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The Mathematical Tale of Two Teachers: A Longitudinal Study Relating Mathematics Instructional Practices to Level of Intellectual Development

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In this article the development of two teachers as they make the transition from pre-service teachers to experienced teachers is examined. While these teachers participated in the same mathematics methods course and similar collaborative environments in their practicum experiences, their mathematics classroom instructional practices revealed stark differences by the time they were experienced teachers. In an effort to investigate these differences, the teachers' beliefs were explored in relation to those promoted in their pre-service course and in relation to their implementation of current mathematics education reform practices.

This study reported here involved comparisons between two teachers' development as primary mathematics teachers as they made the transition from pre-service teachers to experienced teachers. Both teachers had participated in a project during their pre-service teacher education field experiences. This project used a Cognitively Guided Instruction (CGI) (Carpenter, Fennema, Petersen, & Carey, 1987) framework in an effort to expedite the transition from pre-service teacher to experienced teacher. During the project, experienced teachers who had previously worked with university researchers served as mentor teachers for the pre-service teachers. Bi-weekly discussions were held with pre-service teachers, mentor teachers, and university researchers. Discussion topics focused on primary students' mathematical understanding, appropriate lessons, and instructional strategies. Project field experiences, discussions, and other activities were designed to challenge pre-service teachers' traditional beliefs about mathematics teaching and learning, and to provide alternative models for teaching mathematics. The objective was that teachers fully implement mathematics education reform practices in their classrooms as novice teachers. Researchers followed pre-service teachers into their first year of teaching, and revisited the same teachers when they had five years teaching experience after graduation. This article provides a summary of a case study of two of these participants who experienced different learning trajectories, in spite of their common pre-service opportunities and similar teaching assignments.

Relating Instructional Practices to Pre-service Teachers' Epistemological Beliefs

Mathematics education reform documents in the USA and elsewhere recommend that teachers use a problem solving approach to encourage student thinking about mathematics, and to encourage them to make connections between mathematical domains and mathematics and the real world (Australian Education Council, 1991; National Council of Teachers of Mathematics, 1989, 1991, 2000). These recommendations suggest that the traditional view of mathematics as a static discipline with the teacher transmitting knowledge to the learner should be replaced with a view of students as actively involved in learning opportunities which build on their prior knowledge of mathematics. However, findings from research have also suggested that the factors involved with changing this view are complex, due in part to pre-service teachers' preconceptions about teaching and mathematics, based on their prior experiences as students (Ambrose, 2004; Feiman-Nemser, 2001; Foss & Kleinsasser, 1996; Frykholm, 1999). These experiences are more likely to reflect traditional roles of teachers as dispensers of knowledge and students as receivers of knowledge, and can often limit the ability of pre-service teachers to interpret the ideas fundamental to teacher education programs (Sutton, Cafarelli, Schurdell, & Bichsel, 1996).

Teachers' beliefs about mathematics teaching and learning and their epistemological beliefs influence their practice (Hofer & Pintrich, 2002; Holt-Reynolds, 2000a; Muis, 2004; Raymond, 1997; Richardson, 1996; Skott, 2001). Perry's work (1970) provides a framework for understanding epistemic beliefs. After interviewing mostly university-level males, Perry identified four epistemological positions: dualism, multiplism, relativism, and commitment. He described how the intellectual development of students progressed from the dualistic position of viewing truth as absolute and transmitted to an individual from an expert, to the commitment position where truth is viewed as contextual and personal and derived from one's personal interpretations of experiences (Brownlee, 2004). Subsequently, others have continued this line of research to include females (Baxter Magolda, 1999; Baxter Magolda & King, 2004; Belenky, Clinchy, Goldberger, & Tarule, 1986) and to refine or expand on Perry's notions. The consensus amongst researchers appears to be that as one matures and has more life experiences, one moves from the acceptance of knowledge as certain and obtained from an external source, to a consideration of an issue from varying perspectives and integrating expert knowledge with one's own personal experiences in the process of acquiring knowledge.

Many students, including pre-service teachers, enter the university with the belief that all valid questions have certain answers. They view teachers as experts who provide black-and-white, right-or-wrong-answers (Perry, 1970). They see their job as memorizing the right answers and giving them

back on request (Gallagher, 1998; Holt-Reynolds, 2000b; Muis, 2004). This view of the acquisition of knowledge would seem to support traditional views of learning mathematics and hence, by implication, traditional views of teaching mathematics. One might expect that teachers would use what Perry (1999) described as a *transmission model*, in which mathematics is viewed "as a static discipline which is taught and learned through the transmission of mathematical skills and knowledge from the teacher to the learner" (p. 40), in classrooms.

As pre-service teachers develop critical thinking skills and move toward a view of knowledge as contextual, rather than static, they are able to support their own opinions and are capable of viewing a problem from several paradigms (Gallagher, 1998). As university students, they begin to prefer learning environments where they can use their own knowledge to work through ambiguous situations. The teacher is viewed as a facilitator, and their learning can be described as autonomous (Cooney & Shealy, 1997; Cooney, Shealy, & Arvold, 1998; Szydlik, Szydlik, & Benson, 2003; Warfield, Wood, & Lehman, 2005). These beliefs would seem to support a mathematics education reform view of teaching mathematics. One might expect that pre-service teachers would adopt Perry's (1999) *child-centeredness model*, with their students expected to actively participate in the creation of new knowledge within their own classrooms. The teacher's role would be to provide opportunities for students to grapple with problems, to develop connections between mathematical domains, and between mathematics and the real world.

Changing pre-service teachers' beliefs about mathematics, the teaching of mathematics, and their beliefs in the teacher education program is difficult work (Ambrose, 2004; Kagan, 1992; Raymond, 1997; Schuck, 1997; Warfield, Wood, & Lehman, 2005). However, CGI researchers have shown that using a CGI framework during methods courses and practicum experiences can assist in bringing about these changes (Lubinski, Otto, Rich, & Jaberg, 1998; Steele, 2001; Vacc & Bright, 1999). The CGI framework provides teachers with information on how students learn. The assumption is that teachers will use this information to reflect on their practices in relation to students' understanding of mathematics, and make instructional decisions based on these understandings. Researchers who have used CGI with pre-service teachers have also provided supportive environments for practicum experiences. Consequently, pre-service teachers exposed to CGI abandoned their traditional view of mathematics teaching and implemented reform practices during practicum/clinical experiences. However, research has shown that as novice teachers, many did not implement practices aligned with the reform movement in their own classrooms in their first year of teaching (Ensor, 2001; Lubinski, Otto, Rich, & Jaberg, 1998; Steele, 2001).

Researchers have not yet published longitudinal studies examining the transition of pre-service teachers from teacher education programs to experienced mathematics teachers. This study attempts to fill that gap.

Specifically, the following questions were examined: What changes occurred in the participants' levels of intellectual development, beliefs, and instructional practices informed by the CGI program? What relationships, if any, existed among participants' levels of intellectual development, cognitively-guided beliefs, and instructional practices? What factors influenced the development?

The Original Study

The original project provided pre-service teachers with a primary mathematics teaching methods course and practicum experiences that used a CGI framework for learning. This framework encouraged the integration of teachers' mathematics content knowledge, information on how children learn, and information regarding current mathematics education reform pedagogy. The problem solving approach used in the project required pre-service teachers to reflect upon, compare, and contrast the different problem-solving strategies of primary students, and the strategies of their peers in the teacher education program. The CGI approach was implemented and collaborative learning teams of the pre-service teachers, mentor teachers, and university researchers were established in an attempt to increase the pre-service teachers' levels of intellectual development and to provide them with opportunities to reflect on their practices, in relation to children's understanding.

The original project gathered data on the beliefs and teaching practices of the participants during the methods coursework, practicum experiences, and into the teachers' first year of teaching in their own classrooms. The project also provided models for teaching mathematics aligned with NCTM (1991; 2000) and CGI practices, in an effort to encourage the implementation of these practices during the novice teaching experience. In a follow-up study, the teachers were revisited five years after graduation.

The Follow-up Study

Participants

Researchers located and contacted 17 participants from the original project to request their participation in the follow-up study. Twelve of these 17 agreed to complete the same survey instruments, the Learning Context Questionnaire (Griffith & Chapman, 1982) and the Mathematics Belief Scale (Fennema, Carpenter, & Loef, 1987), used for data collection throughout the original project. Once they had completed the surveys, a phone interview was conducted with each participant. During this interview, participants provided information regarding their current beliefs and practices, changes in their beliefs and practices since completing the project, and factors they cited as influential in these changes. Three of the original project pre-service teachers agreed to serve as case studies for the follow-up study. Two were subsequently chosen after preliminary analyses of the survey data and

phone interviews indicated that they provided stark contrasts in their development over time. In addition, as teachers with five years experience, Vicky's and Hannah's beliefs and practices were different from what project researchers had predicted. As a result, their development was studied more closely.

Data Collection

The results reported here are based on data gathered at four critical points in the case study participants' early teaching careers. These critical points are identified as: (a) participants' entry to the pre-service project, (b) at the end of their student teaching experience, (c) during their first year as novice teachers, and (d) five years later during their sixth year of teaching. This final critical point provides new data about the teachers beyond the scope and duration of the original project. The data gathered at these critical points provide *snapshots* of the participants' levels of intellectual development, beliefs, and instructional practices at each identified point. Specifically, this study examined the ability of these two teachers to sustain and continually develop the beliefs and practices encouraged by the collaborative learning environments they were exposed to during their practicum experiences.

The data gathered included information from the Learning Context Questionnaire [LCQ] (Griffith & Chapman, 1982), the Mathematics Belief Scale [MBS] (Fennema, Carpenter, & Loef, 1987), and videotapes and observations of Hannah and Vicky teaching mathematics lessons of their choice, as well as pre- and post-lesson interviews (see Appendix for interview protocols). In addition, a phone interview (see Appendix for interview protocol) was conducted at the final data collection point to provide more information about the participants' current beliefs and instructional practices, the changes participants felt they had made since their novice teaching experience, and factors they attributed to these changes.

Data Analyses

The LCQ was selected in order to help identify participants' levels of intellectual development. The LCQ (Griffith & Chapman, 1982) distinguishes between four distinct levels (dualistic, multiplistic, relativistic, or commitment). Students at the dualistic or multiplistic levels are said to have an external locus of authority and see truth as absolute. An internal locus of authority is related to the relativistic and commitment levels of intellectual development, and truth is seen as contextual.

The LCQ requires participants to indicate their level of agreement with 50 statements on a six-point Likert scale: strongly agree to strongly disagree. Sample items are:

1. When I am asked a question in class, I am often unsure of what answer the teacher wants.
2. I learn most when my sources of information disagree.

Griffith and Chapman designed the LCQ to measure the first seven levels of Perry's nine levels of intellectual development.

The MBS was chosen to identify beliefs associated with cognitively-based teaching (Fennema, Carpenter, & Loef, 1987). Respondents were asked to indicate their levels of agreement with statements on a five-point Likert-type response format: strongly agree (five), agree (four), neither agree or disagree (three), disagree (two), and strongly disagree (one). Sample items are:

1. Children should understand computational procedures before they spend much time practising them.
2. Children can usually figure out for themselves how to solve word problems.

These participants' responses to the two surveys were analysed quantitatively. Participants who 'strongly agreed' with these statements were assigned a numerical score of five; participants who 'agreed' with these statements were assigned a score of four, etc. Therefore, we identified participants as holding cognitively-based beliefs if their mean score on the survey was four or higher.

Scores on the two surveys for each respondent at each of the four critical data collection points were then plotted on a double line graph. These graphs provided a visual comparison of the patterns of development (as indicated by their survey scores) in their levels of intellectual development, and in their beliefs informed by the CGI program over time.

The videotapes / classroom observations were analysed using qualitative measures based on strategies described by Charmaz (2000). Charmaz's grounded theory analysis requires the constant reviewing of the data to create codes that are used to describe and explain the data. The National Council of Teachers of Mathematics' *Professional Standards for Teaching Mathematics* (1991) and the literature surrounding CGI were used as guides to create the initial codes. In particular, we analysed the videos by examining the task provided, the level of the cognitive demand of the questions in the classroom, the use of multiple representations, the encouragement of justification for solutions, the locus of authority in the classroom, and assessment practices. Successive viewings of the videotapes and passes through observation notes further refined the codes and led to the comparison and analyses of the lessons.

Pre- and post-lesson interview questions were designed to ascertain the reasoning for the sequencing of topics, the use of formative assessment, and the nature of the participant's reflection regarding the lesson. The topics of the reflections were also documented. The interview transcripts provided additional data to confirm or dispute the coding. The interviews were also analysed iteratively. The initial pass through the interview data highlighted portions of text that revealed insights into participants' beliefs, and their instructional practices. Comparing these interview excerpts to the CGI literature and traditional versus reform-based practices led to the creation of the following questions to further guide the analyses:

1. How does the teacher view mathematics?
2. How does the teacher sequence topics in mathematics?
3. What perceptions does the teacher have regarding the role of the teacher and the student in the mathematics classroom?
4. How does the teacher use problem solving in the mathematics classroom?

Posing new questions identified subcategories that further refined characteristics of participants' beliefs and practices. Two independent raters confirmed the codes and categorization of the qualitative analysis. Inter-rater reliability was 85% before discussion and 100% after discussion.

Results

In this section the results from the analyses of the surveys, classroom videotapes / observations, and interviews for the two case study participants, Vicky and Hannah, are presented. These participants completed the teacher education program as project participants, yet had very different patterns of development in the learning to teach process. In the following paragraphs, the participants' intellectual development, their beliefs, and their instructional practices are described.

Intellectual Development

Visual displays comparing the data collected from the LCQ are shown in Figure 1. The respondents' LCQ scores correspond with the first seven positions of Perry's nine positions of intellectual development. However, we were only interested in the participants' level of intellectual development (dualistic, multiplicity, relativism, or commitment), not their position. Griffith and Chapman (1982) used the data in Table 1 to relate LCQ scores and Perry's levels of intellectual development.

Table 1
Relating LCQ Scores and Perry Level

LCQ Score	Perry Level
1.00–3.49	Dualistic
3.50–4.49	Multiplicity
4.50–5.49	Relativism
5.49–7.00	Commitment

As can be seen in Figure 1, Vicky entered the project at the dualistic level. At this level, she would view the world in terms of dichotomies, for example, right / wrong, and would rely on an external authority to make decisions. Vicky's scores on the LCQ increased at each data collection point, but she remained at the dualistic level at the end of the study.

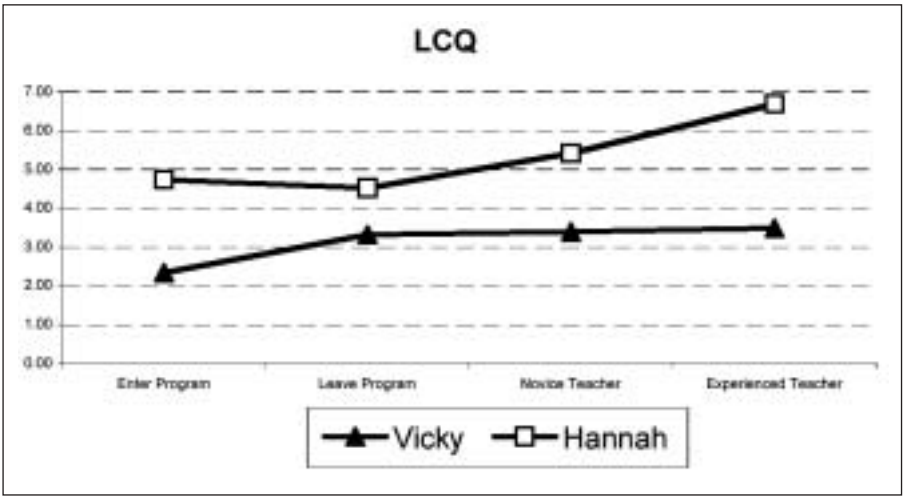

Figure 1. Participants' intellectual development levels on the LCQ at four stages.

In contrast to Vicky, Hannah entered the project at the relativistic level (LCQ score between 4.5 and 5.5) with an internal locus of authority. According to Perry (1970), a person at this level would be able to reflect on multiple viewpoints and rank them according to their merits. During the project, Hannah's scores decreased slightly. Once she entered the teaching profession, her scores began to increase. As an experienced teacher, she was positioned at the commitment level on Perry's Scale of Intellectual Development (an LCQ score above 5.5). At this level, she would commit to a view or perspective after critical reflection based on her own knowledge and experiences.

Beliefs Informed by the Cognitively Guided Instruction Program

On the five-point Likert response format associated with items on the MBS, a score of four indicated that the respondent agreed with the statement presented. Therefore, participants were considered to be cognitively-based if their mean scores were four or more. A cognitively-based teacher would consider her students' understanding when sequencing topics, provide students with problem-solving activities, and make instructional decisions based on their assessment of students' mathematical understanding. Both participants entered the teacher education program with beliefs that were not considered consistent with those of the pre-service program.

The graph in Figure 2 displays the trends in participants' scores on the MBS. The graph provides evidence that the project significantly changed Vicky's beliefs. Her mean score increased dramatically from the first data point to the second point, the time participants were enrolled in the teacher

education program. Her mean score increased again at the third point (novice teacher), but declined at the fourth point. In contrast to Vicky, Hannah's mean score on the MBS decreased at the second data point, indicating that her beliefs at that time were not consistent with the principles espoused by the pre-service program. Her mean score increased at the third data point (novice teacher) and continued to increase as she made the transition to an experienced teacher. At this final data point, her beliefs were considered consistent with those of the pre-service program.

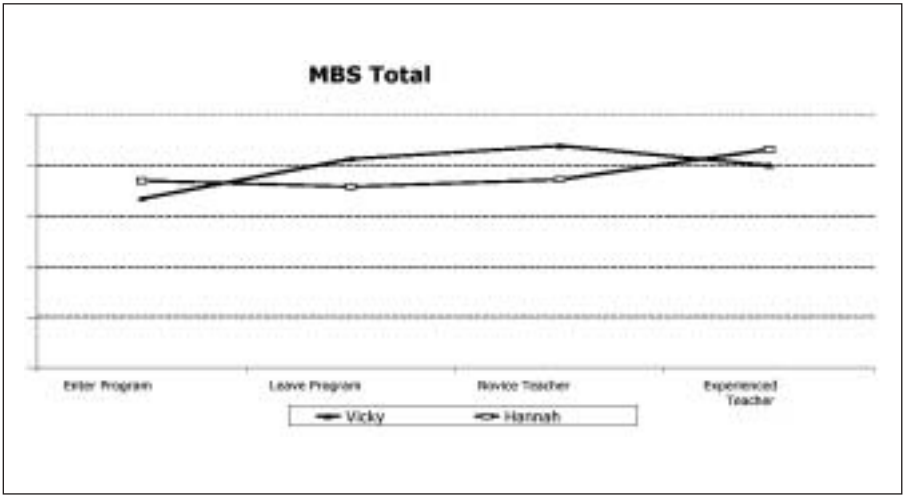

Figure 2. Participants' mean scores on the MBS at four points in teachers' development.

Instructional Decisions and Practices

Before entering the original project, Vicky and Hannah had not been exposed to CGI practices and neither had taken a mathematics methods course nor participated in practicum experiences. Therefore, it was not expected that these pre-service teachers had extensive knowledge of a typical primary student's mathematical understanding, or of recommended practices for teaching mathematics. Both participants' videotaped lessons before entering the program were teacher-centred and teacher directed. Neither asked students to work in groups or encouraged discussion. Hannah did, however, encourage her students to use manipulatives in a procedural manner.

Snapshots of Vicky's lessons

Vicky's first-grade lesson at the end of her student teaching experience revealed that her students were solving two-digit word problems. Students were assigned to small heterogeneous groups, and manipulatives were available if students chose to use them. There was no whole class discussion

or student presentation of solution strategies. Vicky asked probing questions of individuals as they worked in their groups, indicating a focus on student thinking. Although Vicky probed for students' thinking, her assessment of students' learning focused on procedures and solutions. When asked what she thought her students had learned, she responded, "they were refreshed about the ideas of two tens plus one ten, you know adding tens," and "listening skills, because they have to listen to the oral story problem and understand what the teacher is saying." During the post-lesson interview, she was asked how she would use the information gained during the lesson about her students' thinking. She responded, "I wasn't going to plan on using anything I did today." If she could teach the lesson again, Vicky stated, "I don't know if this is the right thing to do, but I would start with join-change-unknown [problem], because that's where we learned [referring to the original project] you should start."

The lesson she presented at the novice teacher phase showed her fourth-grade students creating floor plans to explore area and perimeter. Formulas for area and perimeter were presented at the beginning of the lesson. She repeatedly stated during the pre-lesson interview that the lesson was about multiplication and practising multiplication. During the lesson, she continually reminded students that area meant multiply and perimeter was found by adding. When one student found the perimeter of a square by multiplying the length of one side by four, she did not initiate a class discussion. In the post-lesson interview she stated that she thought this method would confuse students since she had told them to multiply to find area, but not to multiply to find perimeter.

Students worked in groups for this lesson and Vicky again prompted and probed students to explain their thinking. However, she focused on procedures and correct solutions. Vicky saw understanding as being able to recall the definition of area and perimeter. She stated that she decided to ask students about perimeter, to "see if they could remember what it is." In the pre-lesson interview, Vicky explained that she was not providing students with examples from the text, and that she considered allowing them to struggle with finding the area of irregular shapes. However, at times during the lesson, she was quick to intervene and tell students how to solve their mathematical problems.

Vicky's lack of confidence in her own content knowledge was revealed in the post-lesson interview. She recounted a discussion she had with a student, which could not be seen on the videotape. The student had created a floor plan with irregular shaped rooms and she confessed:

> I was unable to draw a figure on the board like that and think about what numbers should go where when you section it off to find the area. I knew that his numbers weren't right. There was no way I could section the whole thing off and find an actual area of the whole thing. I didn't want to tell him that this was not right. I was hoping that he could see the connection between the two.

After leaving the university, Vicky began teaching in a large, suburban, school district in the Midwest (USA). During an observation at her school in the experienced teacher phase, Vicky implemented a lesson that had been discussed during the project. Third-grade students worked in groups with coloured tiles to find all possible pentomino shapes. After several minutes of working in groups, students were asked to draw the shapes they had discovered on the board. After the student drew the pentomino on the board, she placed the corresponding overhead pentomino on the overhead projector. However, when placing the pentominoes on the overhead, she flipped or turned the pentomino shape a student had drawn on the board, so that the orientation was different from the drawing. Yet, when someone drew a transformation of a shape that had already been drawn, Vicky asked if this were truly a new shape. When students suggested that if a previous shape were "flipped" or "turned" it would be the same shape, Vicky did not ask students to elaborate. She also asked students how they would know if all the possible shapes had been found. Vicky brought the lesson to a close before discussion materialised. In the post lesson interview, she admitted that she chose this lesson because it was a lesson from the project. When asked how this lesson fitted in with previous lessons and future lessons, she said it did not. It was just a lesson for fun.

At each data collection point, Vicky was reflective about students' behaviour and her classroom management in the post-lesson interviews. She had thought about how the lesson went, and had ideas in mind to improve the lesson for the next time. However, her initial responses focused on student behaviour, and she needed to be prompted to reflect upon students' mathematical thinking. In the phone interview, Vicky expressed concern at meeting the expectations placed on her by the district and preparing her students for the high stakes achievement testing at her grade level. Her responses indicated that she felt assessment was the recall of facts and procedures. She also felt that problem solving was an application of learned skills.

Snapshots of Hannah's Lessons

At the end of her student teaching experience, Hannah's second-grade lesson involved students determining the number of golf balls ordered by a sporting goods store if the shipment consisted of two cases, four boxes, and seven individual golf balls. Cases contained ten boxes, while boxes contained ten golf balls. Initially, students were working individually without manipulatives. Hannah asked open-ended questions, but did not encourage discussion during this time. She later placed students in groups only because she was dissatisfied with students' mathematical thinking about the problem posed. She stated in the post-lesson interview, "I thought that if they worked together they might be able to help each other."

When students struggled with place value during this lesson, she took out base ten blocks, but then directed students how to solve the problem

using the blocks. She failed to have students explicitly explain what the base ten blocks represented in the context of the problem. She acknowledged in the post-lesson interview that she had realized that many students were not engaged and brought out the overhead projector to initiate a whole class discussion. At first, a student explained his reasoning using the base ten blocks and the projector, and she did not interfere while the student was explaining. When she determined that other students were not listening, she took over rather than have another student explain their strategy, and began to ask more directive, leading questions that focused on procedures.

This lesson and the pre- and post-lesson interviews indicated that Hannah was struggling with the ideas presented in the project. In the post-lesson interview, she stated the purpose of her lesson was "to develop the concept of regrouping while subtracting and three-digit place value concepts." The problem she presented was to be the first opportunity students had to regroup one hundred into ten groups of ten to facilitate subtraction. After the lesson, she admitted that she would like her students to understand regrouping before she taught an algorithm. This indicated a belief that problem solving can be used to develop new concepts. Yet, several alterations in her plans for instruction were made to facilitate her clear presentation of concepts, rather than advance student thinking.

Hannah's lesson during her first year of teaching (novice teacher phase) encouraged students to work in small groups. After telling students about finding a ladybug on her car, she asked her first grade students to draw their own ladybug. Then students were asked to estimate the total number of spots on all the ladybugs in the classroom. She allowed students to write their estimates on the chalkboard, and elicited several strategies for determining a reasonable estimate. However, the ideas were not expanded or elaborated. Students were not asked to explain or justify their responses or even assess the reasonableness of their estimates.

Strategies for determining the actual total number of spots were then discussed as a class. Again, the reasonableness of the strategies was not discussed. At this point, Hannah instructed students to find the total number of spots on the ladybugs in their group. Group totals were recorded on the board. At this point, Hannah asked if any students would like to revise their estimates. She asked, "What do you think about these estimates, 100, 110, and 500?" Students did not respond, and the discussion was not pursued. Students were then instructed to find the class total by adding the group totals. In the post-lesson interview, Hannah acknowledged that she did not pursue this discussion, and in hindsight wished she had, in order to develop students' reasoning with larger numbers and to encourage reasonable estimates.

After leaving the university, Hannah spent one year teaching students with disabilities. Then she relocated to a large suburban school district in the Midwest. At this school, during the experienced teacher phase, she acknowledged that she adapted the lesson from the fifth-grade textbook so

that all students were involved in collecting data, graphing data, and finding the *line of best fit*. She let students determine the scale for the graph, and planned to discuss the differences in the scales at the next lesson. Prompting and probing questions indicated a focus on students' thinking. The lesson sequence was coherent. She indicated in her post-lesson interviews that she had strayed from her original plan after assessing students' thinking during the lesson, and that her reflection regarding her assessment of students' mathematical thinking was used to plan the next lesson.

When asked during the phone interview about her favourite lesson, she described a lesson on fractions using fraction pattern blocks. After discussing the fractional value of the various pieces, she asked what value would be represented by five of the one-fourth pieces. She predicted that students would incorrectly identify the one-fourth piece as one-fifth, and was ready with several questions that would challenge their misconception and lead them to the concept of improper fractions. She viewed assessment as the number of connections students made between concepts. Although she taught at a grade where students took high stakes achievement tests, and taught in a district with high expectations, she did not refer to the test when determining the sequence of topics or allow the test to influence her pedagogy. However, she admitted that she took the test into consideration when deciding what content to cover.

Mathematics Content/Pedagogical Content Knowledge

Vicky admitted in her interviews throughout the study that her content knowledge was weak. She had difficulty identifying the mathematical concepts in her lessons and finding real world contexts relating to her lesson's mathematical concepts. In several lessons, she made mathematical errors and / or stated in interview that she was apprehensive about pursuing students' line of thinking because she was unsure of the mathematics herself. She relied on memorized rules and algorithms, and expressed confusion when students did not respond in the manner suggested by CGI videotapes or literature.

Hannah's content and pedagogical content knowledge were high upon entering the project. She was able to identify the mathematical concepts of each of her lessons, and provided real-world contexts to explore these concepts. Her interview statements indicated that she predicted student responses and purposely chose tasks to create perturbations in her students and / or to reveal student misconceptions.

Self-reported Factors Influencing Change in Teaching

During the phone interview conducted as part of the follow-up study, both participants indicated that experience in their own classrooms was the most influential in learning to teach. However, both also identified the project as being influential. Professional development was influential in shaping Hannah's practice. Her attendance at the state's Council of Teachers of

Mathematics conference and the National Council of Teachers of Mathematics conference reinforced the principles espoused by the project. Vicky continued her education and received an advanced degree in administration just before the final data collection was conducted, and stated she did not have time to attend mathematics professional development. She did not make connections between any of the courses taken in her advanced mathematics education program or indicate how they influenced her teaching practice.

Discussion

In a comparison of the development of these two teachers through the transition from pre-service teachers to novice teacher, two distinct patterns of change emerged. The graph displaying the MBS results (Figure 2) shows that Vicky's scores increased significantly during the teacher education program and increased slightly at the novice teacher phase, indicating that her beliefs had become aligned with the philosophy of the teacher education program. This change was evident to project researchers. She was also implementing some aspects of reform practices during practicum experiences, and at the novice teacher phase her practices were indicative of reform practices. She presented problems for students to solve in groups, manipulatives were available, questions were asked to ascertain students' mathematical understanding, and students were expected to justify responses and reflect on classmates' solutions. However, at the experienced teacher phase, her beliefs and practices reflected a more traditional position. Researchers had not anticipated this trajectory. Other researchers who used a CGI framework in their investigations reported that pre-service teachers' beliefs move toward a cognitive basis during the pre-service teachers' practicum / clinical experiences, similar to Vicky (Ensor, 2001; Lubinski, Otto, Rich, & Jaberg, 1995; Steele, 2001; Vacc & Bright, 1999). In addition, those who tracked pre-service teachers into their first year of teaching noted that pre-service teachers' beliefs were challenged, and reported that some reverted to traditional practices (Ensor, 2001; Lubinski, Otto, Rich, & Jaberg, 1995; Steele, 2001).

In contrast to Vicky and to other studies, Hannah's beliefs and practices showed little change during the teacher education program, and project researchers wondered how the project had influenced her beliefs and practices. As a novice teacher, Hannah made an attempt to support student group work. However, when students struggled, she stepped in and led the lesson procedurally, more indicative of traditional practices. The follow-up study provided insights into the learning to teach process that were not available from other researchers or from the original study. We had anticipated that the dramatic changes seen during the teacher education program in Vicky's beliefs and practices would be even more apparent at the experienced teacher phase. It was surprising to see that she had moved away from beliefs developed during the pre-service course, and that her practices

were observed as more traditional after the support from the project was removed. In contrast, Hannah had not made the dramatic changes in terms of beliefs and practices during the project and while support was available. When Hannah's classroom was revisited after five years, she had implemented standards-based practices once she saw the impact of her practices on her students' understanding of mathematics. Interviews with Hannah at the experienced teacher phase suggested that her beliefs were aligned with project goals. This growth, once the support of the project was removed, also surprised researchers.

The longitudinal nature of this study, and the multiple data sources, may offer insights into why Hannah's development took a different route. This study collected data regarding pre-service teachers' intellectual development or epistemic beliefs, in addition to collecting information regarding CGI-related beliefs and practices. Since many university students (including pre-service teachers) hold beliefs that rely on an external authority (Cooney, 1999; Cooney & Shealy, 1997; Perry, 1970), many of the participants in other studies may have entered their teacher education program with beliefs dependent on an external locus of authority and readily accepted the principles of their program, similar to the way Vicky accepted the principles of CGI during her practicum experiences. However, in this study Hannah was identified early on to be at a level of intellectual development having an internal locus of authority and to be making decisions based on integrating knowledge from experts with her own experiences. As a pre-service teacher and novice teacher, Hannah lacked teaching experiences in a primary classroom upon which to draw, and therefore, did not readily adopt the principles of the program.

Vicky's and Hannah's different starting points and development may account for the changes documented in their beliefs and teaching practices. Vicky entered at the dualistic level and, while her scores increased over time, she remained at the dualistic level at the end of the study. At this level, her locus of authority was external (Perry, 1970). Her reliance on an external authority was evident in her post lesson interviews. After her first-grade lesson she stated:

> She [a student] surprised me right here [referring to the videotape] that she had to count all the way up to 67 on her fingers. She's never done that before. Doesn't that represent a student who's very low in their counting if they have to count all the way up?

In another post-lesson interview, she was asked if an understanding of multiplication could be discerned from asking students to write the number sentence 8 x 7 = 56 to show how they determined the area of a rectangle. To this, she replied:

> We talked about that a lot when we did multiplication [referring to the project]. It's a way they [the researchers] showed me how to do it with cubes and everything. So I know they [students] understand what I mean by that.

In all of her post-lesson interviews, she would either ask the interviewer for advice or talk about aspects she had learned in the project, rather than relying on her own knowledge or experiences. These excerpts suggested a reliance on an external authority when making decisions, and a lack of confidence in her own pedagogical content knowledge. Perhaps this lack of confidence in her own pedagogical content knowledge would account for the changes seen in her beliefs related to CGI and reform practices during the project. But, if she relied on an external authority, she may have viewed the university researchers as authorities and followed their recommendations. If she relied on an external authority, it would follow that after the support of the project was removed, she would revert to traditional practices and/or seek new sources of authority for making decisions. In the interview conducted at the experienced teacher phase, she indicated that her instructional decisions regarding content and sequencing of topics were made to "get students ready for the achievement tests", suggesting that the pressures of the high-stakes achievement testing had influenced her instructional decisions. Since researchers had anticipated that at this point she would be making decisions based on her assessment of students' thinking about mathematics, not the high-stakes achievement tests, we propose that her level of intellectual development could account for her reaction to testing. It appeared that she turned to another external authority such as the text, district curricula, and achievement tests to make her instructional decisions once the support from the project was removed. She also expressed confusion when students did not react the way CGI literature had stated they might react. This led researchers to conclude that she experienced difficulty with multiple viewpoints, typical of a dualistic thinker.

In contrast, Hannah's LCQ scores indicated that she entered the project at Perry's (1970) relativistic stage. According to Perry a person at this level of intellectual development would be able to rank multiple viewpoints based on their merits, and would not necessarily accept information as truth until their own experiences confirmed the information. This may account for the relatively small change in Hannah's beliefs related to CGI and her reluctance to adopt the principles of the project in her clinical experiences during the teacher education program. Perhaps, her limited experiences in the classroom had not provided her with enough evidence that these practices indeed enhanced students' understanding of mathematics. By the experienced teacher phase, she acknowledged in her interviews that she saw a relationship between her practices and her students' mathematics understanding. When describing her practices she stated:

> I use a lot of manipulatives and a lot of discussion…I hear so much mathematics discussion going on and the kids are interested. They don't realize how much enthusiasm is in their voice when they are talking to their neighbours about this particular problem or that problem. In addition, I never heard that before with the [traditional] series. Even when I had the kids work in groups and stuff, I never heard them excited about mathematics. But now they are.

Her score on the LCQ at the experienced teacher phase indicated she was at the commitment level on Perry's scale of Intellectual Development. At this level, one has evaluated information from experts and empirical evidence and committed to a view or philosophy. In Hannah's case, she made a decision to use the principles espoused by the project after testing these ideas in her own classroom, but only because she had proven to herself that they developed students' understanding. She expressed this commitment to reform practices by saying:

> I have them work in groups, so they can go to another student that has a clear understanding and might be able to explain it to them. After several children then I may step in and help clarify the situation by asking questions. Children learn mathematics through hands-on experiences, trial and error and not telling them the answer, but helping them find the most efficient way for them to solve the problem.

Since Hannah had entered the project at the relativistic phase, it is possible that she needed time to reflect on the principles espoused by the project. At her level of intellectual development, she was not as ready to accept the principles without further reflection and her own validation of their effectiveness. After trialling the activities and practices suggested by the project and reflecting upon them, she felt they enhanced students' understanding and, consequently, implemented them in her classroom. Hannah's internal locus of authority and the emergence of her own voice are consistent with Cooney and Shealy's (1997) findings regarding the emergence of one's own voice as being critical when dealing with the constraints of the classroom. This longitudinal study also suggests that an internal locus of authority is essential for self-sustaining change, since Hannah continued to develop beliefs aligned with the project once the support of the project was removed, while Vicky did not.

Hannah's internal locus of authority and the emergence of her own voice also permitted her to view multiple viewpoints. She could reflect upon and connect ideas that might appear disjoint to Vicky. Hannah was also a mathematics specialist and had taken more content courses than Vicky. While one cannot discount the role that sound content knowledge of mathematics plays in the implementation of reform practices, the ability to see multiple viewpoints, reflect upon, and rank these viewpoints results in connections that may also influence the development of pedagogical content knowledge. Hannah's interview excerpts indicated that she valued alternative solution strategies and encouraged students' invented strategies. On the other hand, in her post-lesson interviews, Vicky expressed concern that her students did not respond to tasks in the manner suggested by CGI or university researchers. She expressed confusion when this happened and did not plan to explore further her students' thinking in future lessons. Vicky's lower level of intellectual development may not have permitted her to see multiple viewpoints.

Conclusion

The learning to teach process is a complex, situational, and lengthy one. Teacher education programs can provide opportunities that challenge pre-service teachers' models for teaching and learning mathematics and change their vision of the primary mathematics classroom. Without a longitudinal follow-up, the full impact of the teacher education program is not always apparent. Vicky readily adapted the principles of the project in her practicum experience classroom, and survey scores indicated that her beliefs changed significantly to become cognitively based, while Hannah did not. As experienced teachers, Vicky had begun to revert to traditional beliefs and practices and Hannah had implemented reform practices. One factor attributed to the difference in the development of these teachers was their level of intellectual development, specifically, the development of an internal locus of authority.

Another factor the teachers cited as contributing to their implementation of reform practices was professional development. Both Vicky and Hannah attended workshops and/or classes as novice and experienced teachers. However, the professional development they chose to attend was different. Vicky's professional development would be classified as more general education and leading towards a degree in administration. Hannah, on the other hand, participated in mathematics education related workshops. Researchers hoped that some of the education courses taken during Vicky's masters program would have seemed relevant to mathematics education and that she would be able to make some connections. According to Perry's (1970) description of dualistic thinkers, Vicky's dualistic nature would prevent her from seeing these connections. Researchers had also hoped that these courses would influence her teaching, yet she did not indicate in the phone interview that any of the courses taken influenced her teaching, nor did these courses appear to influence her implementation of reform practices or the principles of the project.

The environments that novice teachers find themselves in can also influence the implementation of reform practices. Both Vicky and Hannah were well respected by their respective school administrations. Hannah's district asked her to serve on a mathematics textbook adoption committee and to pilot a reform textbook series. This experience was cited by Hannah as influencing her practices as she saw how the reform textbook series, and the practices it espoused, enhanced her students' understanding of mathematics. On the other hand, Vicky's district did not encourage reform practices and adopted a traditional series, which influenced Vicky's practices.

Implications and Further Research

The conclusions drawn above have several implications for teacher educators. The first implication is the influence of professional communities on novice

teachers. Vicky and Hannah's participation in the professional communities of their schools had different effects on their development. Vicky had been encouraged to pursue an advanced degree in administration. Hannah was asked to serve on the mathematics textbook adoption committee and piloted a reform textbook series, which the district ultimately adopted. However, their professional development differed. Hannah's was mathematics related and Vicky's was related to administration. Teacher educators may want to examine the influence of professional development that is subject specific for novice teachers, and/or professional development that encourages the development of an internal locus of authority. In addition, both school districts had high parental involvement and both teachers taught grade levels where students took high-stakes achievement tests. Yet, the teachers reacted differently to these pressures. This would suggest that teacher educators might also explore the relationship between novice teachers' levels of intellectual development and their reactions to the pressures placed upon them by their district, their colleagues, and the community.

The second implication involves alternative models for teaching. Participants cited the project as being influential in changing their ideas about the teaching and learning of mathematics. The CGI framework and alternative models of teaching mathematics offered in practicum experiences can effectively alter traditional beliefs. While it may be difficult to generalize these two case studies to a broader population, it appears that teacher education programs should offer alternative models for teaching mathematics and frameworks similar to CGI that challenge traditional beliefs in an effort to influence the implementation of reform practices. Yet, sustaining these beliefs after entering the profession can be difficult. Therefore, revisiting teachers several years after leaving the program to document the program's full impact is encouraged. More longitudinal studies should be conducted to replicate our findings. Studies should document the influence of a supportive environment and/or professional development for novice teachers that encourage the implementation of the program's philosophy into the classroom.

Our conclusion regarding the importance of developing an internal locus of authority in implementing reform practices and developing pedagogical content knowledge suggests that teacher educators should explore activities that move students to higher levels of intellectual development. It was surprising to find that the pre-service teachers' levels of intellectual development did not increase during the original project, even though the project provided opportunities for them to reflect on their teaching within a collaborative environment of mentor inservice teachers and university researchers. The mathematical problem solving activities provided during the methods courses also encouraged connections, conjectures, and justification, verbally and in writing. However, these activities did not result in a significant difference in LCQ scores in this longitudinal research study.

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Appendix

Interview Protocols

Pre-Lesson Interview

1. What is the purpose or objective of today's lesson?
2. What is the content of your lesson today?
3. What influenced your decision to teach this content?
4. What grouping organisation will you use and why?
5. Briefly, what activities have you planned?
6. What influenced the choice of activities?
7. What material are you using today and why?
8. Have you considered any alternatives to implement during instruction, should your lesson not proceed as planned?
9. Did you consider anything about what your students know while planning?

Post Lesson Interviews

1. What went well?
2. What would you change?
3. What do you think the children learned? Be specific / provide examples.

Phone Interview

1. What is the format for the majority of your mathematics lessons?
2. What kinds of tasks are your students engaged in during mathematics class?
3. How would you describe the mathematics learning environment in your room?
4. What will you do tomorrow in your mathematics classroom?
5. What factors do you consider when planning for tomorrow?
6. What criteria do you use to determine the topic you will teach?
7. What factors do you consider when sequencing topics for instruction?
8. How do you know if your mathematics lesson is successful?
9. What do you hope your students gain from your mathematics classroom this year?
10. How will you assess your students' growth and development in mathematics?

11. What role do manipulatives play in your classroom?
12. How do you assess your students' understanding?
13. What do you do when a child doesn't understand?
14. What influence do achievement tests (such as ISAT) have on your teaching?
15. What changes do you feel you have made in your classroom since you were last video taped?
16. What factors contributed to these changes?
17. Describe your biggest challenge when teaching mathematics?
18. Tell me about your best mathematics student.
19. Tell me about your least developed mathematics student.
20. What do you think mathematics is all about?
21. What do you think is the best way for students to learn mathematics?
22. Describe three characteristics of a good mathematics teacher.
23. What do you think is the most effective way to teach mathematics?
24. Is this different than the way you teach other subjects?
25. What experiences in your methods courses or student teaching influenced your teaching practices?
26. What role do professional development activities play in influencing your classroom practices?
27. How would you describe your school's environment in regards to supporting continued learning for classroom teachers?