DEVELOPING PROCESSES FOR LEARNING HIGH SCHOOL MATHEMATICS

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High school mathematics students often complete homework and study for unit tests without support to consider how these actions could contribute to their mathematical learning. Learning to learn mathematics invites students to bring into view how they learn mathematics. The constructivist grounded theory study reported in this presentation describes how grade 12 students inquired into the systemically defined and externally imposed learning strategies that they perceived as static and superficial. The Framework for Developing Processes for Learning Mathematics *illuminates the complexity of becoming aware, incorporating suggestions, verbalizing possibilities, and (re)forming intentions to shape personal processes for learning. Viewed as dynamic and authentic, the processes for learning mathematics students developed shaped them as learners who made sense of mathematical ideas.*

Keywords: High School Education, Learning Theory, Metacognition

Mathematics education reforms have emphasized students' personal development of mathematical ideas (National Council of Teachers of Mathematics, 2000; Western and Northern Canadian Protocol, 2008). Absent from these reforms and from experiences in many high school mathematics classrooms is explicit discourse about the processes of learning – both identifying the strategies students use to learn (e.g., homework, taking notes, test preparation, study groups) and then how to individually adapt those strategies. While study how-to books abound (e.g., Coles, White, & Brown, 2003; Ooten & Moore, 2010; Peltz, 2007), the publications are didactic in their approach and divorced from the particular contexts of learning mathematics, rather than working from individual students' current intentions and processes for learning mathematics.

Within mathematics education, research using the psychological construct of metacognition (Brown, 1978; Flavell, 1976) has supported improvement in students' mathematical thinking (e.g., Hamilton, Lesh, Lester, & Yoon, 207; Schoenfeld, 1987). This research report extends the work of these cognitively-based studies to address the complexity of learning which view mathematics students as persons in the process of becoming. Research in mathematics education has identified successful students as those who understood their personal learning processes (Dahl, 2004; Smith, 1999), and this study extends this recognition to explore students' *development toward* becoming capable mathematical learners.

Purpose of the Study

The empirical research being presented in this research report is part of a larger study that addressed the question: *What is the nature of students' learning when they engage in conversations to shape their personal processes of learning high school mathematics?* The purpose of the study was to understand how high school students learn to learn mathematics. Results of the larger study demonstrate that students were able to see themselves as capable learners of mathematics because of a learning-based orientation in the world that simultaneously grew as they developed approaches to independently learning academic mathematics. This research report will focus on one facet of my theorizing about students' experiences of learning to learn mathematics in order to closely examine how students shifted from the use of systemically-imposed learning strategies to personally-developed processes of learning. Novak and Gowin (1984) help tease out the distinction between "learning and knowing. They are not the same. Learning is personal and idiosyncratic; knowing is public and shared." (p. 5) In taking up this notion of learning, I am proposing an alternate perspective on students' engagement in high school mathematics classes, namely the possibility for inviting students to shape processes for learning mathematics in ways that are personally dynamic and authentic.

Mode of Inquiry

Constructivist grounded theory [CGT] (Bryant & Charmaz, 2007; Charmaz, 2006, 2009) returns to the symbolic interactionist root of grounded theory while looking through a constructivist lens as an interpretive process for inquiring into dynamic phenomena. Within this postmodern orientation, theory is constructed by a researcher on a provisional basis and contingent to the context. There is an "emphasis on processes, making the study of action central" (Charmaz, 2006, p. 9), recognizing that shifts in people's actions and experiences signify growth and changes within the people and their interactions. The researcher, seen as a subjective knower, is immersed in the research setting while co-constructing qualitative data with participants. As data is analyzed abductively, the researcher moves from rich empirical data through levels of abstraction toward developing a mid-range interpretive theory. Processes like coding, memoing, categorizing, theoretical sampling, saturation, and sorting are offered as "systematic, yet flexible guidelines for collecting and analyzing qualitative data … rather than formulaic rules" (Charmaz, 2006, p. 2). The reflexivity of the researcher results in explicating the theorizing as both process and product enabling other researchers to apply and extend the work.

The focus of this research, students' experiences of learning to learn mathematics, is supported by CGT's framing to notice and interpret the growth of individuals. Grounding interpretation in students' experiences, rather than applying extant theoretical frameworks, supports the uniqueness of the study in attending to the development of mathematical learners. Theoretically, constructivism is the predominant epistemological orientation to the teaching and learning of mathematics (Bishop, 1985; Davis, Maher & Noddings, 1990), often used in conjunction with symbolic interactionism for mathematics education research (Cobb & Bauersfeld, 1995; Sierpinska, 1998; Voigt, 1994). The use of CGT responds to the growing importance in theorizing to make progress within the field of mathematics education (Hiebert, 1998; Proulx, 2010).

Research Context and Participants

The study was situated in an academically-focused suburban school in a city in Western Canada. Thirteen grade 12 students who were taking a pure mathematics course volunteered to participate in the study. Their pure mathematics courses were offered in a didactic format where the teacher lectured, students copied out worked solutions to examples, and then worked through similar questions independently as homework. The students were enrolled concurrently in a course, *Mathematics Learning Skills*, that provided support for their mathematical learning. In the class, students worked on homework and requested help from the teacher. Within the *Learning Skills* course, I assisted the teacher in coaching students to improve their approaches to learning mathematics while simultaneously collecting data. The teacher also participated in the study to provide contextual information and offer her perspective on emerging analysis.

Data Collection

Data collection occurred over four months. After observing each class, I wrote detailed field notes of students' (inter)actions in the class and descriptions of daily informal conversations with the teacher. Students took part in bi-weekly interactive journal writings (Mason & McFeetors, 2002). They responded to prompts about the progress of their learning strategies and I replied in order to interact with their ideas, modeling thinking about learning and fostering a relationship with each student. Students were placed into one of three small groups with a focus on developing a learning strategy as a group (transitioning from notes to homework, developing big ideas from completed homework, and studying for unit tests by creating summary sheets). Each small group met for three to five sessions of approximately 30 minutes each. The students also participated individually in two informal interviews as a retrospective look at their progress in shaping their learning strategies. Each interview was approximately 30 minutes and occurred halfway through the study and at the end. While the interactions were intended as multiple sources of data, they also afforded students the opportunities to develop processes of learning to support their mathematical learning and to notice improvements in learning. Providing these opportunities was framed by Dewey's (1938/1997) notion of experience which is characterized by continuity and interaction and where activity is transformed into experience through the reflective act.

Data Analysis

Using line-by-line coding and the constant comparative method (Glaser & Strauss, 1967), data analysis involved the development of codes for students use of learning strategies across all forms of data. The codes, such as "do questions" and "see the process", remained close to the students' words and were refined through several passes through the data. The codes were stored in a spreadsheet which enabled parsing codes to create initial categories. Names of categories, such as "becoming aware" and "incorporating suggestions", are descriptive of the students' actions and abstracted from the data to highlight the process-based nature of learning to learn mathematics. I constructed the *Framework for Developing Processes for Learning Mathematics* through the interpretive act of theorizing by exploring the relationships of the categories. The categories and framework will be described in the results section below.

Perspective

Rather than using an interpretive framework, I adopted Blumer's (1954) notion of sensitizing concepts to "merely suggest direction along which to look … providing clues and suggestions" (pp. 7-8). Drawing on Blumer's work as a symbolic interactionist responds to the misconception that grounded theory studies begin atheoretically. Rather, the sensitivities of the researcher – what the researcher is drawn to attend to because of her/his experiences of conducting research, scholarship in the field, and interests – are acknowledged, explored, and employed as a starting place in the collection and analysis of data. The purpose of a CGT research project is not to refine sensitizing concepts but to interpret the participants' experiences.

My sensitizing concepts developed out of two of my related research projects. In one project, high school students' success in non-academic mathematics was interpreted as an emerging of voice, where students came to say things about themselves as mathematical thinkers and learners with the intention of (re)forming their identity (McFeetors, 2003, 2006). In another project, students' trajectories of learning, through choices of high school mathematics and science course, indicated that students selected among mathematics courses in relation to their identity as learners, and their ways learning within courses was connected to who or what they perceived as sources of mathematical knowledge (Mason & McFeetors, 2007). The four sensitizing concepts are: intentions, voice, identity, and relationships with sources of knowledge. After each explanation, I provide examples of literature for those who desire a more thorough discussion.

Intentions are internal constructs which give meaning to actions. These thoughts and desires arise from attention to previous experiences and to the consequences of actions, often through reflection. When students are intentional, they are acting with the intentions they have formed and hold, to move toward a particular aim. This aim, as an end-in-view, is fluid and the method of moving toward it contains ambiguity. Intentions point to what students want to do or achieve and a notion of how they might go about doing. So, intentions both mark an aim and a process. (See Bereiter & Scardamalia, 1989; Searle, 1983.) *Voice* points toward having space and confidence to say things and to do so, a reflective stance to make sense of experience through conversation, and being deeply implicated in actively shaping oneself. Voice is dynamic concept, one in which a student's voice is continually being refined through experience and through the voicing of the experience and growth of self. (See Baxter Magolda, 1992; Confrey, 1998.)

Identity is an understanding or sense of self. It is a dynamic processes, where the (re)forming of identity is continually undertaken through experiences and relating with others. While occasionally marked by large shifts, (re)forming identity is more often seen as shaping a way of being in the world and understanding that way of being. Shaping an identity is the ongoing negotiation of a student's relationship with mathematics, learning, schooling, others – identity is malleable and complex. (See Britzman, 1994; Sfard & Prusak, 2005.) *Relationships with sources of knowledge* – such as teachers, peers, and textbooks – point to students' beliefs about knowing and coming to know (epistemological stances) which are inextricably connected to the experiences of learning mathematics. The relationships could include dependence, independence, and interdependence and are often illustrated through examples of where authority in mathematical knowledge lay and through the choice of approaches to learning. (See Belenky, Clinchy, Goldberger, & Tarule, 1997; Chickering & Reisser, 1993.)

Results

In students' first journal, they listed the prescribed ways to learn mathematics, such as study, review, copy notes, work with others, and do homework. Learning strategies were ways students were told by their teachers to learning mathematics and were labels that did not probe the steps students would need to take to enact the learning strategies. The uniformity in naming learning strategies arose from the systemically defined characteristic of learning strategies, that school as a normative structure has systematized these procedures without consideration of these particular students. Teachers, as actors in the system, compelled students to use the learning strategies through their authoritative stance, resulting in externally imposed ways to learn content. Although the students desired to succeed in mathematics class and acknowledged that these learning strategies should support that success, they struggled to implement them to any effect. Vanessa illustrates this in her first journal when she writes "I tried reading my math notes when I get home. But I find that when I try to do the homework and understand the notes, I've already forgotten how and what to do by the end of the day."

The unquestioning implementation of learning strategies demonstrated the students' lack of intentions and personal investment in procedures espoused by the school system. Students perceived the learning strategies as being static and superficial. Teacher demands, especially for notes and homework, led students to use the strategy as prescribed even if they did not see it as supporting their learning – the strategy was static both in its implementation and lack of contribution to learning mathematics for understanding. The learning strategies contributed in a superficial form of learning (memorization of mathematical procedures), glossed over the challenges of learning, and viewed one way of learning as equally effective for all students. However, not only were the learning strategies static and superficial, but these characteristics positioned the students as static persons whose learning was also superficial. Through the use of simplistic learning strategies, students did not have opportunities to be changed by deep engagement in a learning process and mathematics. They continually saw themselves as ineffective learners and prioritized the surface goal of high marks. Against this backdrop, the students and I began to explore the ways they were struggling to learn academic mathematics.

This exploration is better characterized as an inquiry into learning strategies. My interpretation of the students' engagement resulted in the *Framework for Developing Processes for Learning Mathematics*. The four facets of the framework provide an emerging picture of how students engaged in inquiring into learning strategies, moving toward the development of personal processes of learning mathematics. These forms of engagement in shaping ways of learning mathematics represent the categories constructed from and grounded in the students' data. Being enacted simultaneously and in an interrelated fashion, *becoming aware*, *incorporating suggestions*, *verbalizing possibilities*, and *(re)forming intentions* were the ways in which students shaped how they were learning mathematics through their *Learning Skills* class and the procedures for data collection for the study.

The students were *becoming aware* of the learning strategies, the limitations of those strategies, and the personal nature of their mathematical learning through their inquiry. Kylee, who had previously created a system of cue cards for learning terms in biology, noticed their limitation for mathematics through her second journal, "I realize how much of my time I waste making Q-cards (sic) before my test when I could instead be studying them," and found an opening to refine an existing process of learning. Shane's insight in our first interview, "I would focus on learning how these numbers work and now I guess how the numbers work is a concept in itself, but I never thought of it that way" signals a new awareness that his mathematical learning could fit his identity as a conceptual learner. The growth in students' awareness was situated in a space where their voices could be heard and valued, even in its tentative state.

As the students shaped ways of learning in the small group sessions, they were *incorporating suggestions* from their peers and from me. Kylee described my interactions with her as "you weren't telling me to do something or getting mad because I did that on a math test. You were just encouraging", as I offered alternatives and worked from students' current capabilities in learning mathematics. Drawing on both peers' and my support, Elise exemplifies the notion of incorporating suggestions by actively modifying suggestions (as opposed to compliantly implementing teachers' learning strategies). In her recording "big ideas" at the end of a homework assignment, Elise asserted that "what we wrote down here broke down what it actually meant … So, I understand what to do when I have a question" showing that she had adapted my suggestion of identifying one or two main concepts from a lesson which I had suggested. Elise also modified Danielle's approach of using sticky notes on summary sheets as "I kind of like the way she does it, but I think it works better for me the way I do it." While the students listened to the ideas of others, they recognized that they themselves were expert sources of knowledge about how they learned.

When students deliberated on how to modify ways of learning and put their ideas into words, they were *verbalizing possibilities* for ways to learn mathematics. Danielle demonstrated that sometimes these were internal conversations, where "I was just sitting on the bus, and I was thinking … how would I be able to separate my ideas and stuff." In my field notes I also recorded that "as Danielle handed in her fifth journal, she explained aloud how she would use different colors of sticky notes to represent different kinds of content such as definitions, formulas, and examples." After noticing that Danielle wrote "With [the] method I developed, my ideas are organized and laid out in a way that really helps me understand" in the journal itself, her oral utterance is an example of her first attempt to articulate for herself the details of a new possibility for her process of learning at the end of a unit. As we worked together in a small group on this studying process, Danielle not only refined her explanations for the use of sticky notes as an organizational technique, but used them to demonstrate how she connected mathematical ideas across a unit of content. The verbalizing of possibilities occurred both orally and in writing through my conversations with students and demonstrated that students, like Danielle, could be sources of knowledge for how they learn and perceived their voices as being valued in the learning context.

Students were *(re)forming intentions* for particular ways of learning mathematics as they moved away from the unquestioning use of learning strategies. Grace realized a memorization-based approach to academic mathematics was not sufficient, and explained in our first interview how she refined two processes of learning with the intention of developing mathematical understanding. First, the students' talk in her study group shifted from "how you got the answers" to "we discuss why you're doing it" when completing homework questions. While this shift supported Grace's growing belief about mathematics as a process, the intention she had for her collaboration with peers evolved from comparing answers to mathematical discussion. Second, in authoring various forms of notes, Grace explained she added on side notes – that were "in my words … [s]o it's easier for me to understand" – to the teacher's notes she copied down. She formed the intention of putting mathematical ideas in her own words which impacted all her processes of learning mathematics. The students' intentions developed out of shaping the learning process and increased the complexity of the process of learning. As students became aware that learning processes could be adapted to fit who they were as learners, the intention was not only how the process would support their mathematical learning, but they also became intentional about learning to learn mathematics.

As students inquired into the learning strategies they were told to use to learn mathematics, they were developing processes for learning. Examples of these processes of learning (juxtaposed with strategies in parentheses) included creating summary sheets (study), making and using cue cards (review), authoring various forms of notes (copy notes), collaborating with peers (work with others), and learning from homework (do homework). Processes for learning mathematics are ways in which students make sense of mathematical content and are developed by students in response the particularities of each one. In contrast to learning strategies, processes for learning were perceived by the students as being dynamic and authentic. A process of learning was dynamic because the students continued to shape it and noticed their peers doing the same. Additionally, process for learning supported students' construction of mathematical understanding, were the discipline of mathematics was seen as malleable and the content was of their own making. There was authenticity in the processes for learning, not only because the students were aware of the effectiveness of the processes but because they authored the processes and could describe the development of the processes. The students experienced growth as mathematical learners, a dynamic process, and came to have a nascent authorial stance as they saw themselves as personally developing their processes for learning.

Discussion

The *Framework for Developing Processes for Learning Mathematics* represents the complexity of students' learning when they engage in an approach that opens up space for them to develop processes of learning. This extends beyond the limits of how-to literature on studying to contribute to a way of being with students that supports their learning to learn mathematics. By explicating four ways of engaging in learning to learn mathematics, I hope to invigorate research into metalearning in mathematics education in order to refine these constructs.

This study is an example of an alternative research design which could serve to broaden approaches to inquiring into students' mathematical learning. Researchers may find the methods of data collection, which students found to be legitimate processes in learning to learn, useful in their research with high school students. Additionally, researchers may find CGT to be a methodological approach to research in mathematics education which holds much promise for theorizing informed by the experiences of students and teachers in schools.

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