Mathematical Autobiography Among College Learners in the United States

Shandy Hauk

Assistant Professor, Mathematics
School of Mathematical Sciences
University of Northern Colorado
<hauk@unco.edu>

Abstract

This study examines the K-12 mathematical experiences of U.S. university students via an expressive writing assignment: a mathematical autobiography essay. The essays of 67 college students, out of over 300 enrolled in 16 sections of a college liberal arts mathematics course, were analyzed using constant-comparative methods. Two categories of experience connected to aspects of mathematical self-regulation emerged as significant: (1) locus of control for mathematics knowledge and learning; (2) self-evaluations of mathematical ability, efficacy, and potential. Interviews of 18 of the 67 students provided support and clarification for the analysis. An argument grounded in existing research for increased mathematical self-regulation as a result of completing the mathematics autobiography is made. Finally, connections are drawn between learning and psychological theories to support the assertion that using the assignment may help build pedagogical content knowledge among novice college mathematics teachers.

Introduction

Given the constructivist pedagogical orientation of curricular change in U.S. schools over the last 25 years (National Council of Teachers of Mathematics [NCTM], 1980, 1989, 2000), a shift from teacher-regulation to student self-regulation in mathematical learning has been inevitable. Development of the kinds of “mathematical habits of mind” called for by constructivist pedagogies must be folded into school and college instruction (De Corte, Greer, & Verschaffel, 1996; Schoenfeld, 1992). How can this be done? Answering this question requires an understanding of reflection, intentionality, and habits in mathematical contexts and gives rise to many more questions: What is the nature of the relationship among reflective, intentional, and habitual facets of the intended curriculum (NCTM, 1989, 2000) and of the perceived curriculum (i.e., what is reported by students who have experienced it)? How will these experiences inform the next generation of teachers, parents, and curriculum developers in the United States? Even more fundamentally, just what *is* the nature of the lived experience of mathematical learning for this next generation?

The work presented here is a phenomenological study of the mathematical memories of people who were in middle and high school during the 1990’s, when the NCTM recommendations were being implemented. In addition to giving voice to young adults in the U.S., the study examines one method for fostering reflective awareness of mathematical habits among college students: mathematical autobiography. In particular, the study addresses the questions:

1. What experiences and perceptions of reflection, intention, and habit in learning mathematics do young adults in the U.S. bring with them from school to their college mathematics service

courses (e.g., mathematics for prospective elementary school teachers, mathematics for liberal arts)?
2. Does the use of the mathematical autobiography as an expressive writing tool activate reflection in any useful way?

Below, an overview of the theories from psychology, cognitive science, and memory research informing the study is succeeded by a précis of methods. Supported by evidence drawn from essays and interviews, the results and discussion address reflection, intention, and habit through contentions about students' locus of control for mathematical sense-making and their self-evaluations of ability, efficacy, and potential in mathematics. In closing, implications for theory development and K-16 teaching practice are discussed.

Theoretical Framework

Research at all grade levels has suggested that mathematics learning requires sufficient available working memory, pertinent domain-specific skills, and the ability to use them flexibly (Bandura 1997; Boaler, 1999; Boekaerts, Pintrich, & Zeidner, 2000; Darke, 1988; Selden, Selden, Hauk, & Mason, 2000; Malmivuori, 2001; Pajares & Schunk, 2002;). Given a problem situation, self-evaluations of one's ability to generate a solution are activated. Simultaneously, affective self-conceptions are aroused. A learner's assessment of how to balance the resulting mental and emotional demands leads to a self-regulating decision that may or may not be consciously considered: control emotion and put effort into cognition (learning intention) or limit cognition and put effort into preventing "distortions of well-being" (coping intention) (Boekaerts, 1995, 1997). This theorized dichotomy of intention is consistent with brain-imaging research on reasoning tasks showing different parts of the brain active when different intentions are realized (Goel & Dolan, 2003).

Social cognitive theory asserts that human achievement is part of a complex self-system of interconnected Personal, Behavioral, and Environmental factors through which people filter experiences, build understanding, make decisions, and act (see Figure 1; Bandura, 1997). In the context of mathematics learning, this self-system is built up from new and past mathematical experiences (Malmivuori, 2000).

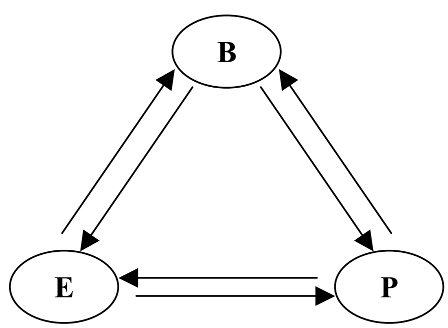

*Figure 1. Social cognitive model for triadic reciprocal causation: **B** is for behavior; **P** represents personal factors; **E** is environmental factors (Bandura, 1997).*

Emotions, cognitions, meta-cognition, meta-affect, and physiological states as well as perceptions of Environments and Behaviors are integrated at the Personal node into the cycle of attending, organizing, rehearsing, goal-setting, self-evaluating, and acting intentionally that constitutes *self-regulation* (Boekaerts et al., 2000; Schunk & Zimmerman, 1994). An important reflective component of self-regulation is *self-efficacy*: a constellation of one's perceptions about "what one can do under different sets of conditions with whatever skills one possesses"

(Bandura, 1997). Self-efficacy is not a measure of skill, it is perception about task-specific competence. To clarify, consider a student confronted with a pop-quiz: "Solve $3x + 7 = 8$ for x." The student may not be able to bring to mind immediately any strategy other than one used, unsuccessfully, in the past. Awareness of her own competencies in solving such equations means she recognizes a likelihood of task-failure. Additional levels of affective arousal like anger at having an unexpected quiz, fear of the consequences of failing, or emotions from memories elicited by the activity may accompany her self-efficacy judgment.

If conceptual structures like concept images (Tall & Vinner, 1981) or schema (Dubinsky, 2000) are sparse, then significant effort may be required to understand a problem-statement before considering goal-setting regarding its solution. A student may use up a great deal of working memory deciding *which* knowledge to use (Mason & Spence, 1999). The dissonance between cognitive and affective demands may overwhelm her into the coping state of inaction that is a hallmark of mathematics anxiety (Hall, 2002; Robertson, 1991; Tobias, 1993). Effective self-regulation on the student's part would include managing her responses to focus on applying an existing strategy or attempting something new in a purposeful way.

More generalized than self-efficacy, *self-concept of ability* may depend on comparison to the abilities of others and include variable feelings of self-worth associated with performance (Seegars & Boekaerts, 1996). In the pop-quiz example above, the student might glance around the room and gauge the apparent ease of working the problem among her peers. If everyone has finished, her conception of her ability may suffer (by comparison). On the other hand, if she sees those around her struggling to complete the problem, though her efficacy self-evaluation is unlikely to change, a positive sense of relative ability could help in regulating volitional response and might lead to her persisting in the problem situation.

The degree to which one identifies with a culture affects the purposes, structure, distribution, and manifestation of self-evaluations. People from highly individualistic cultures perceive themselves to be most efficacious when working alone while those from more collectivist or consensus-based cultures feel they work most productively in group settings that value mutual pursuit or like-mindedness (Fullilove & Treisman, 1990; Oyserman, Coon, & Kemmelmeier, 2002; Zaccaro, 1987). Therefore, it is important to note that depending on personal and classroom culture, self-efficacy, self-concept, and self-regulation can interact in different ways.

Regardless of cultural underpinnings, the impacts of efficacy and ability self-perceptions on cognitive efforts may be most volatile when something is first being learned (Trawick & Corno, 1995; Winne, 1995). Students just building skills and knowledge must attend to, coordinate, and regulate multiple thoughts, feelings, motivations, and intentions simultaneously. Over time, as knowledge is structured, tasks that become familiar may require less exertion. A shift in the perceived effort needed for success may allow students to feel "ownership" of their achievement, a key component identifying an "internal" *locus of control* (Pajares & Schunk, 2002; Szydlik, 2000).

Autobiographical memory and expressive writing

Research on autobiographical memory contends that remembrances of past events, behaviors, thoughts, and feelings is largely determined by current self-image and views about its stability (Conway, 1990; Kotre, 1995). So, if a learner believes himself to always have been pretty much how he is now, the tenor and content of recalled memories is likely to correlate with his current views. Certain conditions can influence such recall bias. In particular, recall was more accurate among U.S. college student populations when a reward for accuracy was offered (e.g., a grade) and susceptibility to current-self bias reduced when a deliberate search of memory was prompted (Cantor, Pittman, & Jones, 1982; Conway, 1990; Rubin, 1996). The results of student interviews and journaling reported in some studies (Borasi & Rose, 1989; Carlson, 1999; Davis, 1997; Millsaps, 2000; Nimier, 1993) may be more representative of current-self view than past-self re-view. Extended reflective or expressive writing is likely to yield distinctions between current-self and recollective reporting (e.g., Brandau, 1988). Consequently, the mathematical autobiography assignment used for this report included prompts for reflective memory searching and was 10% of the course grade.

One major theory of autobiographical memory proposes that the self is actually a collection of “possible selves” including who one has been, is now, and may potentially be in the future (Markus & Nurius, 1986). Additionally, the cognitive-affective duality of autobiographical memory suggests that emotionally laden (positive or negative) memories significant in defining past selves can contribute to current- and future-self views and that these memories can be kindled by cognitive engagement (Folkman & Moskowitz, 2000; King, 2002).

Some research suggests that organizing and reporting memories, especially negative ones, may help in dealing with stress (Cameron & Nicholls, 1998; Pennebaker, 1993). Construction of a coherent narrative from poorly organized recollections of past mathematical selves allows for the repackaging of experiential keepsakes into streamlined memory structures that may be regulated more efficiently (Conway & Pleydell-Pearce, 2000). Working memory that had been used to deal with intrusive cognitions and emotions sparked by interaction with mathematics may be freed for use in current cognitive demands. However, the effect may not be immediate nor rely solely on recounting negative experiences (King, 2002). Klein (2002) reported that though improvements in working memory were small one week after an expressive writing assignment, they were statistically significant seven weeks after the assignment: the greatest increase in working memory (11%) was among college students who had written about a negative experience, a smaller increase (4%) occurred for students who had written about a positive experience. No significant change in working memory was evidenced among students who had written about time-management instead of events of personal significance.

What students offer in their mathematical autobiographies are real memories; whether or not they are precise and fully accurate memories of real events may be debatable (Weingardt, Loftus, & Lindsay, 1995). However, it may not matter which they are. Memories of both types shape the way a person perceives experience, conceives of the world, regulates cognitive and emotional responses, and interacts with others.

Method

The study was conducted at a private comprehensive university of approximately 2500 undergraduate and 700 graduate students in the western United States. The content of the one semester liberal arts mathematics course in which participants were students is summarized in Appendix A. The assignment of the mathematical autobiography and grading rubric was made by way of a web page (Appendix B). Assigned in the first month of each 14-week school term, essays were collected, graded, and returned within two weeks. Throughout the course students were encouraged by verbal and written means to be reflective and self-evaluative when engaging with mathematics.

Researcher

At the time of the study (1995-1999) the author was an assistant professor of mathematics. Her background included five years as a secondary school teacher of English and mathematics, a Ph.D. in mathematics, and a post-doctoral fellowship in mathematics education. The author’s own mathematical autobiography was filled with stories of great sadness, joy, pain, and loneliness in relation to mathematics: from the first grade where her punishment for talking too much in class was to be slapped and ordered to teach Ruben how to add, to failing high school geometry, to subsequently completing a year of geometry in six weeks of self-study, to teaching high school, to being the only woman in a sea of men at her Ph.D. graduation ceremony.

The author’s own efforts to exercise self-regulation, in the face of years of dislike for the syntax and culture of mathematics, was developed enough to result in a Ph.D. in mathematics from a Research 1 institution.[1] The author was the product of an upbringing steeped in diversity and low- to mid-socio-economic status. This background for the researcher is offered to allow the reader a glimpse of the affinity the author acknowledges she felt with her math-avoiding and math-indifferent undergraduate students. On the other hand, the author's enculturation was distinct from that of the majority of her students; most were reared in middle-class, suburban, European-American surroundings.

Textual Data Collection

In total, 324 mathematical autobiography essays were produced from Fall 1995 through Spring 1999 by students in the 16 sections of liberal arts mathematics taught by the author; 318 students gave permission for their work to be used anonymously in research. Of these, 293 essays met the minimum requirements of the original assignment.[2] For the study, a sample of 67 papers was chosen from the pool of 293. First, certain student characteristics were identified for each paper: major field of study, gender, socio-ethnic group, age, and course grade. Papers were then separated into four piles, essays by: women who were prospective teachers (110 papers), women who were not (87), men who were prospective teachers (22), and men who were not (74). Approximately one-third of each pile was chosen randomly (36 of 110 by women prospective teachers, 24 of 87 by non-prospective teacher women; 7 of 22 papers by men who were prospective teachers, 23 of 74 by non-prospective teacher men). Subsequently, papers were selected from these four smaller piles until the distribution of socio-ethnic group, age, and course grade in the sample was as close as possible to that found, collectively, in all papers. The result was a sample of 67 papers.

Participants

A summary of the distribution of the 67 students in the sample by gender and declared field of study is shown in Table 1.[3] Many (45%) planned on entering a primary school teacher credentialing program.[4] The rest of the students were in the humanities (26%), professional programs (15%), or undeclared (10%), with one student studying for a degree in mathematics and one studying computer science.

Table 1. Distribution of student's degree programs in the sample by sex.

	Women (45)	Men (22)	Total (67)
Prospective School Teachers (PST)	56% (25)	23% (5)	45% (30)
Liberal Studies (non PST)	4% (2)	9% (2)	6% (4)
Theater, Art, Music, Dance	11% (5)	9% (2)	10% (7)
Psychology, Sociology, Humanities	9% (4)	14% (3)	10% (7)
Mathematics, Computer Science	2% (1)	4% (1)	3% (2)
Professional, Advertising, Film&TV	9% (4)	27% (6)	15% (10)
No declared field of study (undeclared)	9% (4)	14% (3)	10% (7)

The 67 students had identified themselves in university records as 1% Asian-American, 1% Native-American, 3% Pacific Islander, 4% African-American, 6% Mexican-American, 85% European-American (3% identified with Eastern Europe, 7% with Southern Europe and the remaining 75% with Northern Europe). According to university records, 90% were from suburban or rural, middle-income, homes. The socio-ethnic demographics in the sample were approximately those at the university.

Twice as many women as men were enrolled in the author's courses, a ratio of women to men of approximately 6:3, while the ratio for the other (male) instructors hovered around 6:5. The distribution of students at the institution was 6:4. Several explanations could be posited for this persistent imbalance, the most obvious being that women were more likely to enroll in sections taught by a woman. The ratio 6:3 was present in the sample, so the results reported here are for a population with a higher proportion of women than might be found at otherwise comparable institutions.

Finally, after some discussion with colleagues and students, a student was identified to be non-traditional if he or she had a break of five or more years in full-time enrollment. By this measure, 24% (11 of 45) of the women and 14% (3 of 22) of the men in the sample were "non-traditional" students.

Interview Data Collection

Eighteen of the 67 students were interviewed after their respective courses ended (12 women, 6 men). Originally, 22 students were chosen for interviews based on the preliminary analysis of papers. Of these, 16 agreed to interviews. Two more students were interviewed because they asked to be included in the study when they heard from friends about it. Six interviews were within one semester of the student completing the course, six were within one year, four were in the year following enrollment, two were two years after course completion.

The interviews, conducted over tea and cookies in the author's office, lasted from 40 to 70 minutes for each student. Though interviews were not audio- or video-taped, detailed field notes were taken and immediately typed post-interview. Students were asked for memories about the course. Then, each interviewee was given a copy of her or his essay and asked to read it, comment aloud on it, and respond to detail-oriented, exploratory, and clarifying probes. For example, students were asked to clarify meaning as to whether the sense of "earned," "received," or something else was intended when using "got" in a statement like "I got an A in that class."

Data Analysis

Analysis was through the constant-comparative method commonly used for qualitative data interpretation and theory building (Miles & Huberman, 1994; Strauss & Corbin, 1998). All 293 autobiographies were used in determining 36 thematic categories. The 67 papers in the sample were further analyzed by the author and a research assistant to identify the aspects (dimensions) of categories, and associated sub-categories.

Thematic coding on the pool of 293 essays was completed by the author alone. For triangulation, random samples of 50 and 20 papers, respectively, were thematically coded by two colleagues (with the author's codes in hand). Several terminology differences were resolved by consensus and seven categories revised. Thematic coding was followed by a comparative review of data and categories for the sample. Fellow and hierarchical relationships were investigated via the creation and linking of sub-categories. A sub-category is more specific than a category, giving detail about the who, what, when, where, how, or why of an issue. Through the researcher's comparative interpretations, the relationships in the original collection of 36 thematic categories were integrated and refined to the main results. Preliminary drafts of the manuscript were read and commented on by five undergraduates who had participated in the study. As a result of this member-checking, some changes in the number and length of supporting quotes were made. Unless otherwise indicated, all student quotes (in block quote paragraphs or within quotation marks) are taken, verbatim, from written mathematical autobiographies, indicated by a subscript number *[#],* or interviews *[# - I]*, with *all person and place names fictionalized*.

Results

In their essays, students were very clear about whether or not they considered reported experiences to have been hindrances to their interest and/or pleasure in mathematics (negative) or not. The non-negative experiences included those related as being "positive", "uplifting" or "inspirational" as well as "neutral" experiences that the student perceived as neither furthering interest or liking of mathematics nor hindering it. Analysis of experiences reported included consideration of the context within an essay in which the report occurred (i.e., a playful or sarcastic tone taken by the writer may have led to an assertion being identified as positive when, out of context, it might appear to be negative, and vice versa). Also, checking with students during interviews and manuscript review allowed for verification of contextually-based analysis. Overall, 50% of the experiences described in essays were considered by the student-author to be negative: events and classroom atmospheres which occasioned fear, self-doubt, anxiety, unacceptable (to the student) levels of frustration and, in some instances, physical pain. Student accounts of success (and lack thereof) in mathematics ranged from before birth,

> *I was successful doing math in the womb - I divided from one cell into two...that was the last time I was successful in math.* [26]

to junior high school,

> *Locked in my bedroom I would scream at the top of my lungs, `WHO CARES ABOUT THE PROBABILITY OF GRABBING A GREEN MARBLE!!'* [18]

to high school,

> *Math Analysis...it turned out to be half pre-calculus and half hell!* [6]

and college:

> *I was 20 and in baby math [pre-algebra]. I didn't talk. I was too afraid of appearing stupid. Therefore, that was exactly what I remained. I didn't speak in a math class until a year and two F's later.* [60]

Prospective elementary school teachers accounted for 56% (25/45) of the women and 23% (5/22) of the men. Given their career choice, one might expect the group of prospective teachers to report fewer negative experiences. However, students identified as future teachers were slightly more likely to relate negative associations with mathematics (55% of reported anecdotes). Here is how Karen, a very mathematically able pre-service teacher in her final semester of university put it:

> *I always try to find the answer right away and if I can't find it, then I say those three words, "I hate Math." Sure, I'll eventually find the solution, but I'll be frustrated and upset the whole time doing so.*[15]

Locus of Control

The notion that mathematical knowledge was something completely external to self pervaded students' writings and interview responses. Students talked about locus of control issues in mathematical sense-making using descriptors like "access," "ownership," "power," and "alien-ness." The perception that the means to accessing and understanding mathematics was controlled by external factors, an *external locus of control*, appeared most in student discussions of three subjects: the nature of evidence in mathematics, cheating, and grades.

Evidence of Authority

The primary property exhibited in student references to mathematical evidence, whether it was convincing and/or persuasive and whether it should be questioned or not, was the preemptive authority of teacher and text. That is, control of the definitions of mathematical ideas and of what counted as evidence was vested in these external sources. Eight students (4 men, 4 women) discussed the idea of coming into some ownership of their understanding and learning of mathematics since coming to college. As Dan, a health sciences student, wrote:

> *Up until now [college], I've always had to just accept that what the teacher says is fact but never understood why a formula works the way it does... I've been given the knowledge on what to do, but never what to do with it. In my view, it's like giving a kid a hammer and teaching him how to swing it. But if the kid doesn't know that a hammer is used to drive nails, it's worthless to him. Math has been worthless to me.* [1]

An awareness of the possibility of shifting away from an utterly external locus of control came through clearest when students discussed geometry – a high school course that for many was a first exposure to mathematics beyond arithmetic. Violet, a prospective elementary school teacher struggling through first-year college mathematics in her final year at university, talked about her high school geometry experience at 15. For Violet, the ultimate arbiters of truth were the teacher and textbook and it was pointless to try to convince an arbiter of truth:

> *I had a hard time getting past the fact that the triangles, circles, and squares on the paper were not actually the size that was stated, and why I had to prove something that the teacher already knew was correct.* [28]

For most of the semester in the liberal arts mathematics course Violet exhibited a fiercely dogmatic disposition regarding mathematics. She was as a collector of mathematical truths and saw her future teacher-role as curator of the collection. Violet reported, as did seven fellow prospective teachers (6 women, 1 man), that the ultimate authority was the "teacher's edition" of the textbook. About six weeks into the course a discussion arose in class around a problem from the text. Students began to discover that the problem was ill-posed (the main reason it had been assigned; Strazkow & Bradshaw, 1995; section 4.2 number 39). In fact, the brief solution in the back of the textbook did not agree with that offered in the student solutions guide. Violet argued vehemently that there was a right answer and that she and her tutor had come upon it. When her classmates refused to accept her assertion, she demanded that the "teacher's edition" of the textbook be consulted. Most students were astounded to learn that the instructor had no "teacher's edition." Several reported feeling lost and betrayed by this lack of authority and a few attempted to project the ultimate authority role onto the instructor, including Violet. When that role was declined firmly, students wailed: "well, then, how do we know what the answer is?!" Eventually they negotiated amongst themselves to the grudging conclusion that there might not be an answer to the question as it was posed. They had to "settle" for relying on themselves for that conclusion.

After the term, the view Violet verbalized in her interview appeared to be a bit more self-aware:

> *You have to be on the look out, you know. The people who wrote the book could be wrong, like ... make mistakes. That was new to me, you know. I'd always figured if you don't know, well, go look in the book, in the back of the book. This whole idea of having to think, you know, DURING class ... this was very hard for me. [Humphing noise] Yeah, I still don't like it, I don't know ... I'm starting to not even be sure I want to be a teacher, you know? I mean, all these kids are going to look at me like I'm supposed to know and, well, will I? And if I don't, I'll have go to find out, you know? That's a lot of work! [laughs]* [28-I]

In addition to demonstrating a growing awareness of the intellectual work involved in being a schoolteacher, this excerpt from Violet's interview illustrates her moving away from the notion of mathematics knowledge as passively received (or, as one student put it, "absorbed") towards a view of it as actively constructed and internally validated. In other student talk about geometry, pre-service teacher Jennifer noted:

> *I'm planning on becoming an elementary teacher, but if I were to ever change over to high school, I would like to teach Algebra or geometry (please note, crossing truth tables as a teacher wouldn't be that bad because I will have the teacher's book).* [32]

Again, the perception that a mathematics teacher is not necessarily one who is knowledgeable, but rather one who has access to external sources of information – as in the teacher's edition of a textbook, arises. Like many pre- and in-service teachers (Spangler, 1992; Tatto, 1999), Jennifer's personal epistemology regarding the nature of mathematics included mathematics content and processes as *all* quite fixed, algorithmic, and "out *there* [external]" *[32]*.

Cheating

Students sometimes identified their contemporaries as more authoritative sources than themselves. An external locus of control for mathematics appeared to include peers as well as teachers for the five (3 women, 2 men) who discussed cheating as a means to gain information on exams. Tanya, a communications student, cheated early and often:

> *Third grade was my first time that I got caught cheating. A boy named Griff Peels was really good at math, and I used to sit right by him. A few times, when we were doing work out of [the] textbook and I wasn't understanding a problem I would look at his paper ever so casually. I thought I was being sly, but I got caught. The teacher didn't catch me Griff caught me... At first I denied it, but eventually I told him I had. He told me that he didn't care and that I could when I needed to.*[41]

The tendency to cheat reasserted itself in her experiences repeatedly until college, at which point she finally failed a course: "I took Math 71 [intermediate algebra] three times before I passed.[41]" Interestingly, Tanya's epiphany about the "waste of time and energy involved in cheating[41]" happened in her third go of Math 71, in which class the instructor had students share their mathematical histories (aloud, in class). That exercise gave her, she reported, the opportunity to have sufficient information about her Math 71 peers that she could "see I wasn't as dumb as I thought[41]" (an adjustment of her self-concept of ability).

Heather, a 20 year-old television journalism student in her second year, started cheating in the second grade, stopped for a while, and picked it back up again in high school pre-algebra. She reported in her interview that the subjects she had cheated in were "math and science, but that's really all the same thing anyway, MATH.[66-I]" Her second grade teacher discovered her copying from a fellow student, Jackie, and seated her away from that student for the next exam:

> *I remember getting the test back as if it were yesterday. I received no scratch and sniff sticker no gold star just a big "F" in red magic marker. Well there was proof and I was found a cheater in the court of second grade. I then had to spend every recess for two weeks with Jackie Town who I hated more and more by the day listening to her babble on about the rules of subtraction (why she was punished is beyond me). There are two things I learned from this, subtraction, ... and also, if I am going to cheat I might want to change up my answers a little bit from the person I am cheating off of.*[66]

Heather returned to cheating in high school when she went from public school to a private Catholic school. She remembered the lesson from second grade and reported "My classmates and I had discovered the art of cheating and practiced it ritualistically.[66]" She recalled in her interview "successfully cheating my way to a B in Sister Ruth's class....Sister never did catch on yet I realize now that I was only cheating myself. The SAT's proved that.[66-I]"

Apparent in these reports of Heather's experiences are indicators of her external locus of control regarding validation of mathematical understanding: her SAT scores "proved" she did not have a sufficient understanding of mathematics. Heather also reported mathematics as something that was "absorbed[66-I]" and saw Jackie's tutoring of her as Jackie being "punished." Moreover, she felt betrayed by the episode in Mrs. Forth's class and proud, for a time, of her and her classmates' efficacious use of cheating.

Roberta, a prospective teacher who failed her first exam in 11th grade Algebra, was not proud of her one and only foray into cheating:

> *Well, instead of going to my teacher and asking for help, me and my girlfriends decided that I should cheat off of them, so I did. Looking back I have no idea how we were never caught cheating, but we weren't. I remember being nervous and having major anxiety everyday during math class. I also remember that I managed to pass algebra 1 with a B, but I would definitely change this memory if I could.*[9]

In her interview, Roberta referred to her anxiety about mathematics repeatedly and said she felt it all went back to the fact that algebra was "impossible" for her to understand.

One student discussed cheating for a distinctly different reason. George, a communications student, talked about his sixth grade basic mathematics course where homework was graded on the honor system – the teacher read answers out loud, students scored their own homework and then verbally reported their score when roll was called. His desire to avoid notice by his peers led George to a remarkable, if convoluted, vesting of control with himself, though the locus of control for mathematical success remained with his teacher:

> *When I got a tutor I did not want my friends to know because I thought they would think of me as being stupid. All of a sudden my homework grades were much better but when the teacher asked us what we had scored on the homework I would give her a lower grade than I had really received thinking that she would say I was cheating, or not grading my paper correctly.*[12]

It would appear that some of George's mathematics self-evaluative habits were already fairly well formed by age 12. So, despite knowing he was doing as well as or better than his peers (an increase in self-concept of ability), he felt he could not risk an increase in the perception *others* had of his ability.

Five women and three men reported "copying" the homework of friends. This form of cheating was seen by students as quite different from cheating on a test. On a test, getting an answer from someone else was a way of compensating for a lack of understanding (the result of a self-efficacy judgment of imminent task failure). However, homework copying was seen simply as a way to satisfy the behavioral demands of an external authority (the teacher) since "homework usually didn't have anything to do with really *learning* anything anyway. *[35]*" Though the locus of control for mathematics was still vested in the teacher, the decision to copy another's homework might be seen as a separate, internal, locus of control for grades. The tale told by Marcus, a freshman music student, epitomizes well the statements by those who report homework copying. Marcus moved to a new school in mid-term and had to "catch up":

> *Let's be real; what would any high school student do in this position? Copy. Of course. There was no other way for me to succeed. I had all of my homework, flunked the few make up tests, and by the time I caught up and got the hang of things the semester was almost over. The "As" that I earned at the end of the semester balanced out the "Fs" that I earned at the beginning. The result was a "D." So much for being valedictorian.* [18]

Marcus was one of only two men to use the word "earn" when referring to an F grade; throughout his paper and interview he used the word "earn" consistently and indicated grades were never "received" by anyone. The only other male student to use "earn" in reference to an F grade was seeking a degree in organizational leadership*[11]*. He noted that he had "earned an A" and also said he "received" both an F and a C. In fact, the sub-category of locus of control concerning grades was an especially rich vein to mine in the student papers.

Grades

Students frequently used forms of the word "get" when discussing mathematics grades. After student interview responses had clarified some usages, context analysis was used (cautiously) to determine whether the grade "got" by a student was perceived as *earned* (some attribution of self-responsibility for, or ownership of, learning) or *received* (some attribution of external responsibility for learning). For example, the following excerpt was classified as an *earned* attribution:

> *I was having no problem getting all A's in everything except for math. Mrs. Crumble was the meanest, grumpiest teacher that I can ever remember having. I pulled off getting A's for the first three quarters in her class, but I dropped down to a B during the last quarter. I*

was trying so hard to get an A... I asked her nervously on the last day of class what my grade was and she told me: "You got an A by the skin of your teeth."[17]

On the other hand, the following was grouped with the *received* attributions:

The only way I made it through that class was because I copied all of the answers out of the back of the book and then when tests came I would cram and do alright. The whole year I got A's and a B so everything worked out okay except for that I did not learn one thing. [67]

Categorizing student-talk about "received" grades was frequently straightforward:

My sophomore year I took geometry, which was a very unfortunate experience. I received a B both semesters, but I did not earn them.[45]

And sometimes challenging (the following was grouped with "earned" based on the final sentence in the anecdote):

I was 31 years old but determined to get a college degree. I had a hard time following the program in this class [intermediate algebra at a community college]. I struggled. When I received my first test back I had gotten a D and the girl sitting next to me got an A. I thought, 'what does she have that I don't?' It was a tattoo, a pierced nose, ear, lip, eyebrow, and a mohawk. I dropped that class. I guess I had my hands full with the kids at home, ages 3, 5, 7, and 9. I couldn't concentrate.[29]

Sixty-six of the 67 students talked about grades in their essays. Thirty-six (80%) of the female students reported "receiving" grades and 15 (34%) reported "earning" grades (six reported both). Among the male students, 16 of 22 (73%) reported "receiving" grades while 14 (64%) stated they had "earned" grades (nine reported both). One male student (non-pre-service teacher) did not make any reference to grades. Figures 2 and 3 give the frequency of each type of grade in each category by sex.

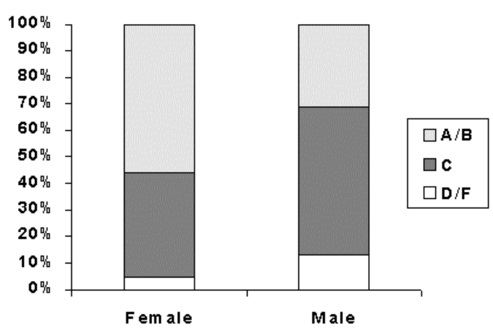

Figure 2. Perceived grades "received."

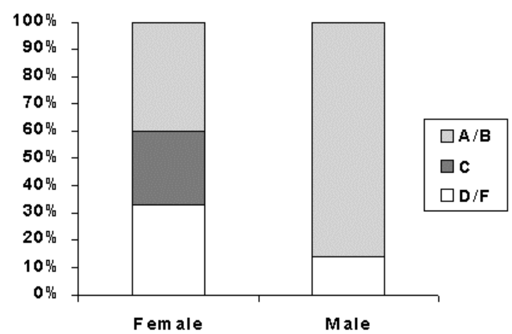

Figure 3. Perceived grades "earned."

Men were much more likely to see themselves as having "earned" high grades while women were more likely to see high grades as "received." Of the 14 men reporting grades in "earned" contexts, *none* reported having "earned" a C. Women who reported grades in "earned" contexts tended to remark most on earning high or low grades. These results are not surprising given similar findings in the research on gender differences regarding perceptions of mathematics achievement among middle and high-school students (Gilbert, 1996; Watt & Eccles, 1999).

Ability, Efficacy, and Potential in Mathematics

In essays and interviews students spoke regularly about emotions, including love, hate, fear, frustration, and fury they felt when mathematically engaged. Jessica, a prospective teacher, echoed 40% of her pre-service teacher peers when she asserted:

> *I love it [math] when I succeed and I hate it when I just don't catch the concept.* [63]

Or, as another female prospective teacher noted:

> *… math has been an incredibly hostile force in my life for so long and while I am being dramatic, it has caused me much distress.*[67]

One interviewee, Amy, a semester after the course in which she wrote her mathematical autobiography commented on an increase in her ability to "manage" mathematics:

> *I don't usually like math at all. But, I feel now like I can allow myself to feel that way and that, somehow, makes it so I feel like I can deal with the math when I am doing it.* [16-I]

Colleen, a capable and self-aware prospective teacher, met every challenge in the liberal arts mathematics course and actively participated in classroom discussions. In her essay she discussed her potential in mathematics:

> *I was terrified of Geometry, and thought Calculus was something that I could never achieve, let alone master. Of course once I got in and tackled these subjects, I found that it was not that bad. I am still intimidated by the thought of taking Statistics. ...Well, I have come to learn that I might actually like math, and that I am not half bad at it.* [49]

Some students also related stories about how their ability self-perceptions influenced career choices. Shelly talked with a career counselor about a budding interest in science early in college:

> *I started my first year of college at Sierra Madre Coastal, a wonderful junior college. I took my first science class, Geology, and I loved the course. I have always enjoyed the sciences and found them exciting. I talked to my counsellor about becoming a Geologist and the first horrifying question he asked me was, 'Do you like Math and are you good in the subject of Math?' Shamefully I said no! I wanted to be good in Math but I have had trouble understanding it, I told him. He advised me not to be a Geologist and to stay far away from the sciences because there is too much Math involved. I took my counselor's advice and now I am going to be an elementary school teacher.* [61]

As disturbing as the final two sentences may sound, Shelly's view of what it took to be an elementary school teacher did shift over the course of a year. Like Violet, she later indicated she had an increased awareness of the intellectual effort required for teaching. Shelly also identified a key point in the decline of her perceived mathematical potential as occurring in the third grade:

> *I had not labeled Math a problem until it was pointed out, [by] my third grade teacher, that I had a problem with it. Mrs. Roy, my third grade teacher, destroyed my self perception of Math... [she] told me numerous times that I would never do well in Math, and she was right.*[61]

In contrast, Layla wrote in her essay that she always thought of herself as doing well in mathematics but a review of old report cards was a revelation to her:

> *My teacher, Mrs. Wills was one of my favorite teachers. Her comments to my mom and dad were as follows, "Ordinary Numbers, Layla needs to be much more diligent in this*

> *area, April 1981." What are "ordinary numbers", and what does that mean? I must not have been a great participator in math in the first grade. That's what I understand from her comments now. Looking back at this report card now I can't believe I was worse than I thought I was, but it was only the beginning.* [56]

Layla began her interview with an upbeat, positive view about her relations with mathematics but, after re-reading her essay, declared, "Oh. I guess I did it again, didn't I! Here I am thinking I've always been fine with math but, when I read this, I realize I am not. Very weird."[5] Layla's primary means of dealing with mathematics when she was in the liberal arts mathematics course was to look for rules and, once they were successfully memorized, be satisfied she "had learned." Her approach led to a great many near and total failures on quizzes and exams because she did not have organized structures (e.g., concept or problem situation images; Selden et al., 2000; Tall & Vinner, 1981) to hold and connect all the memorized declarative material. Only after she began being tutored was she able to extend her memorization of "rules like negative and negative is positive" to include process connections: "I have to remember its negative *times* negative that's positive, because for addition it's opposite.*[56-I]*" This expansion was sufficient for her to pass the course with a D. In her interview, Layla referred back to a particular passage of her essay, about high school algebra, repeatedly. She claimed "reliving" the experience was a contributing factor in her decision to change from a career goal of being a teacher to one of being a police officer:

> *Mr. Gaspar was my teacher and he was a real jerk. He did nothing to try to help me when I was struggling. My parents had a conference with Mr. Gaspar and he told them he would help me, but every time I went to him for help, someone else was more important than me and he would take a long time to finally answer my questions. It was quite discouraging feeling I couldn't go to my own teacher for help.* [56]

Layla voiced concern that

> *"if [like Mr. Gaspar] I get really overworked, around kids, and get nasty because something [mathematical] doesn't work the way [I think] it's supposed to, it will influence them a whole lot more than if I am dealing with adults...I'd rather deal with the adults.* [56]*"*

Jon*[4]*, who was efficacious in mathematics as long as fractions were not involved, transferred from college to college as the meeting of a mathematics requirement "reared its ugly head. *[4]*" He reported that his multiple college transfers were based, in part, on the view of his mathematical potential established by him in fourth grade:

> *... the smartest group was called The Dolphins and there were only a handful of kids in this group. Then there were The Sharks, which comprised most of the class. Then there were The Whales, the slower kids. Then there was a kid from Arkansas, a kid who liked to start fires, and me. We were Plankton. I'm kidding, we were called The Squids, really, in fact I think I named the group myself.*[4]

Jon wrote that his experiences in mathematics "went downhill from there" and his "utter lack of potential in math" led to choosing a degree in theater. He "changed colleges twice and then avoided the required math" until his final semester at university.

Carlson (1999) reports on successful mathematics graduate students who credit a mentor, typically a high school teacher, with challenging, encouraging and assisting them into the pursuit of a mathematics-related career. The group of students in this study evinced a complementary state: 60% (27 women, 13 men) credited a high school teacher with boring, discouraging, or hampering them in mathematics. This led to what many identified as mathematics-avoiding career choices. This group of 40 "math-avoider" students included 12 prospective elementary school teachers. However, no connection appeared to exist between a student's reported judgments of teachers (as "good," "bad," or "indifferent") and that student's identifying her or himself as a "math-avoider." In fact, four women who were prospective teachers said they valued mathematics "in spite of" a bad or indifferent teacher. They wanted to become good teachers of mathematics *because* they had experience with bad or indifferent teachers.

Discussion

Some answers to the first research question about what experiences and perceptions in learning mathematics young adults in the United States bring to their college mathematics were offered above. In summary:

- *Reflection*. Students reported that negative and non-negative experiences influenced their introspective perceptions of their past, present, and future mathematical selves.
- *Intention.* Students bring to their college mathematics courses the perception that intentional engagement with mathematics is externally driven by Environmental factors like grades and the Behavioral expectations of teachers.
- *Habit.* Students have spent years developing the habit of taking the locus of control in mathematics learning to be external, an Environmental rather than a Personal social cognitive factor. Also, student mathematical experiences appear related to an intimately felt collection of Personal factors based on self-evaluations of relative ability, efficacy, and potential that are connected to decision-making patterns (including long-term decisions about career).

The answer to the second question, whether or not the use of the mathematical autobiography as a curricular extension activated useful *self*-reflection, seems to be "Yes, for some students." The expressive writing exercise appeared to foster a valued sense of perspective. This was exemplified in the excerpts from Shelly$_{[61]}$, Colleen$_{[49]}$, Tanya$_{[41]}$, Violet$_{[28]}$, and Dan$_{[1]}$. That the assignment influenced mathematical self-reflection is also supported by the reports of the 18 interviewees. Nine people, seven of the 12 women and two of the six men interviewed, echoed Amy's$_{[16]}$ remark that she felt more self-control around mathematics by allowing herself to write about and feel emotions without getting tangled up in them.

From social cognitive research on negative self-referent thought come strategies for intervention:

> *The most powerful way of eliminating intrusive ideation is by gaining mastery over the threats and stressors that repeatedly trigger the perturbing trains of thought. ... [to] equip people with the knowledge, skills, and beliefs of personal efficacy to manage the things that disturb them. (Bandura, 1997)*

College mathematics instructors are not psychotherapists. Nonetheless, it seems that recalling, reflecting on, and reframing memories that are part of the "perturbing trains of thought" stimulated by the "stressor" of mathematics may enhance self-regulation. Instead of seeking to rid students of their reactions to mathematics, a mathematical autobiography allows students to acknowledge these responses and build reflective awareness of them. The means to influence possible-self and concomitant self-efficacy views lies in self-regulation. Self-regulation may come in many forms: from response to the anticipation of consequences of behavior choices (Boekaerts et al., 2000), to self-aware constructing of goals (Locke & Latham, 1990), to beneficial inner-speech (Meichenbaum, 1984).

However, it must be noted that the strengthening of aspects of self-regulation requires an appropriately supportive classroom milieu. Without in-class prompts and opportunities that encourage personally owned, self-reliant accomplishment in mathematics, the most significantly impacted students may continue to attribute their successes to external rather than personal, internal, sources (Bandura, 1997; Pajares & Schunk, 2002).

Implications for Theory, Practice, and Future Research

The process of reflecting on and writing about mathematical experiences traverses the pathways in the social-cognitive-model (Figure 1) and appears to act at the Personal node as students reconstruct their memories in the context of their past, present, and future selves. What is more, the paths between Personal, Behavioral, and Environmental nodes can be related to learning goals. Take, for instance, Kirshner's (2002) metaphors of teaching for learning as habituation, as enculturation, and as construction. Curriculum centered on helping students learn by habituation encourages interaction of Environmental and Behavioral factors (E⇔B) by repetitive working of similar problems while minimizing Personal factors. Teaching for learning as enculturation relies on the development and interplay between one's own Personal factors and those of others within task Environments (P⇔E). Teaching for learning as construction is driven by a learner's Behaviors and negotiation of meaning and significance with self and others (B⇔P). The three nodes of social cognitive theory can be seen as transfer points in Kirshner's (2002) cross-disciplinary strategy view (see Figure 4).

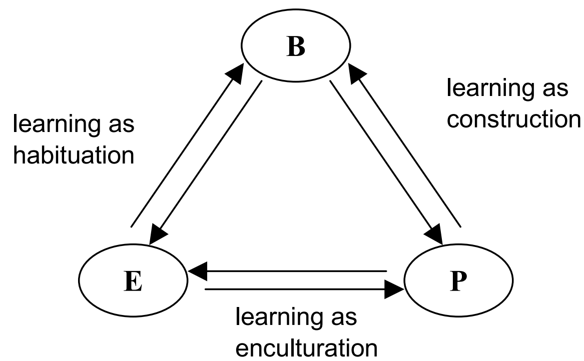

Figure 4. *Possible relationship between social cognitive theory (Bandura, 1997) and Kirshner's (2002) crossdisciplinary multiple learning theory.*

If, as Kirshner suggests, integrating multiple learning theories leads to "educational efficacy," then understanding how theories may be influenced at the Behavioral, Personal, and Environmental nodes can have practical implications for teaching. If mathematical autobiography acts at the Personal node, it may have more significant impact on college students whose learning has been enculturationist or constructivist in tone since each of these has P as a driving node (see Figure 4).

Benefit to Students

Mathematical autobiography may be especially useful among college populations. Developmentally, the kind of self-reflection and recollective thought called for in the assignment is only deeply possible among late adolescents (Rubin, 1996). Can the assignment harm rather than help? Research on expressive writing at the college level indicates that such an assignment is unlikely to be a hindrance to learning (Hirsch & King, 1983). Among the 300+ students who wrote essays during this study, in no case did the assignment ever appear to have a detrimental effect (though a few did complain about "having to write in a math class!?!").

Benefit to Instructors

Notwithstanding the possible positive outcomes for students, a major benefit arising from the assignment is afforded the instructor. Undergraduates in mathematics service courses are likely to have quite different personal mathematical histories from their instructors. As is the case with new schoolteachers, there is a tendency among novice college instructors (e.g., graduate teaching assistants) to “give up too easily” when difficulties arise in communicating with students (Borko et al., 1992). Part of the development of pedagogical content knowledge for college teachers involves anticipating, and incorporating into teaching, the manifold abilities, experiences, and concerns of students. New college instructors who teach lower division and service courses stand to learn a great deal from reading a few dozen student mathematical autobiographies. For a sufficiently self-aware instructor, such knowledge may improve the clarity of communication with students (Cervone & Peake, 1986).

Future Research

The well-entrenched view that teachers are the active regulators of learning in mathematics and that the student’s job is to listen, compute, and get the right answer, fast, have been reported in several places (Sowder, 1998; Spangler, 1992; Thompson, 1992). Researchers have written at length about the cognitive-affective dynamics in school-age learners (DeBellis & Goldin, 1999; Malmivuori, 2001). However, how the teacher is “active” and student is “passive” view develops and persists has remained relatively unexplored among college populations.

Research currently under way by the author suggests that dissonance between personal and socio-cultural environments in college mathematics classrooms has an impact on the influence(s) of the mathematical autobiography assignment. Further research into the effectiveness of the assignment in relation to a variety of social, cognitive, and affective variables – including the influence of teaching style – is a clear next step.

Finally, it is an open question whether newly acquired self-aware response in college-age learners will be experienced only at the short time scale of local affect (minutes, or at most, weeks), might be a recurring mood or an attitude that persists for a school term, or may be sustained for longer periods. Further investigation, into the interplay of aspects of affect, reflective thought, self-concept of ability, perception of self-efficacy, and achievement among undergraduate students, is needed.

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[1] One classification scheme for universities in the United States identifies institutions based on several criteria, including the level of research conducted by faculty. “Research I” was the designation given to the top research universities in the U.S. (Carnegie Foundation for the Advancement of Teaching, 1994).

[2] An essay was omitted from the pool if it was at least 15% shorter than the minimum length of 1100 words (15 papers). A paper was also omitted if it was not on the assigned topic of mathematical autobiography (8 papers - four were schooldays reminiscence with no reference to mathematics; four were about how arithmetic is used in everyday life). Finally, two papers were omitted due to their marginal comprehensibility (neither student continued at the university).

[3] In Table 1, each percentage is within 10% of the comparable population value. To clarify: 56% of the sample was female prospective teachers; for all sections of the course taught by the author, 61% were female prospective teachers; 56 is within 6.1 (10%) of 61.

[4] In the state where the study was done, teacher credentialing is a post-baccalaureate process. Prospective teachers complete a bachelor’s degree and then apply to a teacher-credentialing program. Pre-service teachers typically spend one to two years in methods and pedagogy courses and one semester practice-teaching before becoming credentialed with a teaching certificate.

[5] A reluctance or inability to engage in the self-reflection and recall asked for in the assignment that may be difficult for some and virtually impossible to overcome for a few. Lumley, Tojek, and Macklem (2002) report on people who are repressive or, more extremely, alexithymic (literally, “lack words for feelings”).

Appendix A. Content for the Liberal Arts Mathematics course.

The two-semester mathematics requirement for a Liberal Studies degree consisted of one semester of descriptive and inferential statistics in addition to the liberal arts mathematics course. As a result, neither statistics nor probability were included in this course's curriculum.

The textbook for the course, Strazkow and Bradshaw's *The Mathematical Palette* (1995), was augmented by instructor-created materials incorporating the use and programming of calculators (such as Texas Instruments TI-81, 82, 83, 85, Casio 7700G, Sharp 9200/9300, Hewlett-Packard 48G). When the module on infectious diseases was used, that too was through an instructor-constructed packet based on the first chapter of Callahan and Hoffman's *Calculus in Context* (1995).

Major Study Units : All of topics 1-4 and at least two of 5-8.

1. Numbers, Numerals and Words
   * Ancient Systems
   * Hindu-Arabic Systems
   * Basic Number Theory

2. Sets and Logic
   * Sets, Venn Diagram Models
   * Symbolic Logic
   * Inductive and Deductive Reasoning
   * Flowchart Modeling

3. Algebraic and Exponential Models
   * Function notation
   * Linear Models; Linear Programming
   * Quadratic & Polynomial Models
   * Exponential and Logarithmic Models

4. Finance
   * Interest Theory
   * Annuities
   * Loans
   * Present Value

5. Geometry and Art
   * Euclidean and Non-Euclidean Models
   * Perspective
   * Tiling and Tessellation
   * Modeling Nature with Fractals

6. Calculus
   * Functional Difference Quotients
   * Derivatives; Modeling Rate of Change
   * Basic Integration

7. Trigonometry
   * Sine, Cosine, Tangent
   * Modeling with Right Triangles
   * The Laws of Sine and Cosine
   * Modeling with Acute Triangles
   * Circular functions

8. Modeling Infectious Disease
   * Rate Equations; Difference Equations
   * Programming the Equations
   * Predicting Trends; Effect of Quarantine

Appendix B. The assignment web page.

Mathematical Autobiography Project

Please read this entire page!

Preliminary step: Make a list of TWENTY mathematical experiences. For example, what can you recall of learning to count?...of learning to tell time...? of learning what fractions mean?...of learning how to use money? Each person should reach as far back into her/his personal history as possible. Review old report cards; talk to friends, parents, siblings, caretakers, etc. to collect information, anecdotes and experiences. Does your recollection of grades in your mathematics courses match the actual grades on your old report cards? [You might be surprised.]

Draft step: Write a rough draft of at least 850 words (type it, double-spaced) using at least five of the experiences from the list you generated. It is probably best to write it on a computer (and save it to a disk) so that you can edit later and so that you can use the word-count utility most word-processing programs have!

The assignment: Referring to your rough draft and the list generated in the first step, write an essay of 1100 to 3000 words which relates some of the 20 experiences (at least five) in detail. Discuss how those experiences have influenced current attitudes, feelings, thoughts about mathematics and life goals. Include names, locations. For example: “When I was in the ninth grade at Norco High School (that’s in Riverside County in Southern California) I had an Algebra teacher named Miss Trimble who sometimes had us do math outside. One incident I recall vividly was the warm, sunny day the whole class went to the football field and we..."

The essay will be graded as follows:
10 points for length: if the paper is less than 1100 words then the length score will be reduced; the scores for grammar and content will be proportionally reduced as well.
15 points for spelling and grammar.
75 points for content: as long as the paper is coherent, is about the student’s personal math history and is at least 1100 words long, all content points will be earned.

The instructor is happy to proofread drafts of the paper during office hours.