama and Clements (2009) note above, teachers must also recognize that their own ways of thinking about mathematics may not

[3] Clements and Sarama (2004) identify three components that constitute a learning trajectory of a specified mathematical domain: goals within the mathematical domain that students are to learn, levels of thinking that students progress through as they engage with the mathematical goal(s), and teachers' instructional practices that facilitate students' attainment of these goals.

match their students' ways of thinking and making sense of the mathematics. This is true for all educators, early childhood through later grades, as well as both prospective and in-service teachers.

Ginsburg (2009) also expresses the power of early childhood mathematics education and the importance of teachers in recognizing children's mathematical abilities. He writes:

> Usually, we have little insight into the complexity, abstraction, and relative power of children's mathematical thinking. Children's mathematics is a kind of hidden world that adults have to learn to see. And obtaining this insight is one of the joys of cognitive psychology, and the kind of child study that teachers need to learn to do (p. 408).

The kind of child study that Ginsburg refers to requires teachers to be able to first, appreciate children's mathematical thinking. Subsequently, teachers must then be able to recognize instances where children are engaged in mathematical thinking and capitalize on those moments, often referred to as teachable moments. These moments may occur in contexts that some might consider non-mathematical, such as when children are engaged in free, unstructured play. This also requires the teachers to be sufficiently comfortable with their mathematical knowledge to be able to anticipate what activities may build on children's mathematical thinking. Ginsburg (2009) cautions that teachable moments alone are not enough to enhance the mathematical education of children, but that coupled with other factors, such as curriculum, projects, free play, and an engaging learning environment, these moments can be quite effective.

In the next section on teacher noticing, the idea of deep observation of children's mathematical thinking is expanded upon. While learning to become careful observers of children's mathematical thinking is important, it is also useful for teachers to know *what* to look for and what to pay attention to.

Teacher Noticing

A number of researchers have discussed the importance of having teachers develop the skill of professional noticing (Mason, 2002; Sherin, Jacobs, & Philipp, 2010), while acknowledging the complexity and difficulty of the process (Santagata, Zannoni, & Stigler, 2007; Star & Strickland, 2008: van Es & Sherin, 2002). Professional noticing allows teachers to observe particular features of the classroom and its activities and make pedagogical decisions informed by these observations. Because many daily classroom activities require teachers' attention, teachers must also be skillful at noticing what is useful and filtering out what is not.

While much work has been done on the variety of lenses teachers use to make sense of what they see in classrooms, Jacobs and her colleagues (2010) detailed a framework specifically for the professional noticing of children's mathematical thinking. In the framework, they identified three components that make up professional noticing of children's mathematical thinking: (1) attending to children's mathematical strategies, (2) interpreting children's mathematical understandings as seen in the strategies children use while problem solving, and (3) deciding how to respond based on children's mathematical understandings (paraphrased from Jacobs et al., 2010). In examining differences across four participant groups[4], which included 131 prospective and practicing teachers, Jacobs and her colleagues found that expertise in the first component of their framework, attending to children's mathematical strategies, grew as the number of years of teaching experience increased. But teaching experience alone was not an

[4] The four participant groups were: Prospective Teachers, Initial Participants, Advancing Participants, and Emerging Teacher Leaders. Prospective Teachers did not have teaching experience, nor did they participate in professional development activities. Initial Participants had some teaching experience but no professional development participation (yet). Advancing Participants had teaching experience and 2 years of participation in professional development. Emerging Teacher Leaders had teaching experience, 4 or more years of teaching experience, and had participated in teacher leadership activities such as mentoring, co-teaching, and participation in professional conferences.

indication of expertise in attending to children's strategies—this growth was sustained as teachers participated in two years of professional development focused on children's mathematical thinking. Similarly, expertise in the second component of the noticing framework, interpreting children's mathematical understandings, increased as both the number of years of teaching and the number of years of professional development increased. Finally, when measuring expertise in deciding how to respond to children's mathematical understandings, Jacobs and her colleagues noted that teaching experience did not necessarily have an impact on teachers' abilities to decide how to respond. What did help teachers in deciding how to respond was the amount of professional development they engaged in, with at least two years of professional development, as well as participation in leadership activities, helping teachers develop this particular skill. Results from Jacobs and colleagues' study highlight the importance of sustained engagement in activities that promote a focus on children's mathematical thinking, as well as opportunities to consider how to respond on the basis of children's mathematical thinking. As was seen in study results, participation in professional development activities that focus on children's thinking can help teachers develop their noticing skills. This type of focus on professional noticing of children's mathematical thinking is necessary considering how challenging it can be for adults.

As is discussed in the next section, when teachers attend to children's mathematical thinking, they may encounter instances where the child's thinking is different than their own. They may also encounter instances where a child expresses a mathematical misconception or an error. Teachers' conceptions of children's mathematical errors may have implications for their practice, depending on how they view those errors and what they decide to do with the information encoded within a child's mathematical error.

Children's Errors

Ames and Archer (1988) discuss the ways in which some students learn to embrace their errors as learning opportunities. They maintain that this is more likely to occur when teachers design classroom environments where errors are viewed as a natural part of the learning process. In such an environment, referred to by Schorr and colleagues (2010) as an *emotionally safe learning environment,* students are not afraid to make mistakes and are willing to engage in conversations about them. At times, discussions involving mistakes can provide opportunities for teachers and students to discuss ideas that might otherwise be overlooked or ignored. In order for this to occur, teachers must be able to recognize errors, listen closely to the nature of the error, understand some of the possible underlying reasons that surround the error, and know when and how to address them.

Practicing teachers' treatment of children's errors. Dealing with student errors is not a simple or straightforward matter. Oftentimes teachers attribute errors to different things. For example, Gagatsis and Kyriakides (2000) found that there were four main factors that teachers used to explain student errors. They were: student characteristics, the teacher's role in the instructional process, the mathematical knowledge of the students, and the 'rules' that students tend to call on to guide their work in the mathematics classroom. Another way researchers have investigated mistake-handling activities in the classroom was to document the type of teacher responses that occur 'in-the-moment'. While some teachers opt to make the errors that they notice public and part of a whole-class discussion, others prefer to have a private conversation with the student making the error (e.g., Santagata, 2004, 2005). Schleppenbach and colleagues (2007) found that, for those teachers choosing to make errors part of a larger whole-class discussion, some ask more follow-up questions of their students regarding the errors (thereby

eliciting more student reasoning), while others tended to make statements about the errors (for example, telling a student their response was incorrect, giving the student the correct answer, ignoring the error, having a student correct the error through guided direction, or explaining the error to the class).

Prospective teachers' treatment of children's errors. While these studies looked at practicing teachers, Son and Sinclair (2010) looked at prospective teachers' responses to students' geometric errors and found that the prospective teachers recognized student errors in terms of the more conceptual aspects in the mathematical tasks; when it came time to respond to these errors, they reverted to more procedural approaches. Initially, the researchers began their study with the hypothesis that prospective teachers with higher content knowledge would be better able to respond to students' errors. As noted in their results, this was true for anticipating and even identifying students' errors, but not so when it came time to respond to students' errors. Based on Son and Sinclair's (2010) results, it would appear that content knowledge alone is not enough to be able to provide appropriate responses to students' errors. Ball, Hill, and Bass' (2005) work supports this observation, calling for development of teachers' pedagogical content knowledge (PCK) as an important predictor of effective teaching. As they describe, effective teaching includes not only identifying incorrect student thinking, but also "analyzing the source of the error" (Ball, Hill, & Bass, 2005, p. 17).

VITAL (Video Interactions for Teaching and Learning)

Video cases for use in mathematics teacher education are available in a variety of formats (c.f., Agnew, Mills, & Maher, 2010; Boaler & Humphries, 2005; Carpenter et al., 1999; Chapin, O'Connor, & Anderson, 2009; Ginsburg, Kaplan, & Baroody, 1992; Philipp, Cabral, & Schappelle, 2005; Seago, Mumme, & Branca, 2004). For this particular study, access to clinical

interview video cases was provided by Columbia University's Center for New Media Teaching and Learning, via an online platform titled Video Interactions for Teaching and Learning (VITAL). VITAL was initially designed to be used in a graduate level early childhood mathematics education course at Columbia University. Since then, it has been used in teacher education courses at many other universities (e.g., Inoue, 2009; Lee, Ginsburg, & Preston, 2009).

The VITAL online environment has three main features. The first is an extensive library/repository of videos that included clinical interviews with children, whole-class mathematics discussions and lessons, and videotaped television shows with relevant mathematical content. The second feature is a video viewer that allows users to view assignment videos, and select video excerpts to be clipped, tagged, and archived in a user's personal library for use as supporting evidence in multimedia essays/reflections on the assignment videos. Finally, the third feature is the writing space for the multimedia reflection, where users could respond to the videos and support any of their findings with video excerpts. Once uploaded, the reflections are available for reading by course instructors and other users enrolled in a course using the VITAL software. In addition, the instructor could leave feedback to the student.

Results from university courses that utilized VITAL as part of the training experience for prospective and practicing teachers illustrate the potential growth of teacher knowledge in various areas. For example, Preston (2009; see also, Ginsburg, Cami, & Preston, 2010) examined the argument skills of 20 prospective teachers enrolled in an educational psychology course titled "The Development of Mathematical Thinking." In looking at the arguments the prospective teachers were making in response to children's behavior documented in assignment videos, Preston focused on five elements: claims, evidence, relational statements, modest statements, and references to literature. In his analysis, Preston found that, over the course of the

semester, participating prospective teachers were able to make more careful claims based on their observation and interpretation of the VITAL videos. The prospective teachers supported each claim with more evidence (video and text-based), and they made connections between their claims and the evidence (via relational statements). In addition, some prospective teachers developed what Preston terms "intellectual humility," evidenced by their use of conditional language (e.g., might, maybe, could, appears, seems, etc.) within their written reflections, and their apparent acceptance that interpretations of children's behavior may change in light of new evidence. These findings are particularly encouraging in light of the results of the dissertation study presented herein.

Inoue (2009) discusses a different use of VITAL in educational psychology courses. Prospective teachers enrolled in Inoue's courses completed VITAL assignments four to five times throughout the semester. In these assignments, they discussed topics such as pedagogical content knowledge, students' misconceptions, and cognitive development. For one particular VITAL assignment, the prospective teachers were asked to watch a video of two young children building a house with blocks, and relate their course discussion on Piaget's theory of cognitive development (and in particular the idea of disequilibrium) to the children's behavior as seen in the video. Inoue found that, of the 54 prospective teachers completing the assignment, 91 percent were able to connect the psychological concept of equilibrium to the specific context of the video (the physical environment the children in the video were in, and the social interactions between the children as they used the blocks to construct a house). In addition, Inoue found that 89 percent of the arguments made by the prospective teachers were supported by evidence from the video, although the link between evidence and argument varied amongst the prospective teachers.

This conceptual framework serves as background information to the dissertation study presented in this overall report. In the next chapter, the methodology of the dissertation study is discussed. Following that is a presentation of the results of this dissertation study, which connect to many of the ideas presented in this conceptual framework.

Chapter 3: Methodology

The study reported on in this dissertation sought to examine the nature of the observations that prospective teachers made when watching video clips of clinical interviews, and then examine these together with the written accounts of the clinical interviews that they conducted on their own. This chapter looks at how the prospective teachers that participated in this study were selected, the tool they used to watch and record their observations about clinical interviews, and the themes that were used to organize the data in reporting analysis results.

Sample

The participants consisted of prospective teachers enrolled in an elementary mathematics methods course (n = 18[1]) during the Fall 2008 semester. While the course title, Elementary Math and Pedagogy, suggests it being a requirement for only prospective elementary teachers, many secondary education candidates, particularly those with a major concentration in Mathematics, often enrolled in the course as well. This is because there were no other mathematics methods courses offered to middle and high school mathematics majors at the time. The prospective teachers I studied were seeking certification through the Urban Teacher Education Program (UTEP) at Rutgers-Newark. In the sample for this study, 15 of the 18 prospective teachers identified themselves as belonging in the elementary education certification track, including those reported to be seeking middle school certification. The major/area of study for these students was as follows: seven Psychology majors; three English majors; one History major; one Biology/Chemistry double major; one Management major with a Biology minor; one Sociology major with a Criminal Justice minor; and, one Information Technology major with an English minor. The remaining three out of 18 prospective teachers identified themselves in the

[1] Seventeen of the 18 students gave consent for use of their written work.

secondary education certification track. Of these three, two were pursuing bachelor degrees in mathematics, and the third had studied engineering, chemistry, and mathematics.

Context

The setting of the study, the elementary/middle grades mathematics methods course, was a component of the teacher certification program that was a requirement at the time. The data collected for this study spanned one semester, or approximately sixteen weeks in the Fall 2008 semester (September-December). The course required the prospective teachers to conduct several assignments (including fieldwork/classroom observations, lesson plan writing and revision; written reflections and oral presentations on assigned course readings); in addition, prospective teachers in the course completed weekly VITAL[2] assignments, for a total of eleven reflections on the VITAL website (see Data Collection section, in this chapter, for a description of VITAL). These assignments consisted of written, electronic reflections in which the prospective teachers were asked to watch, interpret and analyze assigned videos (consult Appendix A for assignment instructions); they were also asked to clip excerpts from the interview videos to support details in their electronic essays (see Data Collection section for an explanation of the video clipping method).

As mentioned previously, the video cases the prospective teachers were asked to watch primarily involved clinical interviews conducted with young children, ranging in grade level from pre-Kindergarten to third grade. Herb Ginsburg conducted some of the interviews, while others were conducted by his colleagues and graduate students at Columbia University, and elsewhere. The remainder of the videos consisted of either classroom lessons that illustrated the mathematical concept(s) the prospective teachers were exploring at that time in the course (e.g.,

[2] Video Interactions for Teaching and Learning (VITAL).

video modeling a geometry lesson assigned when prospective teachers in this study were exploring geometric ideas in the methods course) as well as instances of children in informal mathematical settings (such as unstructured play time, either during school or outside of school). The eleven VITAL assignments and their associated videos, which were spread throughout the sixteen weeks of the course, were divided into sections based on the topics that were to be covered weekly throughout the semester. These topics included mathematical content areas, as well as pedagogical issues in the teaching and learning of those topics. The assignments were grouped as follows:

Table 3.1

Assignment Topic & Associated Videos[3]

Date	Topic	Associated Videos & Video Codes[4]	Grade Level
9/23/2008	Numbers & Counting	Video 1 (*V1a*): Counting Beads (free play)	Kindergarten
		Video 2 (*V1b*): Writing Numbers Backwards (clinical interview)	1st
9/30/2008	Freeplay & Mathematical Thinking in the Early Years	Video 1 (*V2a*): Building a road and a tower (free play)	Pre-Kindergarten
		Video 2 (*V2b*): Writing numbers (free play)	Pre-Kindergarten
		Video 3 (*V2c*): Making patterns with bears (free play)	Pre-Kindergarten
		Video 4 (*V2d*): Playing with building blocks (free play)	Kindergarten
10/7/2008	Numerical Operations	Video 1 (*V3a*): Division story problem (clinical interview)	1st
		Video 2 (*V3b*): Double-digit addition with regrouping—Using base-ten blocks and paper (clinical interview)	1st
		Video 3 (*V3c*): Noticing patterns in multiplying nines (classroom lesson)	2nd
		Video 4 (*V3d*): Solving addition & subtraction problems – Derived facts & base-ten blocks (clinical interview)	1st
		Video 5 (*V3e*): Subtraction using number line (clinical interview)	2nd

[3] Refer to Appendix C for a description of the assignment videos.
[4] The video codes are used to reference assignment videos in the Results and Discussion chapters of the dissertation.

10/14/2008	Exploring Curricula	Video 1 (*V4a*): Count Clap & Stomp A (classroom lesson)	Pre-Kindergarten
		Video 2 (*V4b*): Dum Di Dum Dum (classroom lesson)	Pre-Kindergarten
		Video 3 (*V4c*): Hokey Pokey (classroom lesson)	Kindergarten
		Video 4 (*V4d*): Take Away Stories (classroom lesson)	Pre-Kindergarten
10/21/2008	Place Value	Video 1 (*V5a*): Numerals and place value (clinical interview)	1st
		Video 2 (*V5b*): Place value – 300 vs. 103 (clinical interview)	1st
10/28/2008	Reasoning, Communication, Testing	Video 1 (*V6a*): Assessment – Encouraging a child to explain his thinking (clinical interview)	Kindergarten
		Video 2 (*V6b*): Communication – comparing sums without computation (clinical interview)	2nd
		Video 3 (*V6c*): Proving "12 – 9 = 2" with counters (clinical interview)	1st
		Video 4 (*V6d*): Reasoning and proof – 5 + 6 = 11 (clinical interview)	1st
11/4/2008	Rational Numbers	Video 1 (*V7a*): Fraction concepts in three children (clinical interview)	Kindergarten, 1st, 3rd
		Video 2 (*V7b*): Introduction to fractions (classroom lesson)	2nd
11/11/2008	Manipulatives	Video 1 (*V8a*): Discussing addition with Stern blocks (clinical interview in whole class setting)	1st
		Video 2 (*V8b*): Double digit addition with regrouping—Using base-ten blocks and paper (clinical interview)	1st
		Video 3 (*V8c*): Representation—Which represents 3x4 best? (clinical interview)	3rd
		Video 4 (*V8d*): Representing numbers & regrouping (clinical interview)	2nd
11/18/2008	Geometry	Video 1 (*V9a*): Identifying and coloring in triangles (clinical interview)	Pre-Kindergarten
		Video 2 (*V9b*): Identifying shapes (clinical interview)	Pre-Kindergarten
		Video 3 (*V9c*): Identifying shapes tactilely (classroom lesson)	Pre-Kindergarten
		Video 4 (*V9d*): Making pictures with pattern blocks (observation)	1st
		Video 5 (*V9e*): Matching shapes during clean up (observation)	Pre-Kindergarten
11/24/2008	Measurement & Data	Video 1 (*V10a*): Arranging children in order of height (classroom lesson)	Pre-Kindergarten
		Video 2 (*V10b*): Make It Heavier (classroom lesson)	Pre-Kindergarten

		Video 3 (*V10c*): Comparing lengths of ribbons (clinical interview)	Pre-Kindergarten
		Video 4 (*V10d*): Seriation (clinical interview)	Pre-Kindergarten
		Video 5 (*V10e*): Sorting and graphing bears and hearts (classroom lesson)	2nd
12/2/2008	Patterns & Algebra	Video 1 (*V11a*): Difficulties in an interview about patterns (clinical interview)	Pre-Kindergarten
		Video 2 (*V11b*): Caterpillar patterns (clinical interview)	2nd
		Video 3 (*V11c*): Extending a pattern (clinical interview)	Pre-Kindergarten
		Video 4 (*V11d*): Finding mistakes in a pattern (clinical interview)	Pre-Kindergarten
		Video 5 (*V11e*): Noticing patterns in multiplying nines (classroom lesson)	2nd

Coupled with the video case assignments, were required readings of selected chapters from Ginsburg and colleagues (Ginsburg, 1997; Ginsburg et al., 1998) to introduce the prospective teachers to the clinical interviewing process and its applications to the classroom.

One important note to make is that the setup of the video cases, as well as the proposed methods of data collection and analysis, were highly specific (because of the use of the VITAL website), and thus, I was present in the course to ensure the data points for my study existed. My presence in the course was as a graduate student instructor/researcher. For more information regarding my position as instructor/researcher in the course, refer to the section on reliability and validity, in this chapter.

Data Collection

The prospective teachers were given access to the clinical interview video cases that they used to complete their written assignments through a website developed by Columbia University, in conjunction with the Columbia Center for New Media in Teaching and Learning (CCNMTL). The forum was titled VITAL (Video Interactions for Teaching and Learning) and was a National

Science Foundation-funded venture[5] housing an online repository of clinical interview videos stemming out of work from Professor Herbert Ginsburg and colleagues at Teachers College, Columbia University (see project's public site at http://ccnmtl.columbia.edu/vital/nsf). The VITAL platform included:

- a digital library of clinical interview video cases, as well as video of classroom lessons and excerpts of television shows geared towards the early childhood level;
- a word-processing feature, which worked similar to that of Microsoft® Word, that allowed users to produce electronic essays which were responses/reactions to the videos watched; and
- a video-clipping feature that provided users the opportunity to embed video excerpts into their essays in addition to the text (see Sorkin & Preston, 2010, for more information).

The prospective teachers were asked to log on to the VITAL site at the end of every week and complete written reflections on the assigned videos. VITAL captured the written essays produced by the prospective teachers, and allowed the instructor (myself) a space in which to provide feedback to the prospective teachers prior to the discussions that were held at the beginning of each class session the following week.

As mentioned above, one notable feature of the VITAL forum was the ability for the prospective teachers to create excerpts, or clips, from the videos that they were assigned. The clips could be chosen by setting a start and end time and could be identified using tags, or keywords, that would later help the user retrieve a clip for reference. These clips could then be embedded into the prospective teachers' electronic essays to support written statements or assumptions and to support their analysis of the videos watched.

The written, electronic VITAL essays were one of the types of written artifacts that were collected as part of the data set. The other piece of written work was a reflective end-of-semester

[5] Supported by Grant No. ESI-0353402. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of Columbia University and/or the National Science Foundation.

essay, which explicitly asked the prospective teachers to reflect on the usefulness of the video cases, as well as other components of the course, with relation to their own professional teaching agendas. This reflective essay was collected at the end of the course, and prospective teachers were given the option of submitting this assignment electronically in the same fashion as their VITAL essays. The reflective end-of-semester essay was one way to ensure triangulation of the data by capturing the prospective teachers' own perspectives on using VITAL, but more specifically, whether or not they had any opinions on the clinical interview method and its utility. As many authors note (for example, see Creswell & Miller, 2000; Lincoln & Guba, 1985), triangulation of the data by collecting multiple data sources is one of many methods to ensure credibility and reliability of the data being reported.

A third example of written work that was analyzed as part of this study were two[6] clinical interview assignments, in which the prospective teachers chose a subject, planned an interview activity, and conducted their own clinical interviews (consult Appendix A for assignment instructions). For this assignment, the prospective teachers were able to choose mathematical activities to ask their interviewees from a variety of sources: (a) assigned readings related to clinical interviewing (Ginsburg, 1997; Ginsburg et al., 1998); (b) the required textbook for the methods course (Van de Walle, 2007); and, (c) tasks/activities adapted from the VITAL assignment videos. These sources were encouraged to be used during interview question/task selection, as opposed to having the prospective teachers create their own questions/tasks, for two reasons: (a) so that they would have a model to follow for the interview, and therefore, have less stress in trying to create their own developmentally appropriate questions; (b) so that there would

[6] Most prospective teachers in the course conducted the two required interviews and a third interview report that was meant to be a comparison and commentary of the first two interviews OR a redo of one of the first two interviews; a small subset conducted a fourth interview for extra credit.

be examples of some anticipated child responses to questions and possible ways to follow-up with a child being interviewed based on previous interview experiences. The prospective teachers were also instructed to try and interview a child in the Pre-Kindergarten to third grade age range, in order to be able to use some of the mathematical tasks as seen on VITAL. The first of the two clinical interviews was conducted after having completed the fifth VITAL assignment, so that the prospective teachers had enough time to read about and view examples of other clinical interviews. The second clinical interview was completed after the ninth VITAL assignment. The prospective teachers submitted both a written reflection on their interviews, as well as an audio/video record (to ensure that the assignment was completed legitimately). The written assignments were included as data points in order to understand what effects the online video cases of clinical interviews might have had on the prospective teachers' understanding of the clinical interview process, and of the mathematical development of young children, among other things.

As suggested by Marshall and Rossman (2006), observation notes and research memos help to document the development of the coding themes (and subthemes). The observation notes included as data for this study were from class discussions that were held after each written assignment had been completed online and submitted. The research memos were from insights gleaned through my participation in the course during the semester, as well as preliminary codes coming from perusal of the data as it was collected. My participation was in the form of classroom discussions (which were audio-recorded) that were held on the week after a VITAL assignment was given. These discussions typically lasted about half an hour, and occurred at the beginning of each class session, led by myself and two co-instructors/researchers. During these discussions, the prospective teachers were able to restate some of the observations made within

their own VITAL essays, as well as hear the thoughts of their peers. Common themes that emerged from my analysis of all VITAL essays for the week were also brought to light during the whole-class discussions, but only after the prospective teachers had the opportunity to reflect about ideas that they generated. In sum, the written, electronic essays, as well other written artifacts (i.e., clinical interview reports, observation notes, and research memos) served as unobtrusive measures to supplement the audio-recorded data.

Data Analysis

Because the data included my own perceptions of the situation and of the prospective teachers (through my observation notes and the notes of two other mathematics education researchers), as well as data directly from the prospective teachers describing their experiences, a combination of a typological and inductive analysis of the data (Hatch, 2002; Lofland, 1971) was conducted. This analysis was conducted in conjunction with two other mathematics education researchers who were co-instructors of the course. The analysis was typological in nature because I identified typologies, or categories, that came out of the data set. In this dissertation, I use data excerpts as a way to illustrate some of the typologies that were identified through analysis of the data. In addition, an inductive approach to analyzing the data set allowed me to generate domains (or categories) that, while being grounded in the specific cases of this particular group of prospective teachers, might be confirmed (or disconfirmed) with another group of prospective teachers that can be studied at a later point.

Similarly, I purposefully chose prospective teachers for further study that fell into two additional categories: (1) a prospective teacher with a strong mathematics background and (2) a prospective teacher with few mathematics courses taken beyond the general education requirement; this was done to further illustrate the effects of using the clinical interview method

(along with clinical interview video cases) with this subset of the overall study population. These two categories were available for study given the sample for the study (prospective teachers going for either elementary, middle or secondary school certification, as well as mathematics and non-mathematics degree majors). To choose the prospective teachers that fit these and other categories, results from a survey developed by White, Way, Perry, and Southwell (2006) that was administered at the beginning and end of the course was used. The survey was designed to gain information on prospective teachers' attitudes towards mathematics and mathematics teaching, exploring their perspectives on themselves as learners *and* as teachers of mathematics. The entire survey can be found in Appendix B, but the following is a sample of items that were included:

- I find many mathematical problems interesting and challenging.
- I have always done well in mathematics classes.
- I have hesitated to take courses that involve mathematics.
- I am confident about the methods of teaching mathematics.
- I never do well on tests that require mathematical reasoning.
- Of all the subjects, mathematics is the one I worry about most in teaching.

Within the 20-question survey, there were two factors[7] that emerged which were scored for each respondent: insecurity and confidence (in learning and teaching mathematics). Changes in these scores from pre- to post-administration of the survey were examined (using the statistical software SPSS) to determine which prospective teachers were going to be analyzed as cases for this dissertation report. Table 3.2 displays the gain scores across administrations for the two factors.

[7] These factors emerged based on analysis conducted by the survey authors; I replicated the analysis and used the same two factors for my study.

Table 3.2

Gain Scores for Insecurity and Confidence Factors[8]

	Gains	
Participant	*Insecurity*	*Confidence*
Alvin	-0.3334	+0.375
Amelia	-1	+1.25
Alicia	0	+0.875
Allegra	-1	+1.75
Anita	-0.5556	+1.25
Adolfo	-2.4444	+0.625
Annemarie	-0.2222	+0.375
Bette	+0.3334	+0.625
Clarisse	+0.3333	-1.25
Debbie	-0.2222	+0.875
Joanna	-1.3333	+0.125
Monica	N/A (didn't take post)	N/A (didn't take post)
Melissa	-1.888	+1.125
Renee	0	-0.875
Stacy	+0.5555	+0.75
Sara	-0.6667	+0.0357
Tania	+0.4444	+0.25
Tim	-0.6666	+1.5

After reviewing this piece of the data, it was determined that six prospective teachers fit my criteria for further study: Alvin, Adolfo, Melissa, Renee[9], Tania, and Tim.

Cases

Alvin. Alvin, one of the three male case studies, was seeking secondary education certification at the time of the study; he was also enrolled as an mathematics major at the New Jersey Institute of Technology. Alvin was one of the two prospective teachers chosen who was the recipient of a Noyce Teacher Scholarship[10]. Alvin was chosen for this dissertation study because his survey results showed a slight decrease in his insecurity in teaching mathematics, and a slight increase in his confidence in learning mathematics. In addition, Alvin was one of

[8] A negative score indicates a decrease, while a positive score indicates an increase.
[9] Sara was originally chosen as a case study but later rejected because of lack of data points; Renee became the sixth case study.
[10] The Noyce Teacher Scholarship program is a National Science Foundation-funded scholarship that supports science, technology, engineering, and mathematics majors in pursuing K-12 teaching certification and in teaching in a high-needs school district.

the older students in the course, who had a school-aged daughter that he interviewed for his clinical interview assignments. His experiences with his daughter came up during the analysis of his VITAL reflections.

Adolfo. Out of the eighteen prospective teachers enrolled in the course, Adolfo appeared to have the highest decrease in his insecurity to teach mathematics, as per the survey results. Adolfo, a middle-aged male, was enrolled in the secondary education track at Rutgers-Newark. Adolfo was the second recipient of the Noyce Teacher Scholarship. He was pursuing education as a second career at the time of the study, having worked in the fields of chemistry and engineering previously.

Melissa. Melissa, one of three females chosen, was initially included to even out the number of male and female case studies. She was one of the only prospective teachers (other than Tim) with previous teaching experience, as a Primary Directress at a Montessori school; this previous teaching experience appeared to influence her reflections on VITAL (instances which are noted in the Results section). The survey results for Melissa indicated a relatively high decrease in her insecurity teaching mathematics (but not as high as Adolfo's), as well as a relatively high increase in her confidence learning mathematics.

Renee. Like Alvin, Renee was a declared mathematics major and had two school-age children, whom she included as interview subjects for her clinical interview assignments. Her survey results indicated no change in her insecurity teaching mathematics, and close to a one-point decrease in her confidence learning mathematics. This decrease noted in the latter category was an interesting finding, but was not further explored for the purposes of this study.

Tania. Tania had been written about previously (see Arias, Schorr, & Warner, 2010), and was an interesting case to examine because her survey data showed a slight increase in her

insecurity in teaching mathematics (a somewhat unexpected result), as well as a slight increase in her confidence in learning mathematics. It is possible that her insecurity as a learner of mathematics may have influenced her insecurity in having to teach mathematics, if only at the elementary level.

Tim. Tim, the third male in the course and chosen as a case study, had the greatest increase in confidence for teaching mathematics. Tim was a middle-aged male, as was Adolfo, who was seeking Middle School Science certification/endorsement. He appeared to have previous teaching experience as well, as noted in some of his VITAL reflections, but this observation was not confirmed by Tim during the course of the study.

Once potential cases for further analysis were identified quantitatively, the written work (VITAL essays, clinical interview assignments, End Term Essays, etc.) was used to begin to answer the two research questions. Beginning with the 11 VITAL essays, I identified the nature of the observations made with regards to both the mathematical understanding of the children in the videos, and features and/or utility of the clinical interview method. After this was documented, an analysis of the clinical interview assignments served to provide additional data regarding the prospective teachers' understanding of children's mathematical abilities and/or clinical interviewing.

Organization of the Data for Reporting Purposes

Upon initial, careful analysis of the written reflections of the six case studies as a whole, various themes began to emerge. It appeared that all of the prospective teachers, including the six prospective teachers chosen for further study, had changes in their reflections on two broad themes: children's errors and follow-up questioning. The first theme, *children's errors*, referred to instances where prospective teachers noted and/or discussed children's errors during the

interview (either during a VITAL video interview or their own clinical interviews). The second theme, *follow-up questioning*, referred to instances where prospective teachers followed a child's thinking and then asked a follow-up question or questions during the interview; these questions were typically asked to try to gain a deeper understanding of the child's thinking. A second situation where follow-up questioning was also discussed was in their VITAL essays, as they watched others conduct clinical interviews. For the purposes of this dissertation, I will be reporting on instances where the prospective teachers reflected on children's errors. Any instances where they also reported on follow-up questioning, within the context of children's errors, will be discussed where appropriate.

Figure 3.1 shows the theme of *children's errors* and its two main subthemes (*identifying* and *responding* to errors). While identifying errors, the explanations that the prospective teachers provided for the errors were captured in the themes listed under *identifying* errors. If and when the prospective teachers responded to the errors, this was noted by identifying whether it was an instance where they asked a follow-up question that led to a correction or whether the child recognized and corrected their error without prompting. These themes were developed to capture the nature of the reflections on children's errors occurring during VITAL video viewing and for the prospective teachers' own clinical interviews. It also provided a way to organize and report on the data included in chapter 4.

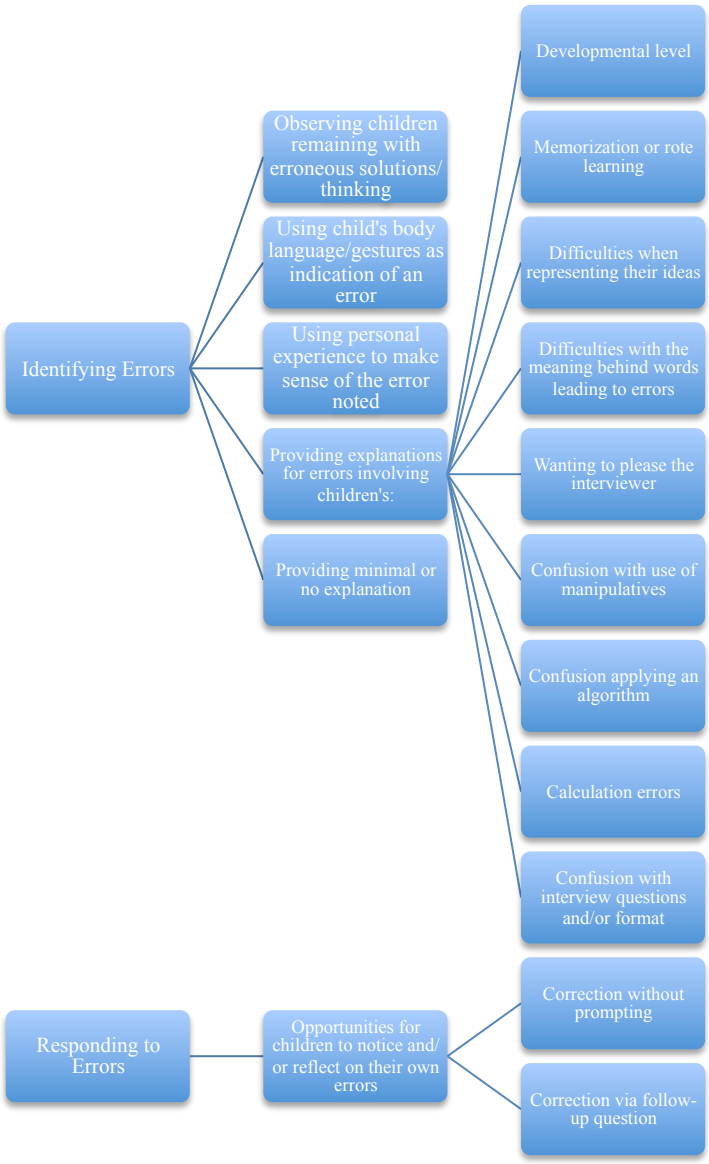

Figure 3.1. Themes used to organize responses to children's errors

Analysis of data for children's errors. I sorted through the assignment videos on VITAL to determine which ones had examples of children's errors (whether it was a calculation error or a misunderstanding of some sort). It is important to note that the assignment videos were not purposely chosen to illustrate children's errors, nor were the prospective teachers specifically prompted to identify and reflect on children's errors. Of the 11 VITAL assignments, there were seven that contained videos that had examples of children's errors. Table 3.3 shows

the instructions/prompts given to the prospective teachers for responding to the videos associated to these seven assignments.

Table 3.3

Instructions for VITAL Assignments Containing Examples of Children's Errors

Assignment Order & Relevant Information	**Instructions**
Numbers & Counting VITAL: September 23, 2008 (Assignment 1)	Based on the two situations you have seen in the videos, what can you say about the children's understanding of number? Particularly with the second video, are there any questions you might have wanted to ask had you been interviewing the child? Remember to draw upon readings you have done to support any of your observations/statements.
Freeplay VITAL: September 30, 2008 (Assignment 2)	Please watch the following videos as an outside observer. Select five different examples of the children's mathematical behaviors and explain why you think each is "mathematical." Please specify the child's name and/or video you are referring to when writing the essay.
Numerical Operations VITAL: October 7, 2008 (Assignment 3)	Tying in connections to Van de Walle & other readings, talk about the numerical operations expressed in each video, the tasks that students worked on while exploring the operations, and what you can tell about the students' understanding of these numerical operations through the clinical interviews & group lesson posed.
Place Value VITAL: October 21, 2008 (Assignment 5)	In these two clinical interviews, you had the opportunity to see Tarik & Shania (both first graders) explore concepts of place value through the interview questions. Are there any definitive statements you can make as far as each students' understanding of place value, based on their responses? How does this method of assessment (i.e. clinical interviewing), as opposed to a standardized test, for example, give you information about student understanding with regards to place value? Feel free to add in other questions you may have wanted to ask the student(s), or other place value tasks you may have wanted the student(s) to explore.
Reasoning, Communication, and Testing VITAL: October 28, 2008 (Assignment 6)	Incorporating what you have read thus far with regards to reasoning, proof, communication, and testing, what did these clinical interviews help to clarify about these concepts? For example, what forms of reasoning were evident in the students' responses? How were the students justifying their solutions? In what ways would they communicate their ideas? What forms of assessment were used? If none, what forms of assessment would be

	appropriate, or would you have used, had you been conducting these interviews? Was there anything that you felt was left out?
Geometry VITAL: November 18, 2008 (Assignment 9)	What geometric concepts are the children discussing or exploring in each video? How does this relate to what Clements (1999) and Van de Walle (2007) discuss about geometric thinking?
Patterns & Algebra VITAL: December 2, 2008 (Assignment 11)	Based on what you've read, and what was seen in the videos, how does the study of patterns facilitate algebraic thinking (at any age)? What can you understand about the children's knowledge of patterns as seen in the videos? Provide evidence for your reasoning.

The assignment videos were chosen prior to the start of the course based on the content (as explained under the Context section of this chapter and in Table 3.1). It was important to see whether or not the prospective teachers would spontaneously note the errors in the videos, and if they did, what written reflections their observations generated.

The video assignments were spread out throughout the semester, so that I was able to analyze responses to children's errors across some time. While a 14-week semester is not necessarily enough time to track significant changes, it still allowed for a window into how the clinical interview videos and writing assignments may have provided a context for prospective teachers to think about children's errors, as well as the possibility to record what implications these ideas may have for their teaching practice.

Responses to children's errors were noted as I began to analyze the VITAL assignments as a whole. In other words, I did not analyze the written reflections for the VITAL assignments with topics in mind; the topics emerged as I began reading the written reflections from the group. This topic was also chosen as an area to examine in more depth based on prior analysis involving one of six prospective teachers chosen as case studies (see Arias et al., 2010).

After having identified the assignments where I might find prospective teachers commenting and reflecting on children's errors, I grouped the written responses for those seven

assignments into one document. Only the six case studies' written reflections were included in this dissertation report. In addition, the results of the analysis are organized around the broad theme of children's errors, as noted above. The theme of follow-up questioning (within the context of children's errors) is mentioned where appropriate. Results are reported on in detail in chapter 4.

Issues of Reliability & Validity

The first issue to address with regard to reliability and validity was the fact that I was conducting research within a setting that I was familiar with, both as a former student in the teacher education program (and a former student of the methods course a few years prior) and my participation as an instructor/researcher during the data collection period. Research literature documents both positive and negative aspects associated with conducting research in familiar settings. Negative aspects include: (1) ethical and political dilemmas; (2) switching roles from having taken the course a few years prior to becoming the instructor/researcher of the course; and (3) predetermined expectations of participants and setting (Alvesson, 2003). The positive aspects, which I posit outweigh the negative, include: (1) easy access to participants; (2) potential to build important relationships, and (3) prior knowledge about participants and setting that may facilitate data collection and analysis (Toma, 2000). My familiarity with the teacher certification program was considered to be an asset in this study, in that the prospective teachers often sought me out to ask questions about the certification process, and about teaching at the secondary level. We also discussed my views on the use of videos in teacher education—in particular, how I found them useful and complementary to their field experiences by providing them more opportunities to work with children and consider children's thinking. Finally, my

experiences conducting clinical interviews with children at various grade levels was also discussed.

LeCompte and Goetz note five problems that ethnographers address to enhance external reliability of the data: "researcher status position, informant choices, social situations and conditions, analytic constructs and premises, and methods of data collection and analysis" (1982, p. 37). This dissertation study addressed *researcher status position* by making explicit my dual role as both researcher and instructor (of the course); this was done within the initial research proposal and to the prospective teachers through the informed consent forms they were asked to fill out prior to the start of the study. In addition, my status within the group being studied was made explicit as well. The prospective teachers were informed of my personal connection to the study (e.g., my position as a recent graduate of the teacher education program of which the participants were a part of, my own experiences with field work requirements and the use of video cases within the teacher education program, and my research as a doctoral student in mathematics education). This was communicated through course discussions at the onset and throughout the semester.

As mentioned previously, the themes that emerged from my initial review of the data were verified and refined in conjunction with two mathematics education researchers.

In the next chapter, results based on the analysis described herein are presented. As in this chapter, a brief overview of the six case study teachers gives necessary background information. Following the overview and background information are the results, organized by the themes identified in Figure 3.1, above.

Chapter 4: Results

This chapter details how the prospective teachers involved in this study reflected on the VITAL videos and their own clinical interviews. The first section will provide a brief overview of each of the six prospective teachers chosen for the more in-depth case studies, describing when and how their reflections progressed over the course of the semester. The second section will focus closely on one particular theme that all six of the prospective teachers noticed and commented on: children's errors. More specifically, that section will focus on when and how the prospective teachers responded to children's errors as they occurred in the VITAL assignment videos and in their own clinical interviews with children.

All six of the prospective teachers identified and addressed instances in which they felt that children made errors. As one might expect, the manner and depth in which they did so varied. Early on in the semester, when the prospective teachers were still new to the practice of interviewing and observing others conducting interviews, the reflections that they wrote regarding children's errors were limited to brief descriptions of the children's errors, as viewed in the videos. Generally speaking, they described exactly what the video showed, and provided little analysis or explanation for what they were seeing. As the semester progressed, and as the prospective teachers carried out their own interviews in addition to the VITAL assignments, instances of reflections on children's errors were accompanied by varying levels of analysis—from no explanation/analysis to in-depth reflections with a variety of explanations.

The data are organized around the themes[1] that emerged from the prospective teachers' explanations, with examples from their written work to illustrate each of the themes. In sum, the

[1] See Figure 3.1, in the Methodology chapter.
[2] Tania's written reflections had been analyzed previously (see Arias, Schorr, & Warner, 2010); this analysis served as a preliminary model for the results reported on in this chapter.

first section will provide some background information and a brief overview on the six prospective teachers chosen for further study. The second section is laid out as follows: the ways in which the prospective teachers *identified* and tried to make sense of children's errors; and, the ways in which the prospective teachers *responded* to children's errors.

As a reminder to the reader, the names of the prospective teachers, children in videos, and interview subjects used below are pseudonyms. To prevent redundancy in the reporting of results, the examples chosen as illustrations are mentioned under the theme where they are considered to be most appropriate; if and when there was more than one theme appropriate for a particular example, it is noted. The reader is also reminded that descriptions for all of the VITAL videos the prospective teachers refer to in their writing can be found in Appendix C. Lastly, to preserve the integrity of the prospective teachers' written work, there have been no edits made to the text (spelling and grammar inconsistencies are noted, where they occur).

Overview of the Case Study Teachers

Alvin. Throughout most of the semester, Alvin demonstrated his ability to provide detailed descriptions of the mathematical behavior of the children seen in the VITAL assignment videos. He described in words what he was seeing the children do in the videos, and provided some explanations for why he thought the children were thinking as they were. In addition, he started off the semester being able to provide conjectures for what he was seeing. He often drew upon his personal experience of having a young child at home to be able to make sense of what he was seeing in the VITAL videos. On many occasions, he referred to the assigned course readings as additional evidence for the conjectures he was making. In one particular assignment, Alvin mentioned the importance of observing both what a child said, as well as what they did, in order to make sense of their thinking. In this assignment, Alvin noted that, in his words, a

child's "gestures" can be a good indication of how the child might be thinking about a topic (e.g., observing a child using their fingers to count suggests the types of strategies a child is comfortable using to make calculations, even if the child does not mention using their fingers when asked to explain their reasoning). While this instance of Alvin's reflection was not related to a child's error, other prospective teachers also used children's gestures or body language during an interview to help them identify and interpret the children's mathematical errors.

For the three clinical interview assignments in which he had to choose a subject and conduct his own interview, Alvin decided to interview his daughter. His daughter was six years old and in first grade at the time of the interviews. The topics for the interviews varied—ranging from working with money, solving whole-number addition and subtraction problems using a number line, and division of whole numbers. These clinical interview assignments provided an additional opportunity to observe how Alvin chose to respond to children's thinking by noting the types of questions he would ask in response to his daughter's thinking during the interview. These assignments also demonstrated a progression in the types of questions Alvin was using to find out more about a child's thinking during an interview.

Adolfo. Adolfo's approach to reflecting on the VITAL videos appeared to be to answer the assignment questions, as per the directions, and provide detailed descriptions of each video. For all assignments to which he responded, Adolfo was able to describe each child's behavior as seen in the video, and describe possible strategies each child was using to make sense of the mathematics they were engaged in. At times, he would use his own experience as a mathematics learner to consider what he was seeing in the videos. For example, when reflecting on the use of manipulatives in the eighth VITAL assignment, Adolfo recalled never having the chance to use them as a student. Yet, he described the value he saw in having students use manipulatives to be

able to model mathematical situations. He even recalled using a chemistry model to help him remember a concept, something he can still remember to this day. In a few instances, Adolfo noted how his teaching philosophy matched the style seen in the VITAL videos. For example, when referring to the second video in the seventh VITAL assignment on rational numbers, Adolfo wrote that it was not necessary to discard a child's incorrect or unexpected response during a whole-class discussion—in other words, these responses can be used as discussion points for the whole class, and then the child who gave the incorrect or unexpected response could see that his/her ideas are valued.

Another strong theme that emerged from Adolfo's reflections was that he recognized that children's ideas about certain mathematical concepts may not necessarily match our own. An example of this is when Adolfo reflected on the Patterns and Algebra VITAL assignment; here, he stated that our own definition of pattern may not match the definition of pattern that young children might draw upon when asked to extend a pattern during an interview. Adolfo also demonstrated an ability to be able to follow children's thinking closely in order to then consider follow-up questions during an interview. The first VITAL assignment contained evidence of Adolfo doing this, as well as three other VITAL assignments throughout the semester. Interestingly enough, Adolfo did not consider follow-up questions for the assignments that did not specify a need to do so. In sum, for the VITAL assignments, Adolfo would provide descriptions of the children's behavior in the videos, and he made sure to answer the assignment questions given, but did not appear to provide additional comments or thoughts.

Adolfo interviewed his niece, a fourth grade student, in each of his three clinical interview assignments. These three assignments provided opportunities to observe how Adolfo used follow-up questions in considering a child's thinking in two mathematical domains:

multiplication of single-digit numbers (and how multiplication relates to addition and division); and, fractions (as parts of a whole and as number names) and equivalent fractions. In his first interview, Adolfo mentioned preparing initial and follow-up questions prior to the interview. Upon reflection, he realized that having too many questions and options for the child, prepared ahead of the interview, might serve to overwhelm the child and leave the interviewer without any true understanding of what a child knows about a particular concept. Because of this observation, Adolfo wrote that he would approach the next interview assignment with only one question and develop follow-up questions based on the child's responses during the interview. The second interview provided an opportunity to see how Adolfo handled a situation where his interviewee was exploring a concept she had not formally been introduced to in school (fractions larger than one whole). It was in this interview that his ability to ask follow-up questions based on his interviewee's knowledge of fractions was evident. Adolfo reflected that the child's prior knowledge, along with appropriate follow-up questions, could help a child tackle a new concept while building on their existing knowledge. The third interview dealt with the same topic as the second interview. Adolfo chose to explore fractions larger than one whole again, as well as look at how his interviewee thought about equivalent fractions. Again, these clinical interview assignments were valuable opportunities to observe how Adolfo was able to consider the planning, as well as the affordances, of conducting clinical interviews with young children.

Melissa. Melissa started the semester by providing a description of the events in the assignment videos, together with some of her insight into what was happening with the children. Melissa used course readings to support her observations in the first VITAL assignment, saying that the children in both videos did not appear to have made a connection between the symbolic and numerical representations of number. She also used her own personal experience working

with young children to try to make sense of what she saw. In fact, her personal experiences seemed to help her throughout her VITAL reflections. Many times, Melissa made mention of her own experiences as a mathematics learner, including her own lack of confidence while working on and explaining mathematics. She contrasted this with her surprise at the level of confidence of some of the children in the VITAL videos when they were asked to explain their thinking. This allowed her to conjecture that children can and will verbalize their complex mathematical thinking when given the opportunity to do so, whether this happens in a clinical interview setting or in the classroom. Throughout the VITAL reflections, she also commented about the children's non-traditional ways of thinking about and solving different mathematical tasks, and contrasted this with the ways in which she learned those same topics and could only explain them in the manner in which she was taught. The other form in which Melissa incorporated her own experience into the reflections was when she would describe children's thinking or behaviors in terms of what she had seen other children do as a teacher of young children in a Montessori school. At times, she would reference the mathematical capability of children at younger age levels, having seen children of the same age be able to think about more complex mathematical topics in her own work.

Melissa's reflections about her own teaching practice and experiences as a learner and how those shaped her teaching continued on into her own clinical interviews with children. For example, in her second interview Melissa was surprised when the parent of the young girl being interviewed told her daughter that she was not allowed to use her fingers to count out her solution to an arithmetic problem. Melissa questioned whether it was true that children were not allowed to use their fingers to count in school, and confessed to still using her fingers when counting herself. Taken as a whole, Melissa's reflections were strongly influenced by her

experiences in and out of school, and in different contexts (as a learner and as a teacher). She appeared sympathetic to the errors children made, or the ways in which they responded to an interviewer's questions. For her, it was important to remember that children learn at different paces, and this was not to be taken as evidence that they could not learn or would never learn. In other words, she appeared to believe that as adults we needed to remind ourselves that our conceptions of a given mathematical topic might not match the child's conception of that same topic.

Renee. As evidenced since her first VITAL reflection, Renee was always careful to support her observations of children's mathematical thinking with video or other supporting evidence, such as from assigned readings or the course textbook. For the first VITAL assignment, Renee used modest language (as described by Preston, 2010) to support her conjectures; this continued throughout Renee's reflections, and into her own clinical interview reflections, where she used words such as "appeared," "might," and "possible" to describe her observations of children's mathematical thinking. Also apparent throughout Renee's writing was her role as a parent to two young children, and as someone with strong mathematics content knowledge. For example, her content knowledge was evident when reflecting on the Manipulatives VITAL, where she referred to the array as one model for multiplication, and mentioned that it works well as a representation of multiplication because it illustrates the commutative property. In the last VITAL assignment of the semester (Patterns & Algebra VITAL), Renee suggested a formula for the pattern that the girls in one of the assignment videos were trying to investigate. Renee also commented about a possible way to encourage the children to see the generalization of a pattern by starting with simpler patterns and working their way to more complex patterns. In addition, Renee commented about the utility of having

children notice patterns within the multiplication tables, and how pattern recognition is essential in mathematics.

In reading Renee's own clinical interviews, which she conducted with her own children, it appeared that her content knowledge, as well as knowledge of her children, influenced the interviews. She mentioned this influence in her second interview assignment. For example, she mentioned working with her children on their homework assignments almost every night, and so she wrote that she already had some idea of what types of strategies they used when solving different types of computation problems. This influence may have also impacted the types of responses she was getting from her children. It is possible that her children did not want to give their mother a wrong answer, and so they were careful about what strategies they used (probably using strategies they knew would always work or strategies that they were comfortable with), and what they said. In one of her interviews, Renee mentioned that her son was learning a particular strategy in school and so he was using that strategy when solving similar problems at home during the interview. She reflected on some of the missed opportunities, where she could have asked additional questions to try to uncover more about her child's reasoning. She also mentioned being nervous during the interviews and not knowing what questions to ask next to get her children to keep talking or to clarify their responses. Renee's ability to reflect on her performance as an interviewer, as well as her ability to formulate follow-up questions and discuss pedagogical implications, appeared to be the most sophisticated out of the six case studies.

Tania[2]. Like her classmates, Tania demonstrated growth in her ability to make conjectures about children's mathematical thinking, support these conjectures with video and other evidence, and consider appropriate follow-up questions based on children's responses and behavior during their interviews. In the beginning of the semester, Tania sometimes made claims about children's mathematical abilities without concrete evidence (i.e., without support from video evidence or assigned course readings). In addition, early on in the semester, the language she used in her observations of the children was often definitive, claiming that a child knew or did not know a topic. For example, in the third VITAL assignment, Tania wrote about a child she believed had knowledge of division, based upon his ability to draw a picture and show how he would share a given number of cookies between friends. While the video provided some evidence that this might be true, there were no other examples presented in the interview video that would allow someone to make such a claim. This type of language changed as the semester progressed, and by the end of the semester, Tania's claims were couched in more modest language, similar to what was observed with Renee (mentioned above). In other words, Tania appeared more careful about the claims she was willing to make of children's mathematical understanding.

Tania's ability to anticipate responses the children might give based upon their behavior, formulate follow-up questions, and support her conjectures with evidence carried into her own interviews with children, as well. By her second interview, Tania demonstrated that she could carefully listen to a child's responses and ask follow-up questions that were based upon her observations of a child's mathematical thinking. In her second interview, Tania noted a strategy that the child was using to think about a fair-share division problem, and followed up with a

[2] Tania's written reflections had been analyzed previously (see Arias, Schorr, & Warner, 2010); this analysis served as a preliminary model for the results reported on in this chapter.

question where his strategy would not produce a result (at least not one that would yield a whole number solution). Tania later wrote how she recognized and appreciated the importance of listening to children during their interviews in order to be able to ask appropriate follow-up questions.

Tim. Throughout most of Tim's VITAL reflections, he appeared to follow student thinking closely, as demonstrated by his detailed analyses and suggestions for follow-up. In fact, Tim mentioned possible suggestions for following up (via questioning or by detailing an alternative outcome for an interview task) more times than his counterparts. Most of his suggestions for following up occurred in the second half of the semester. Tim's VITAL reflections often times included commentary on the interviewer's role/influence on a child's behavior during the interview, or suggestions for a teacher based on observations he made in the videos. For the most part, Tim was careful about the claims he was willing to make about children's mathematical thinking; where available, he used video and text resources to support his claims. When there was no support for his conjectures, he stated so. While not evident from the first VITAL assignment, Tim's writing reflected his using careful language to describe the children's mathematical ability in most all of his subsequent reflections.

Tim was the only case study teacher to mention the possible influence of the camera on the children's behaviors. He noted this while viewing the second VITAL assignment, where he commented that the children were offering responses that did not make sense (to him). Similarly, Tim commented that children might be reluctant to admit or acknowledge errors in their thinking. Whether the type of behavior Tim saw in some of the children can be attributed to the presence of a camera, of an adult, or of another observer is not clear from the VITAL videos alone. Tim mentioned twice in his reflections that perhaps our own 'human nature' might

cause us to avoid being proven wrong or admit to a flaw in our thinking. He was careful to claim a child had an error in their thinking, as evidenced in the last VITAL assignment, when he stated that it was possible that the child was not aware of the term 'pattern' and thereby, could not extend a pattern of alternating colored bears when asked to do so during an interview.

One of the main observations made by Tim that was most important in demonstrating his growth throughout the semester came about halfway through the VITAL assignments (in the fourth VITAL assignment). Here, Tim commented that the videos, along with the assigned reading for that week, "were very compelling" in demonstrating the mathematical capabilities of young children. At about the same time in the semester, Tim also became more careful about providing evidence for his claims about the children's mathematical thinking.

Tim's sophistication in writing, and his honesty regarding what he had learned from the interviews, continued into his own clinical interview reflection. Unfortunately, Tim was only able to conduct one clinical interview on his own (while his classmates conducted at least three, if not four). Despite not having the opportunity to experience different interview situations, Tim provided a detailed commentary for his first interview in which he demonstrated his ability to reflect on his own actions. He wrote about what he learned as an interviewer, in terms of giving students sufficient time to think through their solutions and explanations. He also reiterated what he had mentioned in the VITAL reflections—that young children are capable of thinking about difficult mathematics in sophisticated ways, when given the time and space to do so. He was able to detail the mathematical strategies the child drew upon during his interview, and compared that with the strategies he anticipated the child would use based on information given to him prior to the interview (by the child's mother), and also what he had read about in the course readings and seen in some of the VITAL assignment videos.

The section that follows focuses on these same six case study teachers as they identified and responded to particular instances in VITAL and in their own interviews where a child exhibited an error in their thinking about a particular mathematical task. The reader is reminded that the VITAL assignment videos were not specifically chosen to illustrate children's mathematical errors, nor were the prospective teachers directed to focus on children's errors as they viewed these videos (per the assignment directions; see Appendix A). Rather, reflecting on children's errors was something that the prospective teachers did spontaneously.

In order to organize the large amount of data, examples coming from four of the 11 VITAL assignments will be discussed in this section. These four assignments were chosen because they all included instances where the child being interviewed made an error. These four assignments also provided instances where the prospective teachers were asked to reflect on ways to respond to children's thinking by asking follow-up questions.

Identifying Errors

The prospective teachers were able to identify children's errors in all seven of the VITAL assignments in which observable errors occurred—VITAL 1, VITAL 2, VITAL 3, VITAL 5, VITAL 6, VITAL 9, and VITAL 11[3]. The same occurred when the prospective teachers reflected on their own clinical interviews with children. For the most part, the prospective teachers tried to find an explanation regarding why the children in the videos made an error. In the beginning, the prospective teachers appeared to be quick to label a child as knowing or not knowing a concept, based on very little evidence. At the same time, the prospective teachers were providing few, if any, explanations for why they thought children made particular errors. The bulk of the writing in their reflections was spent describing the events in the videos, early on

[3] As mentioned above, examples from four of these seven VITAL assignments (VITAL 1, VITAL 5, VITAL 6, and VITAL 11) will be reported on to illustrate each theme.

in the semester. In the section below, labeled *minimal or no explanation provided*, an example from one of the six prospective teachers is provided to illustrate what is meant by a reflection that provided little to no explanation.

As the semester progressed, the prospective teachers became more cautious and thoughtful in their reflections regarding how they thought about and explained children's errors. Included in their observations were references to children's body language, such as facial expressions and gestures, as indicators of errors. They also noted when they felt that a child remained with an erroneous thought or idea, despite being presented with evidence to the contrary; in these instances, it was assumed that the child knew there was an error in their thinking, although this may not have been the case for the child. For some instances, their own personal experiences helped them to make sense of children's errors as well. Examples for each explanation, herein referred to as themes, are provided in the sections that follow.

Providing minimal or no explanation for children's errors. Many of the prospective teachers' initial VITAL reflections contained descriptions of a child's error, with minimal explanations or analysis regarding why the error occurred, or how it could be addressed. Below is an example from Tania to illustrate the types of responses typical of the six prospective teachers early on in the semester.

For the first VITAL assignment, Tania pinpointed the child's error in V1b[4] and discussed what she thought this child, Rachel, appeared to be doing incorrectly:

> In the second video the child seems very confused about how to symbolically represent numbers. When she was asked to write the number five and three, she wrote them backwards.

[4] Rachel, the first grade girl in V1b, is asked to write down the following numbers: 5, 2, 3, 12, 14, 16. Rachel realizes she has written a 9 for the 6 in 16 and asks if she can rewrite it. All numbers written by Rachel are backwards except for the digit 2. Then the interviewer writes down 21, 31, and 201 and asks Rachel to identify the numbers. Rachel identifies 21 as 12, 31 as 13, and stumbles for 201 saying that she thinks it is 120.

> When she was asked to write the number sixteen, she begins by writing a nine. Although she catches her mistake, you can clearly see there is confusion. . . . When she was asked to write a two digit number (14) she puts the number that is supposed to be in the ones place in the tens place.

Tania noticed that Rachel was not only writing numerals backwards and upside-down, but she also switched the ones and tens place when writing. Tania did not provide an explanation for why Rachel might be doing this. Tania wrote: "*Towards the end of the video, the teacher* [interviewer] *asks her to tell him what "201" and "21" represent. After seeing "201" the girl becomes more confused and accommodates her original schema to fit her new one and says "21" represents what it actually does, the number twenty-one.*"

It was not until the end of the video, with the help of the interviewer's questioning, that Rachel had an opportunity to consider her mistake. It is not clear whether Rachel understood her mistake or whether she would have thought about the previous numbers differently, but when confronted with the correct way to write a number, Rachel was able to identify it without apparent difficulty. For the first assignment of the semester, Tania made no outright claims about Rachel not knowing anything about number, but did describe Rachel as "*very confused*" about the symbolic representation of the numbers being called out to her.

All of the six prospective teachers reported on in this study were able to provide descriptive accounts of children's errors as they occurred during the VITAL videos—that is, they noticed the errors and described them as they saw them in the video. In the beginning of the semester, the descriptions contained minimal to no analysis of why children were possibly making mistakes. As the semester progressed, they began to use a number of different ways to try to make sense of the ways in which the children in the interviews were thinking about the mathematical problems presented to them. The prospective teachers were also more careful about the claims they were willing to make about children based upon their rather limited view

of the videos. One way that three of the prospective teachers found useful to make sense of children's thinking was to use their own personal experiences with children as a lens. Reflections of this type are noted below.

Using personal experience to make sense of the error noted. For some prospective teachers, previous experiences with children helped them to understand the behavior of the children in the VITAL videos. For two of the prospective teachers, Alvin and Renee, their role as parents provided them with some insight into children's mathematical thinking because they had seen their own children reason in similar ways. For a third prospective teacher, Melissa, her experience as an instructor of young children may have given her some insight into children's mathematical thinking. Some examples are provided below (for two of the three prospective teachers).

Alvin used his personal experience with his daughter to try and understand the behavior of Rachel in video V1b[5] from the first VITAL assignment. He wrote: "*There are students who will tell you that 12 starts with 1 and end with 2, but will write down 21. I say it because I went through it with my 5 years daughter who knew how to count, but was writing inverse numbers some times*. . ." Alvin had seen his own child invert digits when writing out a number, and he compared what he saw in the video with his own experiences with his daughter.

Melissa's experience as a teacher of young children gave her insight when reflecting on the same video as Alvin did above. For V1b, she wrote:

> Having worked with children from the ages 2 1/2 to 6 who were able to identify their quantities and symbols, be able to add, subtract, multiply and divide by the time they reach their Kindergarten year, I was quick to judge that Rachel is behind in her number writing. But it made me think about the different ways children learn and go about things.

[5] For this and subsequent video codes, refer to Appendix C for full video descriptions.

Melissa appeared to be sensitive to the different pace at which young children can learn mathematics. Initially, her experience with some children that she described as being more advanced mathematically, made her view Rachel as being "behind," but upon reflection, Melissa realized that not all children meet mathematical milestones at the same time.

Personal experiences, such as teaching or working with children or having young children of one's own, were some of the ways in which prospective teachers examined and attempted to make sense of children's thinking as seen in the VITAL video interviews. Having previously seen some of the behaviors exhibited by the children being interviewed, both Alvin and Melissa appeared to acknowledge children's varied ways of thinking, however flawed they might appear to an outside observer. This firsthand experience might have also contributed to another general theme that prospective teachers used to make sense of children's errors—the use of body language and gestures.

Using child's body language and gestures as indication of an error. There were two instances in the VITAL videos where neither the child nor the interviewer acknowledged an error, but the prospective teachers commented on the errors based on their observations of children's body language and gestures. In other words, the children in the videos made physical and/or behavioral signals or gestures possibly indicating their errors, and the prospective teachers noted these in their reflections. Two of the six prospective teachers, Adolfo and Tania, had excerpts from their reflections categorized as such; an example from Adolfo's writing is shared below.

While reflecting on V11a[6] in the last VITAL assignment of the semester, Adolfo referred to Genesis' *"facial expression and body language"* giving him clues to why she incorrectly extended a pattern of colored bears when asked:

> As the interviewer asks Genesis of all the colors they have on top of the table, which one is her favorite – she calls out red, and he does not have any red colored bears. Quickly the interviewer asks for her second and she says is yellow. At this point, not having her favorite color of red, from her facial expression and body language, my intuition tells me that Genesis is not too enthusiastic about the proposed pattern, which kind of explains why she did pick more colors for "her" pattern.

Here, Adolfo picked up on some aspect of Genesis' body language to explain why she behaved the way she did when asked to continue the pattern of alternating blue and yellow bears; in extending the repeating unit of blue-yellow, Genesis added in other colors, such as green and orange, which is what Adolfo referred to as "*her pattern*."

In the video that Adolfo referred to above, he noted Genesis' "*facial expression and body language*" as indicators of an error. What is important is that the prospective teachers appeared to be able to notice these cues and reflect on their implications. Adolfo and his colleagues also noted that really listening to a child's thinking involved more than listening in the traditional sense (hearing what the child is saying), but also listening and noting gestures or physical cues. Along with non-verbal cues, paying close attention to a child's words and actions allowed the prospective teachers to observe instances where a child appeared to remain with an incorrect solution, despite evidence pointing to their solution or thinking possibly being incorrect. Instances of this were captured in the next section.

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[6] Genesis, a pre-Kindergarten girl, is shown a pattern of blue and yellow bears on a table; she is asked to continue/extend the pattern with more bears based on what she sees on the table. Genesis chooses one green and one orange bear. When asked to explain her choice, Genesis states that it looked pretty next to the other bears in the pattern.

Observing children remaining with erroneous solutions/thinking. The prospective teachers would, at times, write about children appearing not to acknowledge nor correct their errors. In these cases, the prospective teachers may have presupposed that the child in a particular clinical interview video knew they made a mistake and were unwilling to recognize, discuss, or correct their thinking. The alternative possibility, of course, is that the child did not identify his/her error because they either did not know that they had made one and, consequently, would not change an answer. Having said this, the examples that were identified within this theme were instances where the prospective teachers identified a child as remaining with erroneous solutions or thinking, without discussion or acknowledgment of errors. The example that is shared below to illustrate this theme comes from video V6c, where Eddie had given an answer of two for the number sentence 12 – 9, and continued to state the answer was two even after using counters to perform the subtraction correctly. Two of the prospective teachers, Renee and Tim, also had examples of this theme as it occurred in different assignment videos.

The language used by Melissa, below, indicated how Eddie might have been reluctant to change his answer, but did not correct it within the duration of the interview clip. She said that even after using the counters to come up with a solution and after he "realized his mistake," Eddie trusted his written response more than the answer that he obtained using the manipulatives.

> We first met Eddie from the third video in the beginning of the first semester and we had been amused at how he tried to cover his mistake with the counters in encountering the problem of 12 - 9. He had miscalculated in writing and when he was asked to prove his answer with markers, he had realized his mistake but decided to stick to his guns and go with what he wrote, saying that he trusts what was written more than the counters.

In this part of Melissa's reflection, there was no mention of why Eddie may have obtained an incorrect solution when using paper and pencil. Melissa's focus appeared to be on her observation that Eddie seemed reluctant to accept the solution obtained when using

manipulatives (since he decided to *"stick to his guns"* despite the counters showing evidence that his paper-and-pencil solution was incorrect), and relied more on the calculation and result that was on paper. Melissa also pointed out that the error initially might have been a miscalculation.

Initial descriptions and analyses of children's errors gave way to more in-depth analysis as the semester progressed. The various explanations that the prospective teachers provided to try and make sense of children's errors are detailed in the sections that follow.

Providing explanations for an error. When the prospective teachers tried to find explanations for children's errors, they drew on a variety of possible explanations. These ranged from identification of calculation errors to conjectures about the type of instruction the child may have been exposed to and how these may have contributed to the error. In all, there were nine subthemes that emerged as possible explanations for errors: (a) children's understanding relative to a developmental level; (b) memorization or rote learning; (c) confusion with interview questions or format; (d) recognizing children's difficulties when representing their ideas; (e) difficulties with the meaning behind words leading to errors; (f) wanting to please the interviewer; (g) confusion using manipulatives; (h) confusion applying an algorithm; (i) and, calculation errors. These are addressed in the sections below.

Children's understanding relative to a developmental level. Four of the six prospective teachers discussed the idea that mathematical understanding develops over time, be it through experiences, development, or instruction[7]. Children may not have a fully developed understanding of a topic when interviewed; consequently, their explanations or thoughts, when confronted with a mathematical task, may lead to unanticipated responses and/or reactions. The

[7] This is similar to what Carpenter and Lehrer (1999) describe as learning for understanding.

example that follows was chosen to illustrate the complexity of children's thinking and how the prospective teachers tried to make sense of this by drawing on developmental principles.

Renee wrote about a child's understanding as she referred to one of the children (Tarik, as seen in video V5a[8]) in the fifth VITAL assignment. Renee mentioned that Tarik did "*not yet have complete understanding of place value*", acknowledging that while he did know how to write some numbers that were spoken to him, there were other numbers he may not have had experience with yet, and therefore, could not write them out properly.

> Tarik does not yet have complete understanding of place value. He probably knows that 24 has two tens and four ones and he might be able to show the tens and ones with counters or blocks. His mistake is that when he hears the number 24 he writes the complete 20 first and then adds the 4, resulting in the written number 204. Both Van de Walle and Ginsburg [*assigned course readings*] point our [*sic*] that sometimes children make this mistake in particular with 3 digit numbers that have zero tens. Hence, this seems to be a common mistake until children have more practice connecting all three concepts, the quantity, the spoken name and the written symbol of a number.

Renee's concluding remark of Tarik's understanding of place value from the video was that *"he does not know that the pattern of tens and ones continues past numbers in the 20's or that he has only a very vague idea."*

The example chosen for this theme provided some evidence that, as the semester progressed, the prospective teachers appeared to recognize the complex processes that children go through when learning mathematics, and acknowledged that some errors might be attributed to the learning stage the child was presently in when interviewed. Rather than use the errors as examples of children's lack of understanding of a concept, the prospective teachers were able to use developmental theory/course readings to support their observations of children's

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[8] Tarik, a first grade boy, is asked to write these numbers: 92, 12, 14, 21, and 23. He shows no difficulty in writing the first three numbers, but writes 21 as 201 and 23 as 203. When the interviewer asks him to write 84, Tarik writes 814. When asked to write 100, Tarik replies, "that's easy," and writes 100. For 124, Tarik writes 1204.

mathematical thinking. In addition to a child's level of understanding, there was also evidence that the prospective teachers noted the *type* of understanding that a child had as a way to explain errors. This is seen in the next theme, *memorization or rote learning*.

Memorization or rote learning. Three of the prospective teachers (Melissa, Tania, and Tim) noted that the type of instruction that the children were exposed to, and therefore the type of understanding they may have developed, could help explain their behaviors during an interview. They noted instances where there was evidence of children memorizing procedures or solutions. An example from Tania's writing is included below.

When analyzing the behavior of Eddie in V6c, Tania described how Eddie had obtained an incorrect solution of two when subtracting nine from 12. It was not until he was asked to show his result by using counters that he had an opportunity to confront his incorrect solution. For this part of her reflection, Tania was careful to state what she thought was behind Eddie's reasoning, and then used his response to the interviewer ("12 and 9 are high numbers") to justify what she believed. She ended her reflection by writing:

> This clinical interveiw [*sic*] helped us to see that perhaps Eddie had falsely memorized what 12-9 was and even when he was asked to prove it he still believed it was 2. I think it also clarified that sometimes kids do conceive mathematics as a bunch of facts and rote memorization and despite giving Eddie an opportunity to prove it, he wanted the answer to just match the answer on his paper.

The last part of Tania's reflection on Eddie echoed a reflection she wrote earlier in the semester, in that she mentioned the role of rote memorization versus some other type of learning and how that might have worked against the child in the video. Tania appeared to believe that Eddie had some type of idea of what the answer to 12 – 9 should've been (a small number since you were subtracting two larger numbers from each other), but that he might have just memorized the answer and reproduced it on paper, not stopping to think whether the final statement, 12 – 9 = 2

was true or not. The interview video cannot confirm this last assertion, because it begins after Eddie had already calculated his solution to the subtraction problem on paper. In any case, Tania tried to see the strengths of Eddie's thinking (he estimated very well what the answer was going to be) but she believed he just had some trouble reconciling the paper-and-pencil solution with what the counters were showing.

Overall, three of the six prospective teachers noted in their writing that different teaching and learning experiences could possibly explain observed errors. Whether it was memorization or rote learning, the prospective teachers appeared to be aware that these things might contribute to how a child comes to understand a mathematical concept and later, how they might demonstrate what they know during an interview. The next two themes that are reported on below captured instances where the prospective teachers believed that issues with language (verbal representations and meanings behind certain words) might help to understand a child's errors.

Recognizing children's difficulties when representing their ideas. All six prospective teachers wrote about instances in which children encountered difficulties representing their ideas. Despite the children exhibiting difficulties, the prospective teachers themselves attempted to make sense of children's erroneous responses. Examples from two prospective teachers are included here, within the context of the fifth VITAL assignment (on place value).

For V5a, Adolfo observed that Tarik (the boy in the assignment videos) could write 12 and 14 "with no noticeable discrepancies", but incorrectly wrote 21, 23, and 84 as 201, 203, and 814, respectively. Adolfo attributed this to Tarik's "*conflict understanding representation of the place value rules for writing those given numbers*." He continued:

> It appears to me that he knows how to count beyond 100, and only appears to be a misunderstanding of standard oral names versus representation in the written form. Tarik's

> actions illustrate that he is confused with the representation of what he hears on the verbalized request and his understanding how to represent it in the written form. His confusion stems from the number is verbalization - he equates the answer to writing the whole number of the base ten, 10's (i.e.: 20, 80) and adding to it the number that represents the 1's column. Where as when asked to write one hundred and twenty four, he transitioned his zero to the 100's column by writing 1024, and writing twenty four correctly with the 10's number in the right format. My hypothesis at this point in the video is that Tarik is writing out those numbers as he hears them – appears that he is not clear in how to represent place value of certain numbers in accordance to the 100's, 10's, and 1's number columns.

Adolfo pinpointed Tarik's confusion to be with how he was representing his idea as he tried to make sense of what was being verbalized to him. Tarik would hear a number being called out, and write out the numerals in accordance with what he heard. For example, in writing the number 21 as 201, Tarik wrote out the 'twenty' in 21 as 20 with a 1 in the ones column.

In the next section, the prospective teachers detailed instances where children's struggles with the meaning of certain words may have caused them difficulties when responding in an interview.

Difficulties with the meaning behind words leading to errors. Often times, the meaning of one word may change the way a child responds during the interview. Whether this is a particular mathematical meaning for a word, or the word's meaning in everyday language, our own way of thinking about the word may not match the child's thinking. This can lead to unexpected, or surprising, responses during an interview. The following instances, coming from three distinct VITAL assignments and one of the prospective teachers' own interviews, illustrate the subtleties of meaning of words when conducting mathematical interviews with children.

Renee wrote about Eddie's attempt to make sense of the interviewer's words for the sixth VITAL assignment. In fact, there were two important observations that Renee made about Eddie in this assignment. The first was that the way the interviewer phrased the task to Eddie could explain his subsequent behavior of making the incorrect paper-and-pencil response fit the

manipulative count. It was not clear that any of the other prospective teachers picked up on the subtlety in the interviewer's language in this video.

> In the video proofing [*sic*] 12 – 9 = 2 the interviewer emphasized that Eddie should prove that 12 – 9 = 2 using the counters. The interviewer did not ask Eddie how he would make sure that his answer is correct. The wording could have led Eddie to believe that two is the correct answer and that now he has to show that it is right even if it means making the proof fit the answer.

Renee pointed out further along in her reflection that Eddie was able to correctly determine that 12 – 3 = 9 and 3 + 9 = 12, but that considering this behavior alone does not demonstrate that he knew what the correct solution was. In Eddie's attempt to justify what he believed to be a correct solution, based partly on the interviewer's request to *prove* his solution without letting him know it was erroneous, he continued on a faulty path of reasoning until the end of the interview clip. There, we saw how Eddie began to acknowledge that there might have been some fault to his reasoning. Again, Eddie's interpretation of the meaning of the word 'prove' in this instance led him to continue with an incorrect solution.

Adolfo, Melissa, Renee, and Tania all wrote about children's conceptions of the word 'pattern' and how this might not match our own conception of what a pattern should constitute. An example from Melissa's reflection for the final VITAL assignment of the semester illustrates this theme. Melissa began her reflection of V11a by stating, "*In Pre-Kindergarten, children should be able to sort their colors, identify a pattern and construct a pattern of their own whether based on an example given by the teacher or a previous lesson*." It was not clear whether this statement was based on something read in the assigned course readings, or Melissa's previous experience working with young children in a Montessori school. She continued:

> There may have been two possible problems with the first video and it could be 1) The child has not been taught what patterns are or doesn't fully grasp the concept or 2) There is a

> disconnect between the words the interviewer was using and the understanding of the child in her mind. Although the interviewer had made it easy enough to understand, the child felt no need to continue the pattern the interviewer had made or make her own pattern with the bears. Instead, she said that she was "matching" (a concept she may still not understand as well) and that she put the green, orange and other bears there because it looked "pretty".

One key point made by Melissa in this reflection was that, often times, children may have a different conception or image of a topic than we might; in this case, the word 'pattern' may have invoked a different image in the child's mind than what the interviewer intended because the child has attributed a different meaning to the term 'pattern'. This is one explanation for what the child in the video did when she was asked to extend the pattern. Rather than choose the next color in the sequence to continue the pattern, the child opted for a color that 'matched' what was before her, thereby attempting to make sense of the term 'pattern'. This conjecture appeared to be in line with what Adolfo wrote for the same assignment. Continuing with V11a, Melissa wrote:

> This makes me wonder what connections they are making in their heads with regards to the colors of the bears—whether they are looking at the repitition [*sic*] of the pattern or if they are associating them with their primary colors or the color wheel. . . . This makes me think about the complexities of the human brain and understanding especially at that crucial age -- these children may not necessarily be giving the "wrong" answers, it's just not the right question or the corresponding subject matter.

This last piece of Melissa's reflection supports the idea that children may be responding to mathematical tasks with their own conceptions of a particular topic (in this case, patterns), and their way of thinking about that mathematical topic may not match our own definition of that same topic. Melissa conjectured that the children in both videos were not necessarily wrong in their thinking, but that they may just have been answering a different question than was being asked, based on different interpretations of the meaning of patterns; that is, our interpretation as an adult versus the child's interpretation of what is being asked. In other words, there may be a subtle difference between our intended interpretation of the questions we ask versus the child's

interpretation of what we ask during an interview. It appeared here that Melissa was suggesting that the language and words used when asking children mathematical questions might explain their incorrect or unexpected responses.

When reflecting on Gabriella and Genesis in the eleventh VITAL assignment, as Adolfo and Melissa did, Renee focused on the similarities between the two girls. She mentioned that, "*Neither seemed to understand the concept of patterns. Both had some notion of which colors go together that had nothing to do with the pattern created by the interviewer*." Renee recognized that both Gabriella and Genesis did not appear to have a concept of pattern (at least not the one that the interviewer probably expected them to have) but they did recognize that certain colored bears belonged next to each other when lining them up. Melissa's observation that the girls' notion of pattern may have been different than the one that the interviewer may have been expecting to elicit through the tasks appeared to echo that of Adolfo for this assignment.

Both Renee and Alvin had examples of this theme coming from their clinical interviews with their own children; Alvin's writing is presented here as illustration. Alvin conducted three clinical interviews throughout the semester with his daughter, Barbara. For his first clinical interview assignment, Alvin stated in his reflection that the objectives for this interview were to see if Barbara could (a) recognize the penny, nickel, and dime coins, (b) understand the monetary value each coin represented, (c) recognize the equivalence between sets of coins (e.g., five pennies represent the same monetary value as a nickel, ten pennies represent the same monetary value as a dime, etc.), (d) determine how much money when given a group of coins, and (e) understand how one dollar could be represented using coins (e.g., one hundred pennies or twenty nickels). When conducting the interview, Alvin reached a point where he asked Barbara which

set represented more, a set of five pennies or a set with one nickel. He was surprised when Barbara stated that the set of five pennies was more than the set of one nickel.

> For her one set of five pennies is more than one nickel. I ask her why? She responded by saying that there are five coins of pennies while there is just one coin of nickel. Therefore**,** the five coins of pennies are more than the one coin of nickel. I think that at that point, she was counting the number of coins not the value of money. Later one [*sic*] with the set of ten pennies and one dime, she said that the one coin of dime is also ten cents as the ten pennies are ten cents, but it is just one coin of dime and ten coins of pennies so the set of ten coins of pennies are more than the one coin of a dime.

It is possible that Barbara had some confusion with the term 'more' that Alvin used during the interview (i.e., more coins in the pile or more money). He realized a possible confusion with the term 'more' when Barbara was asked to clarify why she thought five coins were more than one nickel, to which she responded by comparing the amount of coins in each pile (five penny coins versus one nickel coin).

The examples presented above, under the heading *difficulties with the meaning behind words leading to errors,* involved instances where the prospective teachers noted issues with the meanings of particular mathematical terms as they appeared in the interviews; and evidence that the prospective teachers were able to notice and reflect on these instances throughout the semester. Some interviews and assignments appeared to lend themselves to disparities in communication between the child and the interviewer, due to their particular nature; this is evidenced by overlapping reflections on the fifth VITAL assignment (place value) and the eleventh and final VITAL assignment of the semester (on patterns). In the provided examples of the prospective teachers' written reflections, it appeared that the meaning that the children attributed to mathematical terms like 'patterns' and 'place value' were not the meanings that the prospective teachers held for these same terms.

In addition to the VITAL assignments, Alvin's and Renee's own clinical interviews with their children provided another context with which to think about issues related to communicating mathematically. Alvin's reflection about his own interview can also be considered evidence that the prospective teachers were able to transfer what they were seeing and reflecting on in VITAL to their own attempts at understanding children's thinking via an interview.

The next theme, evidenced in the writing of one prospective teacher out of the six studied, includes instances where the child appeared to continue with an erroneous solution or way of thinking, in order to please the interviewer.

Wanting to please the interviewer. Only one prospective teacher, Renee, wrote about children wanting to please the interviewer as an explanation for children's errors. This section was intended to capture instances where the prospective teachers conjectured that a child was responding in a way designed to please the interviewer. This might have meant that a child gave a solution that they believed the interviewer was looking for, or was the desired solution, even if it did not make sense to the child. This section includes an instance where one prospective teacher thought a child changed his answer because he thought that was what was expected of him when the interviewer questioned his answer.

For Eddie in V6c, Renee conjectured that it was possible that the child was trying to just please the interviewer by giving her responses she might want to hear.

> I got the impression that he was not really thinking about his answer anymore but instead tried to give the interviewer what he thought was the "right" answers. His argument, that he trusted the paper because 12 is the higher number, made no sense. In addition the interviewer led him to agree that he could have made a mistake in counting.

She concluded, "*Either his understanding of operations was limited or he might have felt some pressure under the test that his thinking became rigid*." Here, Renee reiterated that there were

two possibilities to explain why Eddie stuck to an incorrect solution of two when solving 12 – 9. The first was that he genuinely did not know what the correct solution was; this explanation seemed less plausible to Renee, though, and Renee used Eddie's previous calculations as evidence to the contrary. The second was that Eddie felt pressured by the interview conditions and was (as Tim might say/agree) reluctant to admit that his solution was incorrect. The reluctance here, as Renee suggests, might be because Eddie believed the interviewer was expecting a certain outcome or solution to the task.

When referring to Gabriella in V11c, Renee wrote that she "…*changed her blue bear to a green one but that had probably little to do with her recognition of the pattern. She might have changed it because the interviewer wanted to know why she chose it*." This type of behavior seemed to be in contrast to what Eddie did in the sixth VITAL assignment (sticking with an incorrect response despite the interviewer questioning it). Renee pointed out here that Gabriella actually changed her response when questioned by the interviewer.

These two examples from Renee's writing illustrate children altering (or being reluctant to alter) their responses that might be based on their own perceptions of what is expected of them during an interview. In Renee's reflection of Eddie's interview, she explained that Eddie might have stuck with an incorrect answer because he felt that his paper-and-pencil calculation was correct and that the manipulatives should show this same result. Therefore, Eddie did not reconsider his incorrect solution when the manipulatives were showing a different solution. For Gabriella, Renee conjectured that the opposite occurred—Gabriella changed her answer in response to the interviewer's question. Manipulative use also came up when trying to understand children's errors, particularly for assignments three and five, as well as the prospective teachers' own clinical interviews. The excerpts from those reflections are included

under the following section.

Confusion with use of manipulatives. Some clinical interview videos provided examples of how children often used manipulatives to solve mathematics problems they were presented with. Melissa, Renee, and Tania wrote about children's use of manipulatives and how they might serve to either help or hinder a child's explanation. For some children, the manipulatives provided another representation by which they could demonstrate mathematical understanding. For others, the manipulatives may have contributed to some confusion to an existing understanding of a given mathematical topic.

Melissa commented about the utility of manipulatives for the fifth VITAL assignment. In V5a, Melissa said that Tarik "*...knew his ones and his teens, but was a little confused with his tens and show* [*sic*] *his confusion. He got all the more confused when he was asked to write in hundreds*!" She then mentioned that we only see Tarik display what he knew about place value by writing what he was hearing, but that in V5b[9], Shania could:

> …show us and prove her explanations both in writing and with the manipulatives. What was great about this video is that it shows us that even WITH manipulatives, children may not always grasp the values and quantities of numbers, especially if they have no understanding of what tens and hundreds are. . . .

Melissa pinpointed V5b as an example of a situation where manipulatives might not necessarily have helped the child explain a particular concept; this was in contrast to the previous assignment's reflection, where she talked about how the manipulatives appeared to help the child communicate his thinking better. Melissa concluded that, *"we can't always rely on materials and manipulatives…"*

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[9] The interviewer asks Shania, a first-grade girl, to demonstrate how the number 103 would be represented using base 10-blocks. Shania uses 10 long blocks and three unit blocks. She also has three flat blocks next to the others and says that this also represents 103. The interviewer asks Shania how the three flats also represent 103 and she says that each represents 100 and there are three of them.

Melissa's overall reflection of Tarik's interview in V5a almost leaves us wondering whether Tarik would have been able to demonstrate understanding of place value had the manipulatives been available to him for the interview. Melissa noted that Tarik did know something about numbers (especially the ones and teens) but that this understanding appeared to break down when he was asked to write larger numbers. Another question that came out of the analysis was whether Melissa was attributing Shania's error representing the number 103 to the use of manipulatives, or if there was something in Shania's understanding that might be flawed and this would be evident with or without the manipulatives.

Like Melissa, Renee and Tania also reflected on Shania. For video V5b, Renee remarked that it was difficult to see where Shania's error was because she did well with the written and spoken representations of the numbers, but had difficulty when she was asked to represent them with the base-10 blocks. Again, it appeared as though confusion with how to use the manipulatives contributed to the child's errors.

> For the most part it looks like she has a pretty good understanding of place value. Shania correctly labels the ones, tens and hundreds when dealing with the written and spoken representations of a number. If she would be asked to count out the number with single cubes, she might not have any problems either. However, Shania is confusing the manipulatives and thinks she can use single cubes and flats interchangeably. During the first five minutes the claims that 3 flats [*10 x 10 sheet of unit cubes*] are called the same as 10 rods [*10 unit cubes*] and 3 cubes.

Renee explained that Shania's confusion with how to use the manipulatives might have been related to her confusion with place value when trying to use these to represent the numbers 300 and 103.

Three of the six prospective teachers made some mention about confusion with how to use manipulatives during the clinical interviews and how manipulatives may or may not contribute to a child's understanding and/or explanation of a mathematical topic. All three

prospective teachers mentioned manipulative use for the same assignment (VITAL assignment 5 on place value[10]); in addition, Melissa talked about the affordances and constraints of manipulatives within the context of her own clinical interview with a young girl. It was interesting that the three prospective teachers considered instances when manipulatives could be helpful if used properly, or unhelpful when used in ways that did not make sense to the child.

In the next three themes, the examples used to illustrate each theme come from the prospective teachers' own interviews.

Confusion applying an algorithm. Only one prospective teacher, Tania, cited *confusion applying an algorithm* as a possible explanation for a child's errors. This occurred during one of her interviews, and was not cited for any of the VITAL reflections. Using this as a possible explanation assumed that the child might have learned a particular procedure or algorithm, and when trying to apply it to a given problem during an interview, the child misapplied or forgot some part of the process. Attributing an error to confusion applying an algorithm also assumes, of course, that the child had been taught (and learned) the algorithm.

One example cited by Tania where a child displayed apparent confusion applying an algorithm was in Tania's first clinical interview assignment with Billy. In the excerpt that follows, Tania explained how Billy solved \$5 – \$3.84:

> When I asked Billy how he had got that, he had again first subtracted from the ones column to the tens column. Billy had initially written five down without any zeros after it and as I watched him subtract these two numbers, I felt because he saw there were no zeros after the five he just brought down the 4 and 8 from the 3.84. As he told me how he got that answer, he then added in the zeros, but did not change the way he thought about subtracting. He said

[10] The VITAL interview videos chosen, and the accompanying assignment directions, related to place value and the child's understanding of place value. For their own interviews with children, the prospective teachers were not explicitly instructed to use or provide manipulatives to the child. In Melissa's own interview with a child, Melissa used the hundreds board because she was working on homework with the child and the hundreds board was part of the child's homework.

> "because you're supposed to subtract zero from 4 so it's gonna be 4 and the same thing for zero minus 8 so its gonna be 8." Then, he said 5 from 3 was 4.

As she realized that Billy was incorrectly solving $5 – $3.84 on paper, Tania rephrased the question and posed it again to Billy, reminding him that he could use any method to show his solution. Billy chose to use money that had been provided by Tania and he showed Tania a solution of "4 dollars, a nickel, and 3 pennies." When Tania questioned Billy on how he obtained this new solution (different from his paper-and-pencil solution), Billy began to talk about borrowing from the zeros in five dollars. Tania then asked Billy to compare the digit in the ones place from his paper-and-pencil solution to the digit in the ones place from his solution using money; then, Tania asked Billy to explain why they were different, to which Billy responded that he had made a mistake. Tania wrote:

> There was a lot of confusion about applying the traditional algorithm for subtraction. Then he continued telling me the next zero also had to be changed into a 10 and subtracting from 8 would be 2 and that 5 minus 3 equals 4. I then said it does? He then said no. I'm not sure if I should have said that because the way I said it sounded like I was trying to suggest that he was wrong. However, it was just a spontaneous reaction to what he said.

Tania noted that her instinctive response to Billy's explanation might have led him to believe he was incorrect in his solution. As she continued her reflection, she expressed shock to see that Billy was able to work more easily with the money, but could not apply the same thinking to the paper-and-pencil subtraction. Further attempts to get Billy to reconcile his two solutions had no success, and Tania reported that she decided to end the interview at that point. As Tania concluded her reflection for this interview, she conjectured that Billy's responses to the task posed did not indicate a lack of knowledge in subtracting numbers (in this case numbers involving decimals and within a money context):

> When Billy subtracted and came up with the wrong answers I didn't think Billy was unable to subtract. I just thought it was because he did not know how and when to apply borrowing or trading using the traditional algorithm for subtraction because he had said he made a

> mistake and was supposed to change both 0's into 10's. I knew Billy was capable of subtracting because when I asked him if 5 minus 3 was actually 4, he demonstrated using the money that it was in fact 2. I don't feel Billy saw the connection between what he had just done and what he could have done for subtracting 3 dollars and eighty-four cents from 5 dollars.

In addition to attributing Billy's error to confusion with the "*traditional algorithm for subtraction*," Tania cited the author of the course textbook (Van de Walle, 2007) to support her belief that Billy probably knew how to subtract, but just displayed some difficulty with subtraction during the interview. Finally, she compared Billy's behavior to that of a child seen in a VITAL video (Eddie from video V6c), and conjectured that Billy may have opted for the solution he obtained with his paper-and-pencil calculation (just as Eddie did), rather than what he had previously displayed using money. She reiterated that further questioning from her part did not get Billy to see which solution was correct.

As noted, Tania was the only prospective teacher of the six studied to attribute an error to confusion applying an algorithm. While trying to make sense of a child's behavior in the first interview she conducted, Tania reiterated that she "*knew Billy was capable of subtracting*" but believed that the algorithm might have been "*too confusing for him*." This may have stemmed from a possible belief that he was taught to use only a traditional algorithm for subtraction, and had no other methods to draw from to solve the subtraction task, but my conjecture could not be supported by Tania's reflections. At times, confusion applying an algorithm might yield calculation errors. Instances of calculation errors were cited by Renee and are specified in the next theme.

Calculation errors. In some of the clinical interview videos, there were examples in which children's computational errors were encountered while the children solved problems. For these instances, the prospective teachers had an opportunity to observe and discuss

calculation errors. Such was the case for the third, sixth, and eleventh VITAL assignments; more specifically, the reflections pertaining to video codes: V3d, V6c, V11a, and V11c. Opportunities to discuss children's calculation errors also occurred within their own clinical interviews. In fact, the example provided here as an illustration comes from Renee's own interviews with children.

Renee's second clinical interview assignment with her daughter, Haley, provided additional examples of Renee writing about calculation errors. When asked to solve 15 x 8 (within the context of a story problem involving 15 children each getting 8 pieces of chocolate), Renee referred to Haley's thinking about a previous multiplication problem to try and understand her thought processes for the new problem:

> In an earlier problem she had calculated 15 x 6 by first multiplying 10 x 6 and then 5 x 6. For the 5 x 6 she drew a dot array but misplaced one dot so she got 29. However her method was sound adding to 69 of the 29 and resulting in 89. I expected her to use the same method to find 15 x 8. Instead she decided to work backwards and subtract from the 150 she got for 15 x 10. At first she subtracted 10 probably thinking only about the 10 pieces instead that of one piece per child makes 15. When she subtracted another 5 she might have been on the right track but further probing only resulted in more confusion on both sides.

Renee explained that although Haley incorrectly solved 15 x 6, her thinking process was "*sound*" and it appeared that Renee would expect Haley to arrive at the correct solution had she added correctly in her last step. Renee also wrote that she expected her daughter to use the same strategy for the new problem, but Haley's strategy was slightly different for the second problem. She subtracted incorrectly and further questioning from Renee did not result in self-correction. When further analyzing Haley's thinking, Renee wrote:

> Trying to solve 8 x 15 she also mentioned eight and two but was not able to explain why she thought of them. She might have thought of 8 plus 2 is 10 as in 10 x 15 makes 150 but somehow lost her concentration. Also in order to successfully subtract from 150 one must know what to subtract. It seems she was not sure whether to subtract the children or the pieces of chocolate. This would also mean that her understanding of the commutative law is still shaky.

In trying to make sense of Haley's calculation error, Renee conjectured that this could be due to a partial understanding of the commutative law for multiplication, which caused Haley to incorrectly subtract 10 instead of 15 from 150. This last conjecture goes beyond attributing the error to a calculation mistake.

All of the examples found to fit under the theme of *calculation errors* came from Renee's written work. She, however, was not the only prospective teacher to attribute errors to flawed calculations (see, for example, Alvin's description of Eddie from video V5b, or Melissa's reflection about one of her own interviews in Appendix D).

Confusion with interview questions and/or format. Alvin and Tania wrote about instances where features of the clinical interview process might have contributed to a child's error; excerpts from Tania's reflections are shared below. For the purposes of this course, the clinical interview was described as an opportunity to talk to a child one-on-one about a mathematical topic and find out how they thought about this topic; it was not for the purpose of teaching the child something, or correcting errors. That being the case, Alvin and Tania noted instances where they believed that their, or the interviewer's, inability to ask questions or hint to a student that they were wrong could have contributed to a child's error. It is worth noting that the prospective teachers, when conducting their own interviews, had to consider what types of questions were appropriate (and made sense) to ask during their interviews, which was a challenge in and of itself.

During her second clinical interview assignment, Tania recounted the difficulty she had when trying to ask questions that would get Billy, her interviewee, to see that five cookies could be shared evenly amongst two boys. Tania posed this question to Billy after seeing him use a strategy of doubling and tripling numbers to obtain solutions, and she wrote that she wanted to

test his strategy by posing a problem with numbers that would not lend themselves to doubling or tripling, such as five cookies being shared amongst two boys.

> Then I said to Billy, so you can't distribute 5 cookies evenly among [*sic*] 2 people? He said no again. Therefore, I thought awhile about how I could rephrase it to Billy so that he might see at least two and a half cookies could go to each person. Then I said to Billy, "Well, what about if they are not even, how much could each person at least get, because if you have 5 cookies at least some of them can go to two people." I don't know if saying what about if they are not even were the right words to say, because Billy then said well one would get 2 and the other would get 3. However, when Billy said this I was able to then say well what could you do with that extra cookie, could that be split even more? Billy then said you have to break it in half. I said then how much would he [*sic*] person get. Billy said two and a half.

Tania wrote about struggling to rephrase the questions she was asking Billy to help him to recognize that each boy would receive two and a half cookies when splitting five cookies. This excerpt appears in the theme labeled as '*confusion with interview questions and/or format'* because one of the features of clinical interviewing is to use the interview as a method for gaining more information about how a child thinks about a particular topic. In this case, Tania was trying to understand how Billy thought about division, and when she realized he used a strategy of doubling and tripling numbers, her questions became directed towards finding out how his strategy might work with numbers that did not have whole number results. Tania further reflected on this particular episode by writing:

> What I also found interesting was that Billy didn't think about how the cookies could be split evenly among 2 people if there were only 5 cookies. He thought about how the 2 people could have an even amount only in terms of whole numbers. When I think back to this problem and how Billy had some difficulty with it, I wish I would have asked him to draw a picture like the boy in the VITAL video had then to question him. At first he said it was impossible, but maybe if he drew a picture and divided the cookies one by one to the two people he would have seen that there was an extra cookie left. Perhaps then he would have thought to break it in half. He might not have also thought about it in terms of decimal numbers because he hasn't yet been exposed to decimals and fractions, so it wasn't readily accessible to think about.

This episode can be considered another example of how the interviewer (in this case, Tania) might have expected a certain response to a question ahead of time, based on preconceived

expectations about how the interview would go, or about the mathematical concept. In the case of Tania, she may have expected an answer of two and a half cookies, not thinking that for a child, splitting the extra cookie in half might not make sense in this situation. Or, as she pointed out, Billy's conception of splitting cookies evenly might not have matched her own conception of being even, and further follow-up questions on her part did not help Billy come up with the solution she was expecting.

Both clinical interviewing situations, VITAL and their own assignments, provided prospective teachers with an opportunity to observe and reflect on the difficulties that come with asking open-ended questions and anticipating and interpreting children's responses. Alvin and Tania had examples in their reflections where the interviewer's questions might have contributed to a child's erroneous thinking—excerpts from Tania's reflections were shared. For Alvin (example not included here), the interviewer's purpose for the interview was to find out how a child thought about place value and not to teach the child about place value. This might have contributed to the child continuing with an incorrect explanation. In Tania's case, the insight she provided when recounting the difficulty she had trying to ask follow-up questions to Billy provided an opportunity to reflect on the complexity of trying to listen to and understand a child's mathematical thinking, and then be able to determine appropriate ways to follow-up or gain more information about the child.

Once they had provided possible explanations for the errors observed in the two interview settings (VITAL and their personal interviews), the prospective teachers also wrote about ways to respond to these errors. The details of this broad theme of responding to errors, and what this looked like in the written reflections is found in the next section.

Responding to Errors

After being able to identify and provide possible explanations for children's errors, the prospective teachers often wrote about next steps they might take if they were conducting the interview. In three of the assignments, the directions for the assignment specifically asked the prospective teachers to write about possible follow-up questions for the students, as well as to discuss what might have been left out or what they would've done differently had they been conducting the interview. This was part of the directions for the first, fifth, sixth, and eighth VITAL assignments (out of the seven total assignments that included video examples of children's errors). The following section focuses on instances where the prospective teachers wrote about children noticing and reflecting on their own errors; this section includes two subsections: *correction without prompting* and *correction via follow-up question*. Both subsections are related, in that they look at instances where children corrected their error either on their own (*correction without prompting*) or in response to a question from the interviewer (*correction via follow-up question*). Any instances where a child continued an interview without correction of an error were captured in the various subsections presented earlier in this chapter (see *confusion with interview questions and/or format*, for example).

Opportunities for children to notice and/or reflect on their own errors. One of the main themes that came out of the prospective teachers' responses to children's errors was their reflection on how and when to provide opportunities for children to notice and/or reflect on their own errors. Within this theme, there were examples where the prospective teachers observed children correcting their own errors, without prompting from the interviewer, as well as examples of children correcting errors after a follow-up question was asked. These will be described below.

Correction without prompting. Often times, children were able to recognize their own errors and provide a new solution or a new way of thinking. The instances of self-correction recorded below appeared to occur without the need for the interviewer to draw attention to the child's error, be it through a follow-up question or otherwise. Three of the six prospective teachers had examples of this subtheme in their writing, and an excerpt from one of the prospective teachers is highlighted below.

Tania's second interview had an instance where Billy, the boy she was interviewing, corrects an initial solution without prompting from her. As Tania reflected on her second clinical interview with Billy (the same boy she interviewed for her first clinical interview), she pinpointed a strategy that Billy appeared to be using to answer the division questions she was posing. She suggested that Billy was using a doubling or tripling strategy to arrive at his answers, and she asked him to solve the problem 12 divided by 3 in the context of 12 cookies shared by three boys:

> . . . . When I asked Billy this question he was smiling into the cameras as though he was so confident about what he was going to say next. Billy thought awhile about this question, so I told him he could use the paper if he felt that it would help. He didn't and said that each boy would get 3. Then he said wait and used the paper to write 3 + 3 + 3 =. Billy added 3 + 3 + 3, first by adding the first two 3's. When he added these two 3's he connected them and put a 6 next to them and then added the third 3 to that 6 giving him 9. Billy knew he was not correct, so he thought a little more. When Billy did this I knew that his method for finding the solution was by picking a number and doubling or tripling it. He knew that by doubling or tripling a number would allow him to keep everything even therefore by using this method he would be sure that every boy would get an even amount of cookies. When he saw that 3 did not give him 12, he searched for another number that would. He then said each would get 4, so I asked him how he found that out. Again Billy wrote down 4 + 4 + 4 =. He added the first two 4's giving him 8 and then added the third 4 giving him 12.

Billy incorrectly answered three cookies for each of the three boys, but as he wrote his solution out on paper, he realized it did not add up to 12 cookies and searched for a new solution. Billy's

correction, from three cookies to four cookies, did not appear to be prompted by a follow-up question from Tania.

The next theme contains examples where children were observed correcting errors after being asked a question (or series of questions) from the interviewer. This next theme also generated a second broad theme not explored by this dissertation study—when and how prospective teachers followed up on student's thinking, whether the thinking was correct or incorrect[11].

Correction via follow-up question. Often times, children did not recognize any errors in their thinking during an interview on their own. In these instances, the subsequent realization and correction of an error occurred when the interviewer asked a follow-up question. Two of the six prospective teachers had instances of this subtheme in their reflections; examples from Alvin and Renee are listed below.

For his second clinical interview assignment, Alvin chose to interview his daughter Barbara, the same subject of his first clinical interview. This second interview took place towards the end of the semester, after the ninth VITAL assignment. Alvin wrote:

> In the beginning of the interview, I handled [*sic*] two sheets of papers with a number line and a number table to Barbara and asked her if she was familial [*sic*] with both. She said yes, but she preferred working with the number line. Therefore, I asked her to do 12 + 9. Using the number line, she started count from 12 going backward and found 3. At that time I asked her if the answer was 3, she said know [*sic*], and then she started to again count from 12 going forward. I asked her why was she going forward now. She answered that it is because it is the addition. She explained to me that if it is the addition, we have to count the number line forward, but if it is a subtraction, we have to count backward.

Alvin's response to Barbara's initial incorrect solution of three was to repeat the solution back to her. When he did this, he explained that Barbara didn't agree with it and changed her response.

[11] See discussion of future studies, in the Conclusions chapter, for more on this second broad theme.

It appeared that, when asked by Alvin if three really was the answer, Barbara realized that she was supposed to add and used the number line provided to count up to 21. Instead of moving on to another question and ignoring the error, Alvin asked Barbara how she knew that she needed to go in a different direction on the number line than backwards to three where she had originally landed. This seemed to allow Barbara to justify her use of the number line without letting her know that 21 was the correct answer.

Renee provided another example of how a child corrected their error after being asked a follow-up question in the first clinical interview she conducted with her son, Oscar.

> The first problem 6 + 6 was chosen so he can answer it without and [*sic*] struggle. He claimed that 10 + 10 and 2 more is 12. When I asked what 10 + 10 is he knew right away that he said the wrong number and corrected his statement to 5 + 5 is 10 and two more is 12. To my question of how he knew what 5 + 5 is, he answers in the same fashion saying that 4 + 4 and 2 more is 10. Only when I requested that he showed me how, did he use the blocks to demonstrate that 4 + 4 is eight. In the meantime, he demonstrated that he had memorized the double facts up to at least 6 and that he can use double facts effectively to find the next higher double fact.

Oscar realized his mistake of implying that 10 + 10 is 10 and that adding two more would give 12. Upon recognizing that he was using double-facts to obtain his solutions, Renee followed up with some additional double-facts to verify his understanding of these.

Renee's first clinical interview assignment also provided an example of a child changing a correct solution to an incorrect one after being asked a follow-up question.

> When I asked him to show me the one with the blocks he first picks a rod. Only after I rephrased my question and asked if the rod stands for the one did he exchange the rod for a single cube. This left me again not knowing whether he responded to the way I phrased my question and he does understand the place value of ten or not.

Renee recognized that her follow-up question left her without insight into what Oscar understood about place value. She then changed the task to ask Oscar if he could represent the entire number 18 using the blocks:

> … He picked eighteen individual cubes but grouped them interestingly. He had two groups of eight and two in his hand as if he did not know where to put them. Unfortunately I made a big blunder and did not let him finish his explanation and sent him in a completely different direction by asking him how many cubes are in the two piles together. After counting out the sixteen he added the two and presented me the eighteen single cubes. It is possible that if I had left him alone with his two piles of eight and two that he would have grouped them into 10 and 8 demonstrating his sense of place value. Or he could have made two piles of 9 because he likes doubles.

Renee recognized that the timing of her follow-up question (how many cubes all together) might have led Oscar to abandon one train of thought for another.

Summary

During the course of the semester, the prospective teachers had various opportunities to examine and reflect on children's thinking in the context of clinical interviews. Whether it was a VITAL clinical interview video, or their own clinical interviews, the prospective teachers used a number of approaches to explain or make sense of what they saw. Several main themes emerged, the main one involving when and how prospective teachers' identified and reflected upon children's errors.

In sum, early on in the semester, the prospective teachers were able to identify children's errors, but would provide little to no reasons for why the child had made an error. Again, this was only seen in the beginning of the semester. The prospective teacher began to offer more detailed explanations as the semester progressed. Often times, they would note an error had occurred by observing a child's body language and facial expressions. They also noted instances where children appeared reluctant to acknowledge and discuss their errors as evidenced by the children remaining with (i.e., not changing) incorrect solutions or thinking. Their personal experiences with mathematics, or as parents with young children, also served to help them make sense of children's behaviors, where appropriate.

When it came time to provide possible reasons for children's errors, all six of the prospective teachers included examples of one or more of the following eight themes in their writing: children's understanding relative to a developmental level; memorization or rote learning; confusion with interview questions or format; recognizing children's difficulties when representing their ideas; difficulties with the meaning behind words leading to errors; wanting to please the interviewer; confusion using manipulatives; confusion applying an algorithm; and calculation errors.

As mentioned above, the prospective teachers' explanations surrounding children's errors were noted as they occurred in their VITAL reflections, as well as when they occurred in their own clinical interviews with children. There were many similarities, and many differences, in the ways in which this was done. For example, Tania was the only prospective teacher to cite confusion with learned algorithms as a possible explanation. Similarly, Renee was the only one to write about children wanting to please the interviewer, and therefore, answering erroneously or in a way that might not make sense. These instances, as well as others, are documented in Table 4.1, below.

All six prospective teachers reflected on the role of language and/or communication being a possible cause of difficulty for children, as evidenced by the theme *difficulties with the meaning behind words leading to errors*. With respect to their own clinical interviews, there was one prospective teacher, Adolfo, who did not report on any errors in his written account of the interviews[12]. This is not to say that the opportunity did not exist, but rather, he had no written account of errors occurring during the interview.

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[12] The reader is reminded that the prospective teachers conducted these interviews as assignments for the methods course they were enrolled in; they were not specifically directed to report on errors.

Table 4.1

Appearance of Explanation Themes by Teacher

	Prospective Teachers					
Themes	Alvin	Adolfo	Melissa	Renee	Tania	Tim
Minimal explanation	X	X	X	X	X	X
Personal experience	X		X			
Gestures or body language		X			X	
Remaining with erroneous solutions/thinking		X	X	X		X
Developmental level	X			X	X	X
Memorization or rote learning					X	X
Children's difficulties when representing their ideas	X	X	X	X	X	X
Difficulties with meaning behind words	X	X	X	X	X	X
Wanting to please the interviewer				X		
Confusion with use of manipulatives			X	X	X	
Confusion applying an algorithm					X	
Calculation error	X		X	X		
Confusion with interview questions/format	X				X	
Correction without prompting	X				X	X
Correction via follow-up question	X			X		

The second component that emerged in the reflections on children's errors was how prospective teachers reported they did or would respond to children's errors. Particularly when discussing observed opportunities for children to notice and/or reflect on their own errors, the prospective teachers noted that children would often self-correct, or provide a correction to an error without external prompting (i.e., from the interviewer); alternatively, other children would appear to change their thinking after the interviewer asked a follow-up question. This theme of follow-up questioning appeared to extend beyond the context of children's errors, and thus, merits further examination (see Conclusions chapter for discussion of future research ideas).

Chapter 5: Discussion

This dissertation study proposed to answer the following research questions: (1) in what ways did the prospective teachers' observations about young children's mathematical thinking change, if at all? (1a) How did their observations and reflections on children's errors, as seen in the VITAL videos, change throughout the semester? (1b) How did their observations and reflections, as seen in their own clinical interviews, change throughout the semester? (2) What, if any, general observations and insights did prospective teachers have about the use of the clinical interview method? This chapter, which discusses results of the data analysis, is organized around these research questions.

Overall Observations (Research Question 1)

Early on in the semester, most of the VITAL reflections were brief descriptions of children's mathematical behavior. In other words, the prospective teachers were able to describe what they saw in the videos, and these descriptions contained minimal explanations or analysis of why they believed the children behaved or responded in particular ways. This might be expected at the beginning of the semester, considering that this was the prospective teachers' first introduction to the practice of viewing clinical interview videos, as well as an introduction into thinking deeply about children's mathematical thinking. As the semester progressed, and as they had more opportunities to consider children's mathematical thinking, the prospective teachers began to provide more explanations and analysis for the children's observable behavior; they also began to form conjectures about the children's thinking, support these conjectures with evidence from the videos and the assigned course readings, and formulate follow-up questions based on children's responses.

As the semester progressed, it was also noted that the prospective teachers appeared more careful before offering quick judgments about children's mathematical understanding based on their observations of the interviews. This was evidenced by their use of careful language or modest statements, as characterized by Preston (2009; 2010). Such language included phrases like "it seems" or "I think" when commenting about children's mathematical thinking. When using this type of language in their reflections, the prospective teachers appeared to take time to step back and carefully consider what a child said or did in the videotaped interview.

The prospective teachers also tried to rationalize the children's behavior seen by citing course readings or previously observed behavior, among other things. While some prospective teachers were able to cite course readings earlier on in the semester (including one example seen in the first VITAL assignment of the semester), the majority of them began to support their observations with text (e.g., assigned readings)[1] and video evidence towards the later part of the semester. The latter form of evidence, video, was encouraged but not required of the prospective teacher as they completed the VITAL assignments[2]. More on the use of video as supporting evidence can be found in the Conclusions chapter, following this chapter.

Observing prospective teachers' overall ability to be more aware of children's complex ways of thinking is an important finding if we consider what types of implications this may have for teaching practice. One example of an implication is that the prospective teachers can become

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[1] All prospective teachers cited course readings to support their conjectures when the directions specifically asked them to; only two prospective teachers, Melissa and Tania, did so on

[2] Some of the prospective teachers took advantage of the video-clipping features of the VITAL software, but this was not true for all. For example, Melissa and Renee supported almost all of their VITAL reflections with video clips, utilizing it for nine and ten out of the 11 VITAL assignments, respectively. Tim and Tania only used video-clips as part of their written reflections for two and four of their VITAL assignments, respectively; these instances all occurred at the beginning of the semester (Tim for VITAL 1 and VITAL 2; Tania for VITAL 2 through 5).

more aware and sensitive to mathematical misconceptions that students may enter school with and how these may play out in the classroom. At the same time, they can also become aware of the wealth of informal mathematical knowledge that children enter formal schooling with and how they may be able to capitalize on this knowledge during instruction. Awareness of children's mathematical thinking, correct and incorrect, also gives the prospective teachers time to think about how they would react to these in the classroom, and how they might tailor their lessons based on these ideas.

It is important to note here that the prospective teachers demonstrated their ability to make observations of the children in the videos in much the same way that teachers often have to do in-the-moment, in the classroom. Through the videos, the prospective teachers were allowed to step back and have time to reflect on these issues; the ability to rewind and re-watch videotaped interview footage may have served as an advantage here. It is also worth noting that the clinical interviews provided one-to-one contact with children, whereas in a classroom, teachers often work with large groups of students. This can make noticing and attending to children's thinking more difficult. It can limit the amount of individualized attention you can provide to students. On this final point, more work needs to be done in bridging the skills learned in experiences such as the ones described in this dissertation report to the actual practice of teaching. In other words, once the prospective teachers become full-time teachers, there needs to be some kind of support in helping them transfer their skills from interviewing children to whole-class settings (see more about this idea in the Conclusions chapter).

Three of the prospective teachers chosen as focus case study teachers for the Results chapter talked about the notion that understanding develops over time, and may not appear complete. Rather than claiming children had limited or no understanding, based on their

observations of erroneous solutions or incomplete explanations during an interview, these prospective teachers recognized children's ways of thinking as being complex and changing, as evidenced by the variety of explanations they offered in attempting to understand children's errors as seen in the VITAL videos. Carpenter and Lehrer (1999) describe learning for understanding in much the same way:

> Understanding is not an all-or-none phenomenon. Virtually all complex ideas or processes can be understood at a number of different levels and in quite different ways. Therefore it is more appropriate to think of understanding as emerging or developing rather than presuming that someone either does or doesn't understand a topic, idea or process. (p. 20)

Similarly, the prospective teachers recognized that children build their knowledge as they progress through schooling (and mathematics instruction), and that this can be a possible explanation for the behaviors seen in some of the VITAL videos. This idea about the development of children's mathematical understanding is similar to what Clements and Sarama (2009) refer to when they describe developmental progressions, or learning trajectories. Much of the work of Clements and Sarama acknowledges that children learn mathematical ideas in their own way and that teachers must learn to capitalize on this. They write:

> When teachers understand these developmental progressions, and sequence activities based on them, they build mathematics learning environments that are particularly developmentally appropriate and effective. . . .Good teachers interpret what the child is doing and thinking and attempt to see the situation from the child's point of view. (Clements & Sarama 2009, pp. 2-4)

For prospective teachers to begin to hold a view of children's mathematical thinking as described above, prior to entering the classroom, is encouraging; the prospective teachers in this study demonstrated being able to do so. This particular view of children's mathematical thinking should be fostered during teacher preparation coursework so that prospective teachers can learn how to use children's mathematical thinking in planning and instruction.

Another observation the prospective teachers made was on the utility of manipulatives to help make sense of and explain mathematical solutions. This reflection about the use of manipulatives is important because it may also have pedagogical implications. For example, if prospective teachers can see the value that manipulatives may have in helping some students grasp mathematical concepts easier, they may be more inclined to incorporate the use of manipulatives into their instruction.

In sum, the prospective teachers reported on in this study were able to shift from making definitive statements about children's mathematical knowledge to exploring conjectures about children's thinking and supporting these with course reading materials and/or video-clips from the VITAL videos. This is in line with what Van Zoest and Stockero (2008) describe as the shift from a definitive to a tentative reflective stance, a hallmark of teachers who can adapt their teaching based on children's thinking (Ball & Cohen, 1999).

Observations on Children's Errors (Research Question 1a)

In thinking about the importance of attending and responding to children's errors, an ideal trajectory that teacher educators might want prospective teachers to go through should take into consideration differing degrees of noticing. Early on in their training, prospective teachers may be inclined to provide descriptions of errors, without much thought or explanation about the rationale behind these. As they engage in more experiences where they are focusing on children's mathematical thinking, they may begin to notice patterns in errors, or possible reasons for errors, and start identifying those. Once they are able to discuss possible roots for children's errors, they can then discuss pedagogical implications, such as how they would address those errors during whole-class lessons or discussions. In fact, current research in mathematics education supports such a trajectory (e.g., Jacobs et al., 2010; Wilson, Mojica, & Confrey, 2013).

In addition, current research also supports the use of clinical interviews in developing prospective and practicing teachers' knowledge of children's mathematical thinking, including their errors (see, for example, Haydar, 2002; Jacobs, Ambrose, Clement, & Brown, 2006; Philipp et al., 2007).

There was some evidence that prospective teachers could consider pedagogical implications within their written reflections. For example, Tim considered pedagogical implications of a child's error when he noted an instance in a VITAL video interview where the interviewer did not correct the child's incorrect solution. He wrote: "*I believe once a teacher notices a negative behavior that interfers* [*sic*] *with the learning process, the teacher needs to find a way to challenge the student in order to curtail the negative behavior*." Here, Tim commented on his observation that the interviewer may have allowed a child to continue down an erroneous solution path during an interview because they did not tell the child their solution was incorrect. It appeared that his inclination was that children's errors and/or misconceptions should be addressed as they happen, so as not to allow children to continue with their incorrect thinking. Prospective teachers' ability to consider implications for instruction prior to entering the classroom is an encouraging result, as it is noted that this is difficult for teachers to do and takes time and prolonged experience working with children (Jacobs et al., 2010; Wilson, Mojica, & Confrey, 2013).

Apart from identifying pedagogical implications for children's errors, the prospective teachers also tried to make sense of children's errors by providing a variety of explanations[3]. One of the reasons cited by a few of the prospective teachers when considering possible explanations for children's errors was that perhaps children were not answering incorrectly;

[3] Referred to as themes in Table 5.1 and previously.

rather, their conception of a given mathematical topic may just have been different than an adult's conception of the same topic. For example, Adolfo and Melissa both referred to differing ideas about pattern, from the point of view of the child and the interviewer, for the eleventh VITAL assignment. The videos for the eleventh VITAL assignment depicted young children working on patterning tasks. The two particular videos that Adolfo and Melissa responded to for this assignment involved pre-Kindergarten children looking at a repeating pattern of colored bears and trying to continue or extend the pattern by placing the bear color they thought came next. Interestingly enough, in Piaget's work with standardized testing, he observed that, "*children's mistakes in particular gave more important clues concerning the nature of their thought and seemed to show that it is qualitatively different from adult cognition*" (Ginsburg, 1981, p. 4). Both Adolfo and Melissa recognized that their own thinking about what defined a pattern was not necessarily the same way that the children were identifying, and extending, the pattern of colored bears.

When considering the VITAL assignments and clinical interviews as a whole, it was interesting to see which particular assignments garnered the most variety in explanations. Table 5.1 provides a breakdown of which explanations by the six prospective teachers were used for each assignment.

Table 5.1

Frequency of Explanation Themes by Assignment

	VITAL Assignment								
Theme	1	2	3	5	6	9	11	Own[4]	Total
Minimal explanation	6	3	2	2			1	1	15
Personal experience	2								2
Gestures or body language			1				1		2
Remaining with erroneous solutions/thinking			1	2	3				6
Developmental level		1		1			3		5
Memorization or rote learning					1	1			2
Children's difficulties representing their ideas				2					2
Difficulties with meaning behind words				1	2	1	3	2	9
Wanting to please the interviewer					1		1		2
Confusion with use of manipulatives			1	3				1	5
Confusion applying an algorithm								1	1
Calculation error								1	1
Confusion with interview questions/format			1					1	2
Correction without prompting			2					1	3
Correction via follow-up question								2	2
Total	8	4	8	11	7	2	9	10	

As can be seen in Table 5.1, there were four VITAL assignments that had the highest frequency of responses. For example, the fifth VITAL assignment, which dealt with place value, had 11 different responses amongst the six prospective teachers. Three prospective teachers cited confusion with the use of manipulatives in affecting children's responses during an interview. Three of the six prospective teachers also cited children's difficulties with representing their ideas, as well as difficulties with the meaning behind words, possibly explaining children's errors as seen in the place value VITAL videos. Two prospective teachers provided detailed

[4] This column represents the prospective teachers' own clinical interviews with children. It includes up to three or four clinical interviews per prospective teacher.

descriptions with little to no explanation of what they observed. Similarly, two prospective teachers noted children remaining with erroneous solutions despite the possible existence of evidence that their responses were incorrect. Only one prospective teacher cited the child's developmental level as a possible explanation for their place value error. Similarly, one of them talked about memorization or rote learning when reflecting on the Place Value VITAL assignment. The other VITAL assignments that had a number of excerpts from the written reflections in different categories were the: Patterns and Algebra VITAL (VITAL 11), Numbers and Counting VITAL (VITAL 1), Numerical Operations VITAL (VITAL 3), and the Reasoning, Communication, and Testing VITAL (VITAL 6). Of all the assignments, the third, fifth, and eleventh VITAL assignments had the most variety in terms of the explanations used (VITAL3 and VITAL 5 each had six different categories within the reflections; VITAL 11 had five different categories within the reflections). Many of the explanations were more detailed descriptions rather than explanations (15 excerpts from the reflections fell under the category *minimal to no explanation provided*). The second most used category was *difficulties with meanings behind words leading to errors*, followed by *remaining with erroneous solutions/thinking* (with nine excerpts and six excerpts, respectively). What was interesting about these results was that you can see from the table that *minimal to no explanations* occurred earlier in the semester, while *difficulties with meanings behind words leading to errors*, *memorization or rote learning*, and *wanting to please the interviewer* occurred in the second half of the semester (with the exception of one person providing minimal to no explanation in the last assignment).

Observations from Clinical Interview Assignments (Research Question 1b)

Many of the observations that were made in the clinical interview assignments with respect to instances where prospective teachers were interpreting and responding to children's errors were similar to those made in the VITAL assignments. This might be explained by the fact that the clinical interview assignments were interspersed with the VITAL assignments. For example, the first clinical interview assignment was due after the fifth VITAL assignment. That means the prospective teachers had an opportunity to become familiar with the clinical interview method by watching videos of others conducting interviews. The course readings that were assigned at that time also helped prospective teachers become familiar with the clinical interview method. The second clinical interview assignment was due after the ninth VITAL assignment, or about a month after the first interview assignment. This gave prospective teachers the opportunity to deepen their understanding of the clinical interview method and consider their experiences from their first interviews when designing their second interviews. In addition, the prospective teachers had more activities to choose from when choosing interview topics for their second interviews; these activities came from VITAL as well as their course readings. In fact, one of the prospective teachers, Tania, referred to a mathematics task seen in VITAL for her second clinical interview assignment (see Arias et al., 2010, for a description). A third interview assignment was meant to provide the prospective teachers with an opportunity to compare their first two interviews, or redo one of their first two interviews based upon new knowledge and insights. Finally, a fourth interview could be completed as extra credit; only one prospective teacher (not reported on in this study) completed a fourth interview.

An excerpt from Melissa's reflection from one of her own clinical interviews elaborates on a theme that was first noticed in the VITAL videos—namely, that manipulatives can serve to both help and hinder a child's understanding of a particular math concept.

> While the manipulatives are a great way to prove one's answers, there is a danger of 1) misusing them or 2) confusing the child or the answer/explanation more. As teachers, we must be cautious about making sure that the child fully understands the concepts as we explain, discuss and use these materials. I know that there are some learners who do better with mental or descriptive, step-by-step explanations and there are others who need to see and feel something tangible (such as manipulatives) to grasp a concept.

Here, Melissa recognized that children can use manipulatives to prove or further explain their thinking, but only when they are used properly and when the child has experience using these manipulatives. On the contrary, when a child does not have experience with a particular manipulative, this may serve to confuse them when in an interview setting (as seen in Melissa's interview) or in the classroom.

What was different between the reflections on VITAL and the reflections of the interview assignments was that some of the prospective teachers noted (and appreciated) the difficulty when having to prepare their own interview protocols/questions. The same is true when the prospective teachers reported going back and reviewing their interviews (whether audiotaped or videotaped) to make comments about questions asked (or missed opportunities where questions were not asked), among other comments. In fact, the topic of follow-up questioning, and prospective teachers' abilities in formulating appropriate follow-up questions, can be more readily observed when looking at the interview assignments. Here, the prospective teachers did not have the luxury of sitting back and watching someone else conduct the interview and ask the questions. Some preparation work had to be completed prior to the interview, and much thought had to be given to appropriate tasks to use with the child being interviewed, as well as

appropriate questions to ask given the child's responses. Adolfo reflected on this after his first clinical interview assignment:

> I learned through this exercise that although I prepared, I faced some surprises. This was totally new to me and only by doing could I appreciate what it takes to set up a clinical interview to be conducted on [*sic*] a natural way. . . . Having too many questions and offering too many options can have a negative effect on the child's ability to detail the resolution of the problem and share their true natural reasoning steps. From this experience I learned to approach the interview with a single question and then listen while the procedure progresses naturally.

Between his first interview and second interview, Adolfo reflected on the importance of having fewer, key questions to ask during the interview. He noted that one reason for this was so that the child would not be overwhelmed by the amount of questions asked. A second reason was so that the interviewer would not be overwhelmed by having to cover a number of topics in a limited amount of time. Focusing the interview on one mathematical topic with a few carefully selected questions and allowing room for listening and following up with questions were key for Adolfo, as well as some of the other prospective teachers.

General Observations About the Clinical Interview Method (Research Question 2)

Throughout VITAL and in their own clinical interview assignments, the prospective teachers made general comments about the clinical interview method. For example, in one of his VITAL assignments, Tim commented about the role of the interviewer*: "The interviewer must be patient and allow the student to work to completion before interfering with the students* [*sic*] *cognitive process."* Tim also noted that a few carefully selected tasks for the interview were better than a slew of tasks that might not give you as much information about the child's mathematical thinking:

> I learned that it is more important to get a total perspective on one or two tasks than to run through several tasks when doing an interview and when doing an assessment of the cognitive level of a child. This last observation directly supports many of the concepts in the constructivist methodology while exposing a fault in standardized tests. When it comes to

> assessing what a child knows it is necessary to look at the entire scenario with which a child goes about solving a problem, not just the result.

In addition, Tim, as well as some of his peers, also noted the differences between clinical interviewing as a form of assessment, as compared to children's performance on more traditional forms of assessment (as illustrated in Tim's excerpt, above).

Prospective teachers also talked about some of the ways in which the clinical interviews they conducted served to challenge their preconceived notions about children's mathematical thinking and mathematical teaching and learning in general. For example, Melissa wrote:

> …a big challenge for me in conducting the clinical interview was that I had already walked into the first interview with Steven with a mindset of how children should be taught since I was taught and trained a certain way.

The next chapter will discuss some of the observations from VITAL and their own clinical interview assignments that merit further investigation. One of those observations is on the use of follow-up questions, which could be recognized more easily in the clinical interview assignments as opposed to the VITAL videos.

Chapter 6: Conclusions

As Mewborn and 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). In this study, the prospective teachers had access to clinical interview video cases that depicted both correct and incorrect thinking. In addition, they were required to conduct their own clinical interviews in order to experience what it means to give children enough time to think. The prospective teachers reported appreciating the difficulty of having to refrain from habits of correcting (Feiman-Nemser, 1983) during their interview assignments, as well as noting the importance of providing children with enough time to grapple with mathematical ideas and provide responses. These are precisely the skills that we would hope prospective teachers take with them into the classroom.

Results from this dissertation study indicate that prospective teachers can, and did, learn to attend to children's thinking via their viewing of clinical interview video cases. They also attended to children's thinking while conducting their own clinical interviews. As one might expect, the level to which they could reflect on children's thinking changed as the semester progressed, and as they were provided with more opportunities to consider children's thinking. In the beginning of the semester, they began by providing descriptions of children's behaviors, as seen in the VITAL video cases, with little to no attention to children's thinking, or possible explanations for children's behavior and thinking. As the prospective teachers watched more VITAL videos, and had the opportunity to conduct their own interviews, they began to provide explanations, and even conjecture about, children's thinking.

Many of the observations made of prospective teachers' understanding of children's

mathematical thinking via their VITAL reflections were also evident in their own written reports of interviews conducted with young children. What was better appreciated in their own interviews was the prospective teachers' ability to consider follow-up questions based on children's responses during the interview. The reason for this was because the clinical interview assignments required teachers to actively participate in the process of speaking to a child one-on-one, regarding their thinking about mathematical concepts. In other words, they were no longer watching and reflecting on what an interviewer had done in a particular video; rather, they became the interviewers and had to participate in the preparation and enactment of the interview. Because the clinical interview assignments provided them with opportunities to plan and conduct their own interviews, rather than watch someone else as they did in the VITAL videos, the prospective teachers were able to reflect on many things. They appreciated the difficulty of having to prepare the initial interview protocol, consider developmentally appropriate questions to ask the interview subject, and dealing with the nervousness that comes with conducting an interview for the first time and not knowing what to anticipate. The prospective teachers also acknowledged the difficulty of having to formulate follow-up questions on the spot, based on how their interview subjects were responding.

Many prospective teachers were able to consider pedagogical implications of their observations in VITAL and in their own interviews with children. Yet, more work needs to be done in terms of helping prospective teachers determine how to respond based on children's mathematical thinking (e.g., see Jacobs et al., 2010 for their framework of attending, interpreting, and responding to children's mathematical thinking and understanding). This is especially true if we expect prospective teachers to be able to take this learning with them into the classroom, to help inform their planning and instruction.

Limitations of the Present Study

The structure and purpose of the VITAL videos and the clinical interview assignments was not intended to highlight children's errors, and so analysis of how the prospective teachers interpreted and responded to children's errors occurred only in those instances that were reported on by the prospective teachers. It is possible that other instances existed, but if they were not written about in the VITAL reflections or in the reports of the prospective teachers' own interviews, it could not be captured and reported on here. It is also possible that more carefully selected[1] videos would have provided opportunities for the prospective teachers to delve more deeply into the mathematical thinking of children, particularly those instances when an error is observed. Similarly, the directions/writing prompts that the prospective teachers were given for the videos and for their interviews did not specify a need to reflect on errors. It is not a fair assumption to make that the absence of reflections on children's errors indicates an inability, on the prospective teachers' part, to consider children's errors.

My dual role as the researcher and as one of the course instructors may have influenced prospective teachers' responses to course assignments (including VITAL and their interviews) because they were made aware of the purpose of the study, and my position as the researcher, at the beginning of the semester. Similarly, when trying to document the prospective teachers' true feelings about the utility of clinical interviewing, it is possible that they assumed the course instructors wanted them to speak positively of the assignments and the VITAL software, and so they complied. In addition, because the data collected was part of course assignments that were required, the feedback that was given to the prospective teachers as part of the dialogue between

[1] If the purpose was to understand how prospective teachers respond to children's mathematical errors in an interview setting, then the VITAL videos could have been selected in such a way that there was at least one video for each mathematical topic in which a child exhibited a mathematical error.

instructor and student may have influenced what prospective teachers reflected on in subsequent assignments, thereby giving a sense of improvement in terms of their capacity to reflect on children's thinking where it may not have existed.

It is also difficult to document potential change in prospective teachers' ways of thinking about children's mathematical thinking using evidence from just one course. Clearly, other course assignments may have contributed to any noticeable changes in the teachers' thinking. In addition, more time to grapple with issues raised by the experience of interviewing children, as well as more opportunities to implement what was learned from the interviews, may have further contributed to changes in prospective teachers' thinking about children's mathematical thinking. This study only followed the prospective teachers for a semester-long course, and did not observe them as they completed their supervised teaching courses in later semesters.

Despite these limitations, the findings regarding prospective teachers' ability to reflect on children's mathematical thinking, particularly in those instances where errors occurred, are encouraging.

Future Studies

Future data analysis will look at the other ways in which prospective teachers attend to children's thinking while watching clinical interview videos and conducting their own interviews. Recall that this dissertation study categorized the responses that were given by the prospective teachers as they interpreted and responded to children's errors. It is possible that these explanations may carry forward to reflections that were not necessarily tied to a child making a mistake of some kind; in this case, this would include the other VITAL assignments not reported on in this dissertation. Looking at the other assignments may produce additional categories, or paint a clearer picture of the changes in prospective teachers' observations and reflections over

time. The same can be said by looking at all prospective teachers enrolled in the course, beyond just the six reported on in this dissertation study.

Future data analysis will also look at the prospective teachers' abilities to formulate follow-up questions in response to children's thinking outside the context of children's errors. Interestingly enough, there was one prospective teacher examined in this study that did not consider follow-up questions for the assignments that did not specify a need to do so. Recall that in this study, there were four VITAL assignments that asked the prospective teachers to consider appropriate follow-up questions or activities. While Adolfo was able to reflect on appropriate ways to follow-up for these four assignments, he did not report on ideas for follow-up outside of these four assignments. Adolfo reported using follow-up questions in his own clinical interview assignments, but these are not follow-up questions that were a result of the interviewee's responses during the interview. Rather, these were questions that Adolfo had prepared ahead of time and asked these during the interview after the initial mathematical activity was completed. This brings up the point of whether the prospective teachers were solely focused on answering the guiding questions/instructions for the assignments, or if there were some prospective teachers that were able to go above and beyond the assignment instructions to reflect on what they were noticing in the clinical interviews (both their own and the interviews in VITAL videos).

An additional way in which the data can be looked at is to separate those prospective teachers that had strong mathematical backgrounds (i.e., math majors or those with strong mathematical content knowledge) from those that did not to see if content knowledge played a role in the types of explanations that the prospective teachers provided. This could be done for instances in which children's mathematical errors were present, but more broadly, instances where children's mathematical thinking was displayed vis-à-vis the clinical interview.

Goldsmith and Seago (2008) looked at teachers' interpretations of students' mathematical thinking as seen in a video case at the beginning and end of a five-month professional development experience. The authors found that for the second viewing of the video case, the participating teachers engaged in a more detailed discussion of the students' mathematical thinking. The authors also found that the facilitation of the professional development also played a role in the depth of discussion seen from the first to the eighth session. One possibility for future study would be to look at the prospective teachers' reflections on the Reasoning, Communication and Testing VITAL video with Eddie[2], taken at the beginning and end of the semester, to capture any changes in their reflections. This data was collected but not reported on in this dissertation.

Another future study would also take into consideration the role of the facilitator in the discussion of the clinical interview video cases. Goldsmith and Seago (2008) mentioned that the facilitator in their study would ask the teacher participants to support their observations and conjectures with evidence from the video and/or transcripts, during their discussions. Because the in-class conversations surrounding VITAL were recorded, it may be possible to go back to this data and see what ideas were discussed by the participants and what ideas were highlighted or encouraged by the facilitator. In addition, it may be possible to see to what extent the use of the particular feature of VITAL that allowed the prospective teachers to support their reflections with video evidence was encouraged. This particular video-clipping feature was underutilized in this dissertation study, but is most definitely useful, as is noted by the work of others using VITAL (i.e., Preston, 2010). Of particular interest is how prospective teachers use the video-

[2] Eddie incorrectly answers that $12 - 9 = 2$ when solving the problem on paper. When asked to prove his result using counters, Eddie is left with three counters after the subtraction, but quickly removes a counter so that he is left with two.

clips as supporting evidence in their observation and arguments relating to children's mathematical thinking.

When looking at changes in observations throughout a given time period, it is difficult to state whether these changes can be attributed to any one feature of the course the prospective teachers were enrolled in. This dissertation report focuses in on one particular aspect of the methods course, which was that of the use of the clinical interview method (through archived video cases and through interview assignments). During this same time period, though, the prospective teachers completed other assignments that may have contributed to their understandings of children's mathematical thinking. These included: fieldwork assignments where the prospective teachers observed a classroom setting in a grade-level of their choice; lesson plans that were focused on a particular mathematical strand; and, course readings that were carefully selected to illustrate relevant issues in mathematics teaching and learning, among other things.

Earlier in the Limitations section of this chapter, it was noted that documenting change in prospective teachers' ways of thinking is difficult given that the data was collected in just one semester-long course. Moreover, for the change to be robust, it needs to be developed in ongoing experiences for the prospective teachers, and more long-term studies where prospective teachers' are followed into their early teaching experiences may facilitate documentation of this change (see for example, Ambrose, 2004; Stockero, 2008). Following prospective teachers into their practicum and student teaching experiences to see what ideas from the methods course they may take into their own practice is an idea worth considering for future study. Longitudinal studies like the one just proposed can serve to provide stronger evidence for the utility of the clinical interview method in teacher education.

Finally, it is important for research of this kind to find its way back into the classroom, where it can have a positive impact on those that matter most, the children. In other words, how can we take what is learned from this research and give teachers something tangible, to take back and use in their classrooms, and have meaningful impact on students' learning? Recent work has begun to look at one particular aspect, which was partly the focus of this dissertation study—capitalizing on children's errors in mathematics instruction. Given that prospective teachers were able to reflect on children's errors prior to entering the classroom, it follows that we should want them to learn to use this information on children's errors when planning their instruction and working with children as practicing teachers. The recent work of Wendy Bray (2011, 2013) speaks to the importance of incorporating discussions of children's errors during instruction as a way to advance the mathematical understanding of all students, not just those that have made errors. This work includes a framework and strategies to help teachers envision how to use mathematical errors in their instruction (Bray, 2013).

It has been documented that teachers' ability to build instruction that is based on children's mathematical thinking can lead to gains in student achievement (e.g., Fennema et al., 2006; Jacobs, Franke, Carpenter, Levi, & Battey, 2007). If prospective teachers can begin to consider children's mathematical thinking via a variety of experiences (including clinical interviews) prior to entering the classroom, then they can be better prepared once they do have a classroom (and students) to call their own.

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Appendix A: VITAL Assignment Instructions

Assignment 1: Numbers & Counting (2 associated videos)
Based on the two situations you have seen in the videos, what can you say about the children's understanding of number? Particularly with the second video, are there any questions you might have wanted to ask had you been interviewing this child? Remember to draw upon readings you have done to support any of your observations/statements.

Assignment 2: Freeplay & mathematical thinking in the early years (4 associated videos)
Please watch the following videos as an outside observer. Select five different examples of the children's mathematical behaviors and explain why you think each is "mathematical." Please specify the child's name and/or video you are referring to when writing the essay.

Assignment 3: Numerical Operations (5 associated videos)
Tying in connections to Van de Walle & the other readings, talk about the numerical operations expressed in each video, the tasks that students worked on while exploring the operations, and what you can tell about the students' understanding of these numerical operations through the clinical interviews & group lesson posed.

Assignment 4: Exploring Curricula (9 associated videos)
Discuss the implementation of the Big Math curriculum as seen in the assignment videos. How does it relate to what is discussed in the article about Big Math (Balfanz et al. article assigned for this week)?

Assignment 5: Place Value (2 associated videos)
In these two clinical interviews, you had the opportunity to see Tarik & Shania (both first graders) explore concepts of place value through the interview questions. Are there any definitive statements you can make as far as each students' understanding of place value, based on their responses? How does this method of assessment (i.e. clinical interviewing), as opposed to a standardized test, for example, give you information about student understanding with regards to place value? Feel free to add in other questions you may have wanted to ask the student(s), or other place value tasks you may have wanted the student(s) to explore.

Assignment 6: Reasoning, Communication, & Testing (4 associated videos)
Incorporating what you have read thus far with regards to reasoning, proof, communication, and testing, what did these clinical interviews help to clarify about these concepts? For example, what forms of reasoning were evident in the students' responses? How were the students justifying their solutions? In what ways would they communicate their ideas? What forms of assessment were used? If none, what forms of assessment would be appropriate or would you have used had you been conducting these interviews? Was there anything that you felt was left out?

Assignment 7: Rational Numbers (2 associated videos)
In the first video, we see Heidi, Phillip & Nate (grades K, 1, and 3 respectively) talking about fractional concepts. What can you observe about the evolution of their thinking through the grade levels with regards to fractions? How does this support, or contrast with, what you have observed previously or perhaps read about? What additional insights did the "Introduction to Fractions" video provide with regards to rational number teaching and learning?

Assignment 8: Manipulatives (9 associated videos)
What are some of your conceptions about the use of manipulatives in teaching and learning mathematics? Feel free to draw from your own experiences as a learner, or observations of other children doing mathematics. How does the use of manipulatives in each situation in the videos (whether it is a clinical interview or whole-class setting) help or hinder the child? If applicable, discuss anything you might've done differently in these situations.

Assignment 9: Geometry (7 associated videos)
What geometric concepts are the children discussing or exploring in each video? How does this relate to what Clements (1999) and Van de Walle (2007) discuss about geometric thinking?

Assignment 10: Measurement and data (5 associated videos)
How are the students in the videos engaged in measurement activities? How does this relate to other videos you might've seen related to measurement (whether in an informal setting like freeplay, or a formal setting in the classroom)? Also, how does this relate to what the literature talks about in regards to students' conceptions and ideas about measurement?

Assignment 11: Patterns & Algebra (8 associated videos)
Based on what you've read, and what was seen in the videos, how does the study of patterns facilitate algebraic thinking (at any age)? What can you understand about the childrens' knowledge of patterns as seen in the videos? Provide evidence for your reasoning.

Appendix B: Attitudes to Mathematics & Mathematics Teaching Survey (White, Way, Perry, & Southwell, 2006)

Item	NA	DF	F	MF	MF TT	MT TF	MT	T	DT
1. Generally, I feel secure about the idea of teaching mathematics.									
2. I find many mathematical problems interesting and challenging.									
3. Mathematics makes me feel inadequate.									
4. I'm not the type of person who could teach mathematics very well.									
5. I have always done well in mathematics classes.									
6. I do not enjoy having to teach mathematics.									
7. I am quite good at mathematics.									
8. I have generally done better in mathematics courses than other courses.									
9. I'm not sure about what to do when I'm teaching mathematics.									
10. Time passes quickly when I'm teaching mathematics in Practicum sessions.									
11. I have hesitated to take courses that involve mathematics.									
12. I would get a sinking feeling if I came across a hard problem while teaching mathematics during Student Teaching.									
13. Teaching mathematics doesn't scare me at all.									
14. At school, my friends always came to me for help in mathematics.									
15. I am confident about the									

methods of teaching mathematics.									
16. I have trouble understanding anything that is based upon mathematics.									
17. It wouldn't bother me to teach a lot of mathematics at school.									
18. I never do well on tests that require mathematical reasoning.									
19. Of all the subjects, mathematics is the one I worry about most in teaching.									
20. If I taught in a team or with a teaching partner, I'd like to have another teacher teaching the mathematics.									

DF = definitely false
F = false
MF = mostly false
MFTT = more false than true
MTTF = more true than false
MT = mostly true
T = true
DT = definitely true
NA = not applicable to me

Appendix C: VITAL Video Descriptions

**Note: these descriptions are for the videos referred to in the prospective teachers' reflections on children's errors; not all videos have descriptions.*

V1a *("Freeplay: counting beads")*: This video is not a clinical interview video. Stanley, a Kindergarten student, along with a couple of other students, is counting beads. As he counts out loud, he is collecting the beads in his hand. Stanley skips a few numbers in his count, but he is able to count up to 100 by the end of the video. It is not clear whether he actually has 100 beads in his hand at the end of the video.

V1b *("Writing numbers backwards")*: In this video, we see the interviewer ask Rachel (a first-grader) to write a series of numbers down. She has trouble writing some of the numbers (writing them backwards or inverting the place value of the digits—for example, for the number '12' she writes '21'). The interviewer then proceeds to write some numbers down on the piece of paper for Rachel to read. She reads '31' as thirteen and '41' as fourteen, but stumbles when she has to read '201'. She begins by saying "twenty…" and then says she isn't sure. After the interviewer asks what other number '201' could be, she says that she was going to say twenty-one but that twenty-one should be written as '21.' This is interesting given the fact that she had written twelve as '21' earlier, but the interview video stops here and we are not sure whether the interviewer may have questioned Rachel on this discrepancy.

V2b *("Freeplay: writing numbers")*: An observer is sitting with three pre-K students while they write down numbers. The students are writing the numbers in order from smallest to largest and announce when they have arrived at the number 10. As the camera zooms in on some of the student's writing, you can see how some of the numbers have been written in reverse (similar to the video seen the previous week with Rachel). Also, one student starts off writing the numbers in small font and they get progressively larger on the paper as the quantity gets larger, while the student sitting next to her writes the numbers the same size from 1 – 10 and then starts back up from 1 again, making them larger.

V3b *("Double digit addition with regrouping: Using base-ten blocks and paper")*: Rayne, a 1st grader, is asked to solve the problem 37 + 26. The interviewer writes the problem on paper but instructs her to figure it out first with the base-ten blocks. Rayne uses five sticks of 10 units to represent the 3 tens and the 2 tens in 37 and 26 respectively. She then realizes that she must use another stick to represent the extra ten from 7 + 6 ("because that's more than 10"). Rayne concludes that the answer is 63. The interviewer then instructs her to do the same calculation on paper. Rayne starts with 7 + 6 = 13, but incorrectly states that you need to carry the 3. She hesitates, and as the interviewer questions her, she realizes that you are supposed to carry the 1 instead and fixes this by crossing out the 3 and carrying a 1. The interviewer then asks Rayne how she would show the calculation she did on paper to someone using the blocks. She demonstrates the five sticks and the 13 ones and then 'trades' 10 of the ones for a stick and is left with 3 ones. The interviewer asks Rayne to match the manipulatives to the paper-and-pencil calculation to which Rayne responds by placing the 3 ones near the 3 in the ones column and the stick next to the 1 that she carried into the tens column.

V3d *("Solving addition and subtraction problems: Derived facts and base ten blocks")*: In this video, Henry, a first-grade student, is asked to solve 8 + 7 and he uses derived facts to explain why the answer is 15. He says that since he knows 7 + 7 is 14 and 8 + 8 is 16, then adding one more to the 7 would make 15 and adding one less on the 8 would still give 15. When asked if he learned this in school, he says he figured this out on his own. The interviewer then asks the student what 13 – 7 is, to which he thinks for a minute and then responds 5. When Henry is asked how he solved this subtraction problem, he states that 14 – 7 equals 7 (with some hesitation) but since there is one less (meaning 13 is one less than 14), there should be 2 less to give a result of 5. When asked to show on paper what he means, Henry uses a combination of base-10 blocks and paper-and-pencil to show 13 – 7 = 5. It isn't until he counts out with the base-10 blocks that he realizes the solution should be 6, not 5.

V5a *("Numerals and place value")*: Tarik, a first grade student, is asked to write numbers, like 92, 12, 14, 21, and 23. He shows no difficulty in writing the first three numbers, but 21 he writes as 201 and 23 is written as 203. When the interviewer asks him to write 84, Tarik writes 814. When asked to write 100, Tarik replies, "that's easy," and writes 100. For 124, Tarik writes 1204.

V5b *("300 versus 103")*: *(almost 15 minutes long)* The interviewer asks Shania (a first-grader) how and why she is using the base-10 blocks in a certain way. For example, Shania counts the unit cubes as ones in one instance and counts them by two's in another instance (both of which have happened prior to the clip, so the context in which this is done is unknown). Shania then demonstrates how 103 would be represented using 10 long blocks (she counts them out by 10) and three unit blocks. She also has three flat blocks next to the others and says that this also represents 103. The interviewer asks Shania how the three flats also represent 103 and she says that each represents 100 and there are three of them (which she counts out by 100s—100 and 1, 100 and 2, 100 and 3). The interviewer continues to question Shania by asking her why one pile that represents 103 looks like it has more than the other pile that also supposedly represents 103. When asked which pile is more, Shania responds that they're both the same number but the pile with the three flat blocks has more. The interviewer then proceeds to write 13 on a piece of paper and asks if the number thirteen can ever be written as '31.' Shania responds that it can't because the second way of writing the number makes it thirty-one. The interviewer asks Shania to show with the base-10 blocks how she knows that the second number is not thirteen but thirty-one. After doing this, Shania and the interviewer discuss the placement of the numbers in 13 and 31 and what is 'ones' and what is 'tens.' The interviewer questions why for 413, Shania used 4 flat blocks and thirteen unit blocks and how this relates to the one that's in the 10's place in 413. Finally, the interviewer circles back around again to 300 and 103. When asked about 300, Shania can read and show with the base-10 blocks what this would look like, and the same is true when she represents 103. Interestingly enough, when she goes back to representing with the base-10 blocks, she reverts back to her original representation of 103 being three flat blocks.

V6b *("Communication: Comparing sums without computation")*: Zoe, a 2nd grade girl, is asked which sum is bigger, 1 + 3 or 2 + 5. Zoe thinks for a few seconds and then says 2 + 5. The interviewer asks Zoe how she knew this, and Zoe explains that since 1 + 3 is 4 and 5 is bigger than 4, then the sum 5 + 2 must be bigger than 4, which is the result of 1 + 3.

V6c *("Proving 12 – 9 = 2 with counters")*: Eddie (a first-grader) has calculated on a piece of paper that 12 – 9 = 2 and is then asked to show with counters what 12 – 9 is. He counts out 12 counters from inside the bag, and then separates a pile of 9. He points to the pile of three counters and says "this is the answer" but when he looks back to the paper to see his original answer, he sees that it's 2 and he takes one counter away quickly and says "this is the answer" (referring to the two counters left). The interviewer asks Eddie which answer he would go with and he thinks for a second before pointing to the paper and saying "that one." She then asks Eddie why he trusts the paper answer and not the counters and he mentions something about the 12 being a bigger number than 9. The interviewer reiterates that Eddie trusts what is written down more than what he counts out, but Eddie responds that he also trusts what he's counted out with the counters. She then asks Eddie to count again, because he may have made an error the first time. He counts the counters again, but the same behavior of hiding one counter away when there are three left so he can have only two showing is demonstrated again.

V6d *("Reasoning and proof: 5 + 6 = 11")*: Nicholas, a 1st grade student, is talking to the interviewer about the hardest problem he's done, which he follows by saying it wasn't too hard; he is referring to 5 + 6. He continues that this equals 11 and when the interviewer asks him how he knows it's 11, Nicholas responds that 5 + 5 = 10 and one more would give 11. The interviewer asks Nicholas how he knows 5 + 5 = 10, and at first Nicholas says he just knows it. The interviewer follows up by asking Nicholas how he would explain this to someone who didn't believe that 5 + 5 = 10 and he says he would use his fingers.

V7a *("Fraction concepts in three children")*: This video explores three students' understanding of fractions. Heidi (a Kindergartener), Phillip (a 1st grader), and Nate (a 3rd grader) are each interviewed regarding fractions.

V7b *("Introduction to fractions")*: This video is not a clinical interview video—it is a 2nd grade lesson on fractions.

V8a *("Clinical interview in the classroom: discussing addition with Stern blocks")*: Students are discussing 8 + 5 with Stern blocks and then are asked to explain how they knew that 9 + 4 would also be 13. Then a student offers 10 + 3 and the teacher asks that boy to explain his reasoning. He explains how he split up the 5 (from 8 + 5) into 2 + 3 and he added the 2 to the 8 to make 10 and that left him with 10 + 3. She then asks one of the girls in the group to explain his thinking again (revoicing).

V8b *("Double digit addition with regrouping: Using base-ten blocks and paper")*: The interviewer gives the student (Rayne, a first grade student) the problem 37 + 26. He instructs her to first use the base-ten blocks and then figure it out on paper. Rayne realized that 7 + 6 is 13 and she could represent that using 3 single unit base-ten blocks along with a stick. She then shows how 30 + 20 = 60 using 6 sticks. The interviewer asks Rayne once again to show how what she got on paper matches what she demonstrated previously with manipulatives.

V8c *("Representation: Which represents 3 x 4 best?")*: Ami, a 3rd grade student, is asked to take a look at four different pictures that represent 4 x 3. One is 4 groups of 3 boxes each, another is 4 groups of 3 dots each, the next is 3 flowers with 4 petals each, and the last is a number line

with 3 groups of 4 jumps drawn above it. When asked which representation he likes best, he initially chooses the boxes, but then changes his answer to the number line. The interviewer continues the conversation by asking Ami if he can see where the groups of numbers are in the other representations, and ends by asking him why the flower representation wasn't a good representation. Ami responds that a student might see the flowers as just 3 flowers, perhaps not thinking to count the petals to see the total of 12.

V8d *("Representing numbers and regrouping")*: In this video (which is not of great quality) Martha, a 2nd grade student, is working on the subtraction problem 309 – 240. She has in front of her some base-10 manipulatives made out of paper as well as a place value mat. The interviewer asks Martha to represent the first number (309) using the manipulatives and the respective columns on the place value mat. He then asks her to represent the second number (240) using the manipulatives and mat. She then has to subtract the two, and because of the nature of the subtraction, she must regroup one of the hundreds from 309 into the tens column to perform the subtraction using the manipulatives. The video has prompts on the screen that ask whether Martha understands regrouping.

V9b *("Identifying shapes")*: The interviewer pulls a green triangle out of a bag and asks Chidera (a pre-K student) to identify what shape it is. Chidera correctly identifies the shape as a triangle, but when asked to explain how she knows it's a triangle, she responds "because it has three shapes and one side." The interviewer pulls out an orange square and asks Chidera to identify this shape. Chidera struggles for a bit, but when the interviewer begins to list off possibilities for what it could be named, Chidera recognizes the word 'square' in the list and says that it's a square. When the interviewer asks Chidera how she knew the shape was a square, Chidera responds that the interviewer told her what it was. The interviewer then proceeds with a blue rhombus. Chidera identifies this shape as a square, but when the interviewer rotates it slightly, Chidera says it's a diamond. The interviewer rotates the shape back to its original position and asks Chidera how she knows it's a square, to which Chidera responds that it has three lines and one line and three lines.

V10d *("Seriation")*: Dillon, a young boy in pre-K, is asked to arrange Cuisenaire rods in size order. The interviewer has the shortest rod placed on what appears to be a line (a piece of string, maybe). Dillon measures to find out which one is the tallest rod, and then arranges the rest of the rods based on which one is the "next tallest." After Dillon finishes, the interviewer introduces a new rod and asks Dillon to fill in where it would go in the order of rods (which, when arranged in size order, appear as a staircase). Dillon measures this new rod with the shortest rod in the set and determines it should go before the shortest, and then before the second shortest, but stops there and does not end up placing the new rod in the correct spot on the staircase. The interviewer tries to get Dillon to reconsider where he has placed the new rod, but Dillon insists that where he placed the new rod is correct.

V11a *("Difficulties in an interview about pattern")*: Genesis, a pre-K student, is asked what her favorite color is, to which she responds white. The interviewer says that there are no white bears in his pile, so if she could pick another color, to which she responds blue. During this interview, Genesis is shown a pattern of blue and yellow bears on a table; she is then asked to continue/extend the pattern with more bears based on what she sees on the table. Rather than

choosing either a blue or yellow bear to extend the pattern of repeating blue and yellow bears, Genesis chooses one green and one orange bear. When asked to explain her choice, Genesis simply stated that it looked pretty next to the other bears in the pattern. She also seems to be hinting at the idea that these colors match with each other.

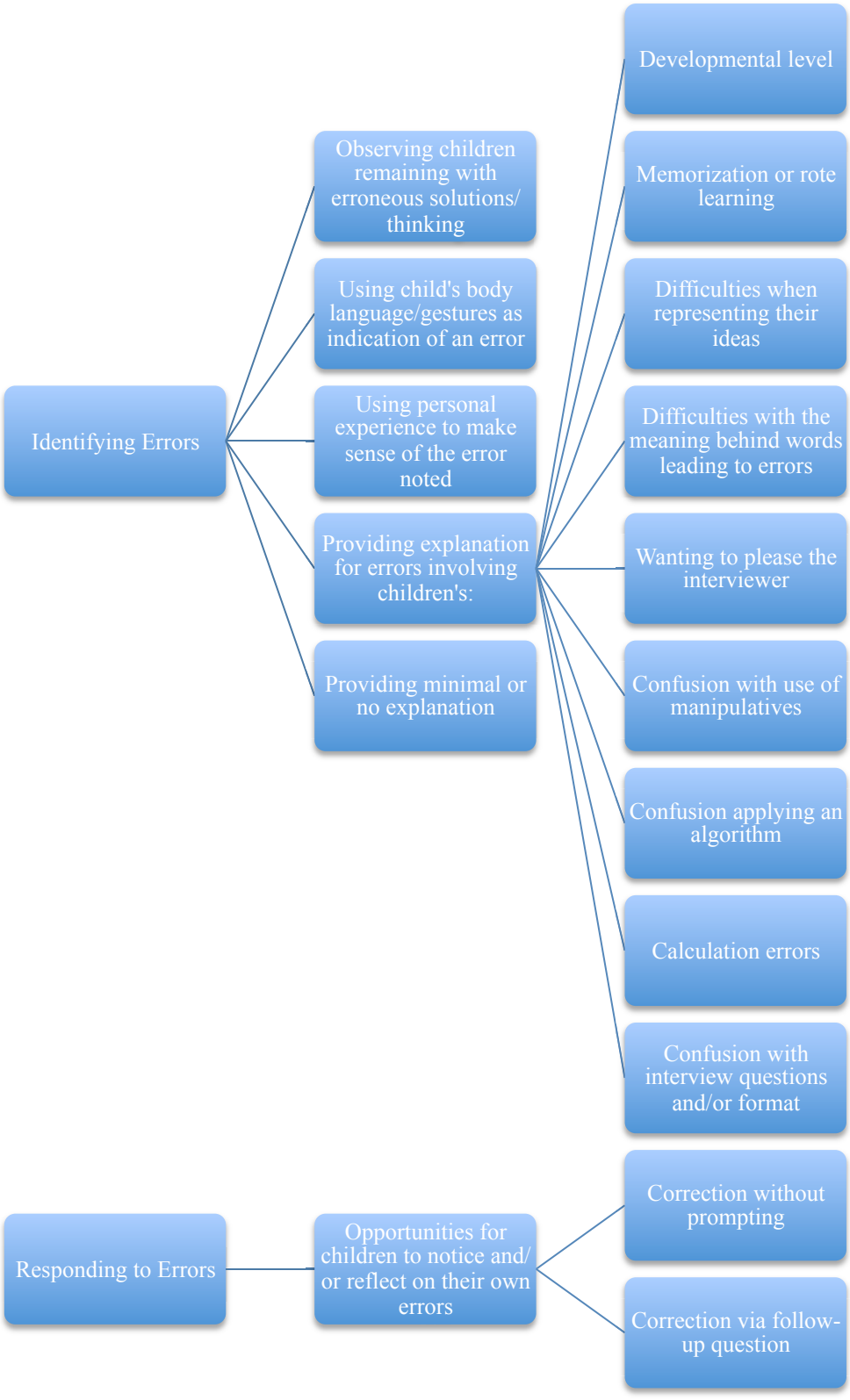
V11b *("Caterpillar pattern")*: There are two young girls working on a caterpillar pattern task in this video (names and grade levels of the two girls are not available).

V11c *("Extending a pattern")*: Gabriella, also a pre-K student, is given a similar task as Genesis in the previous video. This time, the pattern is alternating blue and green bears. When asked what bear to put following a blue one, Gabriella says blue. The interviewer asks her to place the bear in the line and she puts a blue bear next. When asked how she knew a blue bear belonged there, Gabriella doesn't respond and begins to look around the room, being distracted by students that are walking by. The interviewer has to ask her again how she knew a blue bear would go next, and then Gabriella eventually responds, "you put green." The interviewer interprets this to mean that Gabriella meant to put a green bear, and asks her to 'fix it.' When asked how she knew to put a green bear next, Gabriella responds that green needs to go together with blue. The interviewer asks Gabriella what should go after the green bear, and Gabriella chooses a yellow bear. She gives the same explanation for choosing the yellow bear: because yellow needs to be together with green.

V11d *("Finding mistakes in a pattern")*: Jack, a pre-Kindergarten student, is being interviewed. The interviewer places a row of bears (alternating between blue and yellow bears) on the table in front of Jack and asks him if he knows what "that" (the row of bears) is, to which Jack whispers "a pattern." The interviewer then asks Jack to continue the pattern, and offers a handful of bears from where Jack can choose. Jack begins to choose a green bear and the interviewer tells him not to use green. Jack is able to correctly continue the row of bears using blue and yellow bears. The interviewer asks Jack to close his eyes while he removes a yellow bear. When Jack opens his eyes, the interviewer asks if the row of bears (with a missing yellow bear in the middle) is still a pattern to which Jack responds yes. The interviewer asks Jack to make more of the pattern, and as Jack is doing so, the interviewer pauses and tells Jack there is a problem. The interviewer points to the empty spot where a yellow bear used to be and asks him what is supposed to be in the empty spot to which Jack responds "another bear." He then proceeds to move the next blue bear into the empty spot and moves the rest of the bears in closer as well, so that now the middle of the row has two bears side by side. When the interviewer asks if this is still a pattern, Jack responds that it is. Then the interviewer points to each bear as Jack starts to name each by its color, and when he gets to the spot where the two blue bears are side by side, he is about to say yellow to name the second blue bear and then pauses. Jack removes the second blue bear and shuffles the remaining bears to finish the pattern, to which the interviewer exclaims, "you fixed it!"

V11e *("Noticing patterns in multiplying nines")*: This is not a clinical interview video—it is a video clip of a 2nd grade lesson where students are exploring patterns in the 9 times multiplication table.

Appendix D: Themes Emerging from Reflections on Children's Errors



Acknowledgement of Previous Publications

Following are the citations for two conference proceedings that have preceded the publication of this dissertation.

Arias, C. C., Schorr, R. Y., & Warner, L. B. (2010, May). Using the clinical interview method to examine children's mathematical thinking. In J. Stigler (Chair), *Video analysis as a method for developing preservice teachers' beliefs about teaching and their understanding of children, pedagogy, and assessment*. Symposium conducted at the 2010 American Educational Research Association (AERA) Conference, Denver, Colorado.

Arias, C. C., Schorr, R. Y., Warner, L. B., Ginsburg, H. P., & Preston, M. D. (2009). Clinical interviews & VITAL in an elementary mathematics methods course. In I. Gibson et al. (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2009* (pp. 3235-3238). Chesapeake, VA: AACE.