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Interpreting Pre-service Teachers Experiences of Mathematics: A Case Study

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Abstract

The mathematics education reform movement has catalyzed issues concerning curriculum for future mathematics teachers, because of the varied school mathematical experiences of students entering post-secondary education. Post secondary instructors face the problem of addressing these differences in the mathematics and mathematics education courses they teach. This paper uses a case study of a student learning mathematics for teaching to propose a tool for interpreting student experience. This tool could aid post-secondary mathematics and mathematics education instructors to understand the experiences of their students, and thereby adapt to the current reform environment.

Introduction

Mathematics education in North America is changing. A socio-constructivist perspective concerning knowledge, learning and teaching orients current curriculum development and implementation (e.g., National Council of Teachers of Mathematics, 2000). This perspective is in stark contrast to the transmission model of teaching within traditional mathematics classrooms. As such, the students entering colleges and universities can be quite diverse in their mathematical school experiences, ranging from the mostly traditional to the mostly socio-constructivist.

Byers (2004) correctly pointed out that mathematics education reform provokes a challenging problem for College mathematics curriculum, namely, to address a student population with potentially quite different high school experiences from those prevalent in college. This problem is likely pervasive across disciplines, and across universities and colleges in North America.

I teach future teachers how to teach elementary mathematics at a university in Manitoba. I face the problem of encouraging students to embrace a socio-constructivist perspective, regardless of their past experiences. In fact, I have found that many students' experiences are dominated by a traditional approach to teaching and learning mathematics. I also must try to ensure that future mathematics teachers understand the mathematics that they will teach. This understanding must be rooted in perceptions concerning the nature of mathematics, since a socio-constructivist perspective assumes that (mathematical) knowledge is an uncertain product of human endeavor, rather than absolutist. Hence, I have embarked on a research agenda focused on interpreting the experiences of future elementary level mathematics teachers. This paper will be based on a case study of a student in a course I taught concerning Manitoba mathematics curriculum.

Although this research is grounded in an interpretation of post-secondary students experiences, it began with questions concerning the knowledge and skills needed by (mathematics) teachers. For instance, what is the content knowledge required of teachers? Clearly a teacher needs to know how to add before teaching others how to add. And a teacher needs to know how to factor a polynomial before teaching others how to factor. Shifting to the opposite extreme case, a teacher who teaches only addition and nothing more surely need not understand factoring of polynomials. How much content knowledge does a teacher need to know to teach a subject? Is there a bare minimum of content that a teacher needs to master in order to teach a certain level of mathematics effectively? For example, does a grade 1 teacher need to master K-4 mathematics, and does a high school teacher need a B.Sc. with a major in mathematics?

It seems reasonable to discuss a set of core competencies for (mathematics) teachers, a core that gradually increases as grade level taught increases. On the other hand, there is a plethora of research suggesting that teachers need to know the subjects they teach deeply, and understand how children best learn these subjects (e.g., Ma, 1999; Garet, Porter, Desimone, Birman, & Yoon, 2001). Yet teachers continue to teach despite alarming statistics concerning inadequate training in the subjects they teach (e.g., Darling-Hammond, 1996).

Content knowledge is not the only element of teacher knowledge, as evidenced by a large collection of literature concerning pedagogical content knowledge (PCK). PCK is a special kind of content knowledge anchored by pedagogy (Shulman, 1987). A brief survey of the literature concerning the PCK of mathematics and science teachers suggests that teachers with a more sophisticated PCK will be more effective teachers because they: (1) are more comfortable with the content and can produce lesson plans with a greater appreciation for the topic (Winter & McEachern, 1999); (2) can present content more accurately (Even, 1993); (3) can help students notice connections between various concepts in a curriculum (Foss & Kleinsasser, 1996); (4) can use effective representations of content that depart from textbook knowledge and can depart from planned activities as required by children's needs (Hashweh, 1987); (5) anticipate students' misconceptions and distinguish between correct and incorrect problem solving attempts (Ball & Bass, 2002; Winter & McEachern, 1999); and (6) can predict students' skill and understanding (Marks, 1990). Given the diversity of students, teachers and classrooms, articulating the nature of an effective pedagogical content knowledge can be a formidable task.

A brief survey of the literature suggests that the efforts by many researchers to more clearly describe and understand PCK is problematic and even contradictory. For example, some researchers point out a positive correlation between content knowledge and pedagogical content knowledge (e.g., Bischoff, Hatch, & Watford, 1999), while others find any correlation to be problematic at best (e.g., Meredith, 1995). Some have noted deficiencies in the description of PCK. For example, studies concerning the connection between teacher decision making and teacher understanding of student emotion (McCaughtry, 2003, 2004) explore a facet of PCK previously ignored in most traditional studies. Further, PCK cannot be framed by an objective orientation since teaching acts are bound by value-laden assumptions concerning knowledge, learning and teaching (Ball & Wilson, 1996). Finally, the question of teacher knowledge has been interrogated by theorists who emphasize the dynamic, contextual and complex personal professional knowing of teachers (e.g., Craig, 2001; Clandinin & Connelly, 1995). The literature is far from clear concerning the description and articulation of pedagogical content knowledge.

Content knowledge and pedagogical content knowledge of teachers is further entangled by the beliefs of individual teachers. It has been well documented that teacher beliefs play an intricate role in teacher decision-making (e.g., Hart, 2002; Pajares, 1992; Thompson, 1992). Beliefs serve as a filter of perception (Pajares, 1992), motivate action (Cooney, Shealy, & Arvold, 1998) and are context dependent (Cooney et al., 1998). In other words, descriptions of teacher knowledge must account for implicit and explicit teacher beliefs concerning the nature of knowledge, teaching and learning.

Given the reform in mathematics education espoused by professional mathematics teaching organizations such as the National Council of Teachers of Mathematics (NCTM) (e.g., NCTM, 2000), the role of beliefs in teacher knowledge is further entangled by issues of what teachers should believe versus what they actually believe, how these beliefs are articulated in action, and how teacher beliefs can be changed. For example, there is significant evidence that teacher beliefs concerning mathematics and mathematics education are incongruent with and may even impede NCTM's principles of reform (Cooney, 1999). However, it is difficult to change teacher beliefs (Brown, Cooney, & Jones, 1990; Lerman, 1997; Pajares, 1992), beliefs are not always consistent with practice (Hart, 2004; Brown, 1985), recently acquired beliefs are often unstable (Pajares, 1992), and teacher education programs may not be sufficient to substantively counter the stable beliefs of pre-service teachers developed over many years of schooling (Hart, 2002; Cooney, 1999). In short, teacher beliefs concerning the nature, teaching and learning of mathematics are an integral part of teacher knowledge, but, as with content knowledge and PCK, their role is problematic, contradictory, and difficult to clearly describe and articulate.

Given the disparate research summarized above, it seems that content knowledge, pedagogical content knowledge and beliefs about the nature of knowledge, learning and teaching are not so easily delineated, described and articulated in order to generate unproblematic recommendations for teacher education. It seems to be assumed that it is possible to clearly articulate exactly what knowledge and skills every teacher must know, and then implement teacher education programs that successfully produce future teachers with these prescribed goals. But it is unclear what teachers should be taught, and how a teacher curriculum should be implemented so that teachers in training embrace current perspectives on knowledge, learning and teaching.

It seems I have come full circle: The varied school mathematics experiences of students entering college and university suggests a need to interpret the experiences of these students during mathematics teacher training. The uncertainties associated with content knowledge, PCK and beliefs also suggests a need to explore student experiences during teacher training. Further, it is likely necessary to understand student experience before viable curriculum recommendations are possible. Hence the goal of this paper is to use a student case study to describe a tool for interpreting the experiences of my students during undergraduate mathematics education courses. It seems likely that this interpretive tool will be useful to other college and university instructors for understanding their own practice and the experiences of students within their courses.

Summary of Methodological Considerations

The methodology used for this research project was oriented by Narrative (cf. Bruner, 1986, 1990; Bruner & Kalmar, 1998), which is seen as a metaphor for the processes by which a knower organizes experience. Narratives are tools for interpreting a knower's organization of their experiences. Narrative Inquiry (e.g., Clandinin & Connelly, 2000) is a means to interpret the narrated experiences of others and self. It is also simultaneously experience and method. "For us, life...is filled with narrative fragments, enacted in storied moments (Clandinin & Connelly, 2000, p. 17). The world, and experience, is narrated - in living, we story our experience. On the other hand, "narrative inquiry is a way of understanding experience" (Clandinin & Connelly, 2000, p. 20). Thus, narration is part of the experience and experience is part of the narration. Narration and experience emerge simultaneously - they cannot be separated and reintegrated without obscuring part of searching. Using these notions developed by Clandinin and Connelly, I view narrative inquiry as a process of noticing and organizing a person's experiences based on the stories (or narratives) made available.

Summary of Context and Methods

I taught an undergraduate education course concerning the philosophy, structure and content of the provincially sanctioned elementary level mathematics curriculum. This course is a prerequisite for courses involving the teaching of mathematics. The goal of the course is to ensure that students understand the mathematics curriculum, including the mathematical content and the nature of mathematics. Manitoba mathematics curricula endorse the socio-constructivist perspective of current mathematics education reform.

I developed and implemented this course using socio-constructivist principles at both the level of content and pedagogy. Byers (2004) gives an account of the socio-constructivist perspective as it pertains to high-school curriculum in Ontario, but the same ideas are relevant in this context. In particular, I wanted students to experience doing mathematics at an epistemological level, so that they may experience alternatives to the transmission and absolutist-based school mathematics of traditional classrooms.

Students enrolled in the course made their mathematical experiences available as data in the form of course assignments (e.g., journals, problem-solving events) and in-class interactions. The journals were interactive and focused directly and indirectly on exploring the nature of mathematics. The problem solving events required students to write about their thinking while solving mathematics problems, and provided further evidence of how students experienced mathematics.

Analysis began as a process of endeavoring to draw themes from the student data, but tensions and dissonances within the data seemed to undermine any possibility of a categorical coding system. Hence, I focused on the specific tensions within the data of individual participants. Several students who had expressed frustration during the course were selected as cases for analysis (only one case is presented in this paper). I hypothesized specific narratives to understand a student's experiences (with mathematics). These narratives were posited to be available at the beginning of and throughout the course, or to have emerged as the course progressed. This collection of narratives served to organize an interpretation of a student participant's experiences of mathematics/teaching. Then I looked for evidence of interactions between these narratives, which were interpreted as either mutually supporting or competing and conflicting.

The Case of Lydia

Lydia entered the course with an appreciation and enjoyment of mathematics, beliefs about effective teachers as engaging, helpful and knowledgeable, and a traditional image of mathematics as consisting of right answers generated through hard work and problem solving. The following quotations from Lydia's earlier journals are intended to support the above claim.

> I enjoyed math in school, except for one grade. I loved math up until grade 3. My math teachers prior to this grade were great. Their teaching methods were good, adding variety to the lessons and we did many fun activities to help us understand the reasoning for certain parts in math. In grade three, my teacher was horrible...He would simply give us the worksheet and tell us to look it up in the book if we did not understand. I did not do well in grade three. Starting grade four, I did not put any effort into my math work, even though my teacher was a phenomenal teacher...She put in some extra effort to get me back on track with math...[and] I continued to succeed in math in my future classes...Today, I still enjoy doing math and hope to teach it to children in a way where I can pique their interest in the subject...I hope that I have learned from the mistakes that my grade three teacher made, yet build on the positives of my grade four teacher...
> Once I got into grade ten, math started to get a little more difficult for me...on [basketball] road trips, he [my math teacher] was willing to help me with my questions and sit with me on the bus and help me understand what I was doing wrong...
> What boggles my mind is, if I do not understand certain concepts, not only in math, but also in science and other subjects, how am I to teach my students in a grade one or two class...It's like the answers are set in stone. This is because there are no maybe answers...Math is powerful, useful, every day, valuable, and a black and white subject...

These excerpts suggest that Lydia's images of mathematics/teaching can be organized using the following narratives: positive-personal-mathematical-experiences, teacher-as-engaging-helping-content-expert, and mathematics-as-black-and-white.

Lydia's reaction to the even-odd problem (see Appendix A) provides further support for her black and white image of mathematics. Within her solution she wrote:

> I guess you could start by explaining that everything that ends in 1, 3, 5, 7, or 9 is always odd, and anything that ends in 2, 4, 6, 8, or 0 (10) is even! You could tell them it's a rule or a pattern. Odd, even, odd, even and it will always stay that way. Okay, as far as adding numbers, lets do some trials. [She gives several examples of adding odd and even numbers and noted if the answer is even or odd.] I just thought of a way you could get kids to understand the "rules"! [She explains that the answer is even when addends are the same and odd when addends are different.] As far as providing

> reasons, I am sure there could be, but I just can't seem to think! Maybe it has something to do with a pattern, or a method, or maybe it's just a rule that has to be memorized! I DON'T KNOW!

Her explanation for the addition rules is a pattern without explanation. She seems to feel frustration because she is unable to explain this pattern. This frustration could be understood as an inability to resolve the problem by producing one right answer that any person could understand, which suggests her image of mathematics can be partially organized using a math-as-black-and-white narrative.

Lydia entered the course with specific expectations for the student-teacher relationship. She seemed to expect her role to be a learner of a clearly defined set of outcomes, and she would be tested on her learning. I was expected to present these outcomes. The following quotation suggests her frustration when these expectations were not realized.

> Honestly, this whole nature of math thing is bothering me. I don't know what it is; yet you keep asking us questions about it. I honestly don't think that I will ever understand it. I have my feelings on what it can be, but I never seem to get any reassurance on what it actually is.

Lydia is frustrated when I do not provide clear answers to the outcomes of the course. Her frustration seems to increase as a result of a continued lack of realization of her expectations (although Lydia suggests a different reason for her frustration at the end of the course). I have organized Lydia's apparent expectations for the teacher-student relationship using teacher-as-expert and student-as-reproducer narratives.

The collection of narratives posited above seemed to be available at the beginning and throughout the course for organizing Lydia's images of mathematics/teaching. These narratives seem to interact as coherent and mutually supporting. Lydia's success, enjoyment, appreciation and value with mathematics seem to emerge together. Lydia has been quite successful at reproducing solutions to problems that she believes teachers are expecting. Teachers have helped her to be successful because they were engaging, available and clear in their expectations. The expert teacher must be a master of content. Lydia wants to be a good teacher, which she will learn how to do by reproducing the knowledge of teacher training delivered at the higher learning institution of university. She has confidence because she has mostly been successful, but also because she believes in always trying her best to solve the problems of a course. Good teachers sometimes ask hard problems, which is reasonable since all mathematics problems have an answer and teachers are always available to help her reproduce solutions with the correct answer. This coherent and mutually supporting collection of narratives at least partially represents her image of mathematics/teaching.

In the first half of the course, Lydia's frustration seems to increase because I am not forthcoming in providing a clear and well-defined answer to the question of the nature of mathematics. As a result, Lydia tries to devise her own answer, or an answer that she hopes I will accept. The following quotation is one of several examples:

> When I sit and think of the word nature, I think of beauty and wonder that was created. So maybe when I use words like appreciate and enjoy and love, I am linking them to my interpretation of what the word nature means. To me, nature is beautiful, I enjoy it and I have a great appreciation for the beauty that nature holds. So, I see math as seeing beauty in the subject, having an appreciation for how math works and enjoying it. I honestly love math and maybe that helps me to come up with the fact that to me, the nature of math is the feeling I have about it. I don't know if my interpretation is anywhere near what the nature of math really is, but I do know that is what I think.

It appears that Lydia is re-constructing a nature of mathematics based on her positive experiences. She is seeking a black-and-white answer to the problem, which she hopes I will deem as correct. I interpret this event as an example of a coherent and mutually supporting interaction between math-as-black-and-white, positive-personal-mathematical-experiences, teacher-as-expert and student-as-reproducer narratives.

As part of her efforts to find answers to the question of the nature of mathematics, Lydia tries to notice other possibilities for the nature of mathematics. In reaction to the story of the development of non-Euclidean geometries, Lydia wrote, "All right, so if Euclidean geometry is wrong, then we have a problem. Do we not base our entire math on Euclidean geometry, or at least a great majority of it?" In this case, it seems that her efforts to find an answer are conflicting with her initial conceptions of mathematics. This is interpreted as a conflicting interaction between math-as-black-and-white and student-as-reproducer narratives.

Similarly, in reaction to a paper cutting activity where students debated the interpretation of a set of rules for cutting the paper, Lydia wrote:

> Today's class was a little frustrating for me. Trying to get the point across throughout the debate was frustrating. I found that is an aspect of the nature of math. I believe that the nature of math is all about emotions and feelings. It includes the appreciation, love and enjoyment of math. Along with the love of math comes

> the frustration that is also included...I truly feel that the nature of math has a great deal to do with the emotions that math brings. I also think that the nature of math is an area that is gray. Is there even a true meaning to the nature of math? I don't think so?

I have been discussing interpretation during class, and Lydia uses the word gray. Lydia loves doing math but must adapt to her frustration with the course. Lydia is looking for a right answer. In mathematics, these right answers must satisfy the criteria of logic. But she posits an emotional content to math. I interpret this event as another example of a conflicting interaction between narratives - in this case between math-as-black-and-white, positive-personal-mathematical-experiences, and student-as-reproducer.

Just past the halfway point of the course, Lydia seems to solidify a new possibility for the nature of mathematics, which I refer to as Lydia's in-retrospect Eureka. In journal five she wrote, "I have started to see math differently than what I saw in grade school. I am starting to see how math is about interpretation, not just black and white." Lydia has not rejected a black-and-white image, but she has explicitly considered an alternative image of mathematics. I refer to journal five as her in-retrospect Eureka because she chose this journal as her best within the end-of-course portfolio assignment.

> ...but I really think I made a true discovery in this entry...it was my statement about taking the gray into consideration that really piqued something in me now after reading it again...I think that through all the other journals, I discovered things, but in this one, I discovered that it is really okay not to always get a right answer and that red check mark at the end of the solution to that tough question.

Lydia was realizing the importance of process and interpretation, and in-retrospect views this realization as a Eureka.

There is evidence that Lydia also began to notice the role of interpretation when solving math problems, which was evident within her solution to the "tablecloth problem" (see Appendix A). This problem was assigned shortly after journal 5, so the possible role of process and interpretation in mathematics has been visited several times during in-class discussions and been contemplated within her journals. The problem concerns converting a 10x3 tablecloth into a 15x2 tablecloth by cutting and sewing. After drawing a picture she wrote, "All right! So, after reading the question a couple of times, I am not too sure what is meant by two congruent pieces?" Lydia proceeded to find a way to cut and sew a new tablecloth of the correct size, which happened to satisfy her second interpretation of "two congruent pieces." She then reflected, "But I don't know if I did that right! So, let's keep trying!" Lydia then successfully finds a second solution that satisfies her first interpretation, and closes with, "I think that works! Yes it does! And I believe I followed the directions correctly this time!!" Within her second attempt to solve the problem there is evidence of false starts, but she sticks to it and produces a correct solution given a harder interpretation. Lydia deliberately reinterpreted the wording of "two congruent pieces." On the other hand, the potential role of interpretation did not seem evident within her solutions to all previous problems, which suggests that she was making connections between her new understandings from the course and problem solving events. Lydia chose the "tablecloth problem" as her best problem within the end-of-course portfolio assignment.

> I did the problem as I thought it should be done, but there was still a 'gray area' of what the meaning of a couple of words were. Instead of being satisfied with my product, I decided to explore the gray area of what was meant by that word...Maybe I was dwelling on the black and white, but I like to think that I was exploring my curiosity of what would happen if I tried it a different way.

Lydia seemed to make a connection between problem solving and the role of interpretation within the nature of mathematics. I interpret this as an interaction between math-as-black-and-white and math-as-interpretation narratives, although now the interaction is complementary rather than conflicting.

Lydia seems to use of new understanding of mathematics as involving interpretation to reflect on issues of teaching and learning. Near the end of the course she wrote:

> I began to realize that not every child learns the same way...I think about how I learn and I begin to think about how some of the others learn in our class...She [another student] learns well using worksheets, where I feel that isn't letting the child explore their curiosity. My problem is how I could create both a mix of exploration and control...I began to see that you can't just force a kid to see the right and wrong of math, but you have to let them explore and investigate the gray as well. It is through this discovery that I began to see math differently. I began to see that it is okay to explore the unclear areas of math and to let children explore them too.

In this case, her beliefs concerning effective teachers as engaging is interacting with the pedagogic idea of exploring the gray of mathematics. As with the tablecloth problem, I interpret this event as an example of re-constructing a set of narratives (some new) in order to organize a coherent image of mathematics/teaching.

At the end of the course, Lydia seems to see process as her answer for the course. She wrote in the end-of-course portfolio assignment:

> The part I found so frustrating was that after over fourteen years, you somewhat expected us to realize this in six weeks or so. That was the most frustrating part for me. But, at the same time, I began to realize it very quickly. It actually only took one comment from you in my journal [#3] to realize that math was not about product and more about process. You said something to encourage me, but at the same time it was like a boulder you dropped on my head and I realized how I have been seeing things. You said, "this" (meaning what is going on in my head) "is more important than this" (meaning answering the question that you asked for the journal response). When I read that, I began to realize that it is the process that is going on through my mind that is what really matters. I know the right answer matters in standards and exams, but if the process is completely wrong in my mind head, how am I supposed to get the right answer to begin with?

Lydia is trying to incorporate her new ideas concerning math by using the idea of process. Process is attached to the gray of mathematics, and is an opportunity for learning as exploration. Product is attached to the black-and-white of mathematics, and is part of the measurable outcomes of math classrooms. I believe Lydia's images of mathematics can be re-constructed with a new collection of coherent and mutually supporting narratives, which include the initial narratives as well as math-as-interpretation and math-as-process. This re-construction is part of a process of re-establishing a sense of coherence, where narratives that once conflicted are now mutually supporting.

In summary, I organized Lydia's images of mathematics/teaching at the beginning of the course using a collection of coherent and mutually supporting narratives. Lydia adapted to the frustration she experienced from unmet expectations for the course, which I interpreted as a negotiation of differing, competing and conflicting narratives. After Lydia's in-retrospect Eureka occurred in journal 5, the student-teacher relationship was qualitatively different. Lydia no longer seemed to experience frustration and perceived my role as facilitator. Her initial narratives were still evident, but Lydia began to see possibilities for problem solving, teaching and learning, which I interpret as a process of reconstructing a coherent collection of narratives for organizing her images of mathematics.

The shift in our student-teacher relationship was across an in-retrospect pivotal moment, which Lydia believed she must find for the course to be of use (to provide some sort of useful answer). Lydia, in-retrospect, in her Eureka, found something that worked for her that was different from what worked for her in the past. In particular, Lydia's reflections concerning the nature of mathematics seemed evident in her convictions concerning the need to find an answer versus the potential importance of process. In the portfolio assignment Lydia reflected on the course as a whole:

> At the beginning of the course, I was excited to begin to understand the power and value of math, but didn't realize that I would discover its power through all this frustration. I began to see after over fourteen years of math, where I saw everything as a product that it is not always about the product. Even though that is how I was taught and I am sure everyone else in the class as well, I began to see that math is more about the process. It is not about what is at the end of the question, but more so how I got there and what went on in my mind.

Lydia realized the importance of process and interpretation, and views this realization as a Eureka and as her answer to the question of the nature of mathematics. I interpret this in-retrospect Eureka as evidence that process and interpretation narratives have become part of a collection of coherent and mutually supporting narratives for organizing Lydia's images of mathematics/teaching. I believe Lydia entered the course with a coherent sense of her identity in relation to mathematics, adapted to her frustration by seeking alternatives, and exited the course with a re-formed and different sense of coherence.

Implications

I developed an interpretation of one student participant's evolving images of mathematics/teaching in terms of negotiating tensions, dissonances and contradictions among available narratives used to organize her apparent experiences during the course. I see the negotiation of available narratives as an interpretation of an adult's identity in relation to a specific body of inquiry, namely mathematics. I view an individual's identity in relation to math as a coherent, rational and autonomous unity. But as a person experiences frustration, they adapt by re-constructing their identity as coherent. In other words, I have interpreted a students identity with mathematics as a process of seeking to re-construct a coherent image in the face of conflicting possibilities.

Although the claim made in this paper is based on a case study, it seems possible to explore these ideas in other contexts. I am claiming that it may be possible to interpret a person's adaptation to frustration in terms of negotiating differing, competing and conflicting narratives in order to re-construct a sense of coherence. I will address this possibility in terms of the discipline studied, teacher education, and the processes needed by post-secondary instructors.

First, can these ideas be applied to disciplines other than mathematics? At the level of epistemology, socio-constructivism represents a rejection of absolutist philosophies of mathematics. Absolutism is a position available within any discipline. Within the discipline of science, issues arise concerning transmission and absolutism-based school experiences in traditional classrooms. Science education is in the midst of change toward socio-constructivist principles. Post-secondary instructors of science and science education face similar challenges as in mathematics. Hence, inquiry could focus on the philosophical underpinnings of science, in terms of the experiences of students in science and science education courses. I suspect that similar patterns might emerge, such as competition between subjectivity and objectivity in terms of knowledge narratives.

Second, can these ideas be extended from mathematics teacher education to teacher education in general? The practice of teaching is currently in the midst of a shift from transmission to inquiry-based approaches. An inquiry approach is largely consistent with the socio-constructivist principles of mathematics education reform. But this shift in teaching practice is far from complete or universal, so there are various instances of conflict across the educational experiences of teachers-in-training. Thus, a focus on interpreting student teacher experience via competing and conflicting narratives may provide insight into these experiences. Further, such interpretations may provide insight into the development of teaching beliefs and teaching practice, which sometimes are in conflict. There is a potential for uncovering viable possibilities for teacher education, and for reconstructing the notions of teachers changing and changing teachers.

Finally, can these ideas become part of the processes needed to be an effective post-secondary instructor? It seems reasonable to suggest that any instructor of adults could follow the processes that I used while coming to understand Lydia's experiences. These processes involve questioning the nature of knowledge and the nature of knowledge that is valuable to students. By asking these questions and seeking the varied and often competing narratives available to students, instructors may come to a greater understanding of the experiences of their students. As a tool of growth, post-secondary teachers may find value in interrogating their own practice, both in terms of the complexity of practice and the narratives that organize practice. Further, there are possibilities for understanding the enculturation of mathematics majors in ways that move beyond transmission metaphors of education. For example, do students of mathematics experience conflict between the abstract nature of mathematics and their perceptions of preparation for a future career? A similar question could likely be raised for any post-secondary discipline. By examining student experience in terms of negotiating varying, competing and conflicting possibilities, it may be possible to develop more effective post-secondary curriculum.

References

Ball, D. L., & Bass, H. (2002, May). Knowledge of mathematics teachers. Paper presented at the

Canadian Mathematics Education Study Group Annual Meeting, Kingston, ON, Canada.

Ball, D. L., & Wilson, S. M. (1996). Integrity in teaching: Recognizing the fusion of the moral and intellectual. American Educational Research Journal, 33, 155-192.

Bischoff, P., Hatch, D., & Watford, L. (1999). The state of readiness of initial level pre-service middle grades science and mathematics teachers and its implications on teacher education programs. School Science & Mathematics, 99(7), 394-400.

Brown, C. A. (1985). A study of the socialization to teaching of a beginning mathematics teacher. Unpublished doctoral dissertation, University of Georgia, Athens.

Brown, C. A., Cooney, T. A., & Jones, D. (1990). Mathematics teacher education. In W. R.Houston (Ed.), Handbook of research on teacher education (pp. 639-656). New York: Macmillan.

Bruner, J. S. (1986). Actual minds, possible worlds. Cambridge, Massachusetts: Harvard University Press.

Bruner, J. S. (1990). Acts of meaning. Cambridge, Mass.: Harvard University Press.

Bruner, J. S., & Kalmar, D. A. (1998). Narrative and meta narrative in the construction of self. In M. Ferrari & R. J. Sternberg (Eds.), Self-awareness : its nature and development (pp. 308-331). New York: Guilford Press.

Byers, P. (2004). Responding to mathematics reform at the college level. College Quaterly, 7(3). Retrieved July 15, 2005, from http://www.senecac.on.ca/quarterly/2004-vol07-num03-summer/index.html

Clandinin, J., & Connelly, F. M. (1995). Teachers' professional knowledge landscapes. New York: Teachers College Press.

Clandinin, J., & Connelly, F. M. (2000). Narrative inquiry: Experience and story in qualitative research. San Francisco: Jossey-Bass.

Cooney, T. J. (1999). Conceptualizing teachers' ways of knowing. Educational Studies in Mathematics, 38(1-3), 163-187.

Cooney, T. J., Shealy, B. E., & Arvold, B. (1998). Conceptualizing belief structures of preservice secondary mathematics teachers. Journal for Research in Mathematics Education, 29(306-333).

Craig, C. J. (2001). The relationship between and among teachers' narrative knowledge, communities of knowing, and school reform: A case of 'The Monkey's Paw'. Curriculum Inquiry, 31(3), 303-331.

Darling-Hammond, L. (1996). What matters most: A competent teacher for every child. Phi Delta Kappa, 78(3), 93-201.

Even, R. (1993). Subject matter knowledge and pedagogical content knowledge: Prospective secondary teachers and the function concept. Journal for Research in Mathematics Education, 24, 94-116.

Foss, D. H., & Kleinsasser, R. C. (1996). Pre-service elementary teachers' view of pedagogical and mathematical content knowledge. Teaching and Teacher Education, 12, 429-442.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. American Educational Research Journal, 38(4), 915-945.

Hart, L. C. (2002). Preservice teachers' beliefs and practice after participating in an integrated content/methods course. School Science and Mathematics, 102(1), 4-14.

Hart, L. C. (2004). Beliefs and perspectives of first-year, alternative preparation, elementary teachers in urban classrooms. School Science and Mathematics, 104(2), 79-88.

Hashweh, M. Z. (1987). Effects of subject matter knowledge in teaching biology and physics.

Teaching and Teacher Education: An International Journal of Research and Studies, 3, 109-120.

Lerman, S. (1997). The psychology of mathematics teacher learning: In search of theory. In E.Pehkonnen (Ed.), Proceedings of the 21st International Meeting of the International Group for the Psychology of Mathematics Education (Vol. 3, pp. 200-207). Lahti, Finland.

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

Marks, R. (1990). Pedagogical content knowledge: From a mathematical case to a modified conception. Journal of Teacher Education, 41, 3-11.

McCaughtry, N. (2003). Development of pedagogical content knowledge: Moving from blaming students to predicting skillfulness, recognizing motor development, and understanding emotion. Journal of Teaching Physical Education, 22(4), 355-368.

McCaughtry, N. (2004). The emotional dimensions of a teacher's pedagogical content knowledge: Influences on content, curriculum and pedagogy. Journal of Teaching Physical Education, 23(1), 30-47.

Meredith, A. (1995). Terry's learning: Some limitations of Shulman's pedagogical content knowledge. Cambridge Journal of Education, 25 (2), 175-188. National Council of Teachers of Mathematics. (2000). Principles and Standards for School

Mathematics. Reston, VA: Author. Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. Review of Educational Research, 62, 307-332.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57(1), 1-22.

Thompson, A. (1992). Teachers' beliefs and conceptions: A synthesis of research. In D. A. Grouws (Ed.), Handbook for research on mathematics teaching and learning (pp. 334-368).

New York: Macmillan. Winter, E. C., & McEachern, W. R. (1999). Subject specialization in teacher education: An experience in a Canadian Native School. Education, 119(4), 713-723.

Appendix A - Two of the math problems used during the course

Week 3 - Even and odd numbers

Assume a child does not know what multiplication and division are. How the child does know how to count from 0 to 10. How do you explain that the numbers 2, 4, 6, 8 and 10 are even numbers, and 1, 3, 5, 7 and 9 are odd numbers? Is it true that: When you add two even numbers, the answer is even? When you odd two odd numbers, the answer is even? When you add an even number and an odd number, the answer is odd? Can all of these be reasoned out without using the concepts of multiplication or division? Can you provide reasons for each?

Week 5 - Resizing a Tablecloth

Rachel and Marissa went on picnic, but when they reached the park, they found that the picnic table was an unusual size. It was a rectangle 2 feet wide and 15 feet long. The red-checkered tablecloth they brought was 3 feet wide and 10 feet long. They realized that the area was the same so they wanted to efficiently cut and piece together the tablecloth to fit the table. How could they cut the tablecloth along the checkerboard lines into two congruent pieces that could be rearranged to fit the table?

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Contents