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UNDERSTANDING STUDENTS' PERSPECTIVES: MATHEMATICAL AUTOBIOGRAPHIES OF UNDERGRADUATES WHO ARE NOT MATH MAJORS

SHANDY HAUK, SENIOR RESEARCH FELLOW, WESTED

INTRODUCTION: A student encounters a mathematics problem. The student stares at the problem, brain working furiously. However, to an outside observer, little in the way of mathematical activity seems to be happening. It turns out that the working memory needed for thinking about a mathematical problem situation can be taken up by dealing with intrusive thoughts and emotions sparked by the interaction with mathematics. Some research suggests that expressive writing – organizing and reporting memories – may help in dealing with stress, particularly with anxiety associated with memories (Cameron & Nicholls, 1998; Pennebaker, 1993). Writing a mathematical autobiography of the sort reported on here is an expressive writing activity.

When we create a narrative from poorly organized recollections of past mathematical selves, it allows for the repackaging of partially and loosely connected memories into streamlined memory structures that may be dealt with more efficiently (Conway & Pleydell Pearce, 2000). However, the effect may not be immediate and may not be restricted to 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 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.

Just as undergraduates in mathematics are likely to have quite different personal mathematical histories from their college mathematics instructors, most middle and high school students have different experiences with, and expectations of, mathematical learning than their teachers. And certainly, most students will not have the same careers as their teachers. Research has noted that some teachers, particularly those still in the formative career stage (e.g., the first five years of full time teaching), may "give up too easily" when difficulties arise in communicating with students (Borko, Eisenhart, Brown, Underhill, Jones, & Agard, 1992). Part of the development of the knowledge for effectively teaching mathematics involves anticipating, and incorporating into teaching, the manifold abilities, experiences, and concerns of students.

NON-MATHEMATICS MAJORS: This article offers insight into the primary and secondary school experiences of a particular group of learners: non-mathematics majors enrolled in lower division "service" courses like college algebra, liberal arts mathematics, pre-calculus, mathematics for future school teachers, and various flavors of calculus (e.g.,

applied calculus for business, biology, etc.). Results are from Hauk (2005), which reports on experiences sampled from over 300 student essays. The names of all people and places have been fictionalized. Though the assignment is included as an appendix, please read the *Note on using the assignment* at the end of this article before making a decision to use it. While the particulars may be unsettling for some readers, the vignettes offered here are authentic and representative of the experiences of much of the U.S. college-going population. I thank the hundreds of undergraduates who have taken the time and energy to share their stories by completing a mathematics autobiography essay.

Finally, a suggestion to the reader: put on your student hat now and remember what it was like for you as a child or young adult learning mathematics. For example, what can you recall of learning to count? . . . learning to tell time? . . . learning what fractions mean? . . . learning how to use money?

When asked to recount their personal mathematical autobiographies, student accounts of success (and lack thereof) in mathematics range 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.*

to sixth grade,

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

to high school,

> *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. ...Well, I have come to learn that I might actually like math, and that I am not half bad at it.*

and undergraduate service courses:

> *I was 31 years old but determined to get a college degree. I had a hard time following the program in this class [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.*

In comparison, those with a long-time love of mathematics who have succeeded in advanced mathematical learning, including many high school teachers, tend to focus on the "thrill of that moment, when you just *know* you have it." There is a shared passion for

the certainty that comes with understanding in mathematics:

> *An infatuation with learning mathematics has guided my life goals. Until I took really advanced math, I can only remember success being related to mathematics. Even though advanced course work brought my first of many encounters with failure in mathematics, I have continued to study it, and the only explanation I can give for this is this idea of "addiction" to attainment. That despite the agony of confusion, I still feel confident I will make sense of things and in that heart-pounding, breathless, spine-tingling instant of AHA, I will find all the reward I need.*

Like those with degrees in mathematics, the majority of those who identify themselves as future secondary teachers, tell positive stories about inspirational teachers and "inherent motivation – I just have to figure things out" and may remark that "I love math because it is like a puzzle, and I learned about that from logic puzzles, not in school."

By comparison, among future K-8 teachers, stories are just as likely to relate positive associations with mathematics as they are to mention negative ones. Here is how Karen, a mathematically able pre-service teacher in her final semester at 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.*

Across the spectrum of learners, deep and powerfully experienced emotions – thrill, satisfaction, disappointment, agony, hate, and passion – are connected to mathematics.

THE ROLE OF THE EVIDENCE OF AUTHORITY – TEACHER AND TEXTBOOK: In their written reflections about becoming intimate with mathematics, most students referred to the powerful "authority" of the instructor and of the text. One quarter of students (equally split between men and women) discussed the idea of coming into some ownership of their understanding and learning of mathematics after 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 until now.*

College students planning to become teachers talked about the need for the authority of the teacher and the "complexity" of mathematics most often when discussing geometry – a high school course that for many was a first exposure to proof. For Violet, who planned

to teach middle school, the ultimate arbiters of truth were the teacher and textbook and it was pointless to try to convince one of those arbiters:

> *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.*

Violet saw herself as a collector of mathematical truths and saw her future teacher-role as curator of the collection. Violet reported, as did 15% of prospective teachers, that the ultimate authority was the "teacher's edition" of the textbook. Most undergraduates are astounded to learn that the instructor in a college mathematics course may have no "teacher's edition." Several reported feeling lost and betrayed by this lack of authority. They reported having to "settle" for relying on themselves. In an interview about her mathematical autobiography after Violet completed her first college mathematics course, she expanded on the idea of the authority of the textbook:

> *You have to be on the look out, 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]*

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).*

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 philosophy regarding the nature of mathematics included mathematics content and processes as fixed, algorithmic, and external, "out *there*."

While many successful mathematics teachers and graduate students credit a mentor, typically a high school teacher, with challenging, encouraging and assisting them into the pursuit of a mathematics-related career (Carlson, 1999), the non-math-major undergraduates seemed to be coming from a complementary state: 60% credited a teacher with boring, discouraging, or hampering them in mathematics. This led to what many identified as mathematics-avoiding career choices. One-fifth of this group of

"math-avoider" students were prospective 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, 20% 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.

CHEATING: Students sometimes identified their peers as more authoritative sources than themselves. About 20% told stories of cheating in primary, middle, or secondary school as a means to gain information on exams. Tanya, a communications student, cheated early (starting in the first grade) but was not confronted about her cheating until third grade:

> *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.*

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." Interestingly, Tanya's epiphany about the "waste of time and energy involved in cheating" happened in her third go of Math 71 when students did an activity where they shared their mathematical histories.

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*." Heather's second grade teacher, Mrs. Forth, 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.*

Heather returned to cheating in high school when she went from public school to a private school. She remembered the lesson from second grade and reported, "My

classmates and I had discovered the art of cheating and practiced it ritualistically." 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 . . . "

Roberta, a prospective teacher who failed the first exam in her high school algebra class, 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.*

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

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.

> *When I got a tutor I did not want my friends to know because I thought they would think of me as being stupid [for needing help]. 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.*

It would appear that some of George's mathematics self-evaluative habits were already fairly well formed by age 12. Despite knowing he was doing as well as or better than his peers, he felt he could not take the risk of exposing his improved understanding of mathematics.

Fewer than 10% reported "copying homework" of friends. This form of cheating was seen as quite different from cheating on a test. Getting a test answer from someone else was a screen for a lack of understanding. However, homework copying was seen as a way to satisfy a behavioral demand of an external authority (the teacher): "homework usually didn't have anything to do with really *learning* anything anyway." The tale told by Marcus, a first-year music student, epitomizes the statements by those who reported 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.

GRADES: Virtually everyone talked about grades as an aspect of their relationship with mathematics. In fact, in the hundreds of essays the author has read (from my own students and those of others), in only one essay was there no mention of grades. Moreover, in the social contract that underpins schooling in the United States, teachers may have access to a great deal of power through grading and grades. Student reports reflected their experiences with the many ways that people assert and wield power.

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).

Among women, 80% reported "receiving" grades with 34% "earning" them (some reported both). Among the men, 73% reported "receiving" grades while 64% stated they had "earned" them (again, some reported both). Figures 1 and 2 give the frequency of each type of grade in each category by sex. Every person who "earned" an A or B also reported having "received" an A or B.

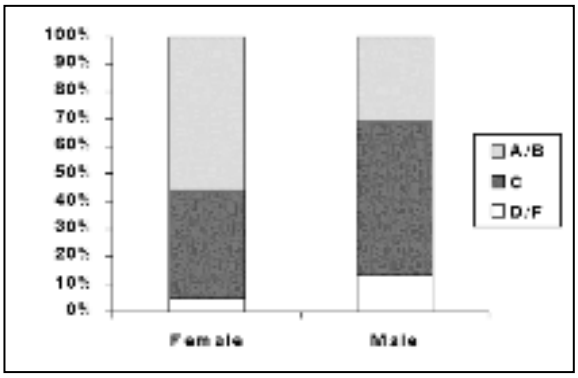

Figure 1. Perceived grades "received."

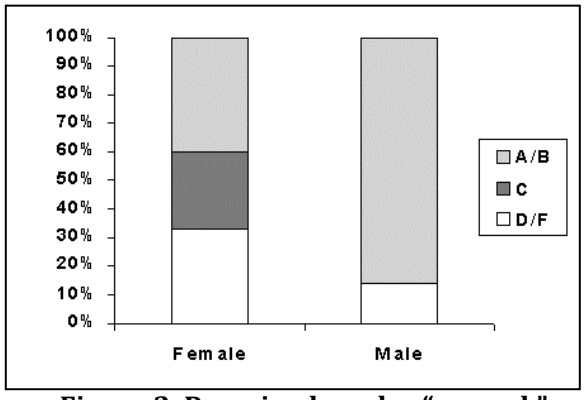

Figure 2. Perceived grades "earned."

Men were more likely to see themselves as having earned high grades and women were more likely to see high grades as received. Of the 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 similar to research into gender and mathematics at many levels. Men and boys who do well tend to report that they succeeded because of their own traits (e.g., hard work, intelligence, etc.) and those who fail tend to blame it on external causes (e.g., bad or

unfair teacher, unlucky, etc.) In contrast, women and girls tend to ascribe success to external factors and failure to their own internal traits (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. Some students related stories about how their ability self-perceptions influenced career choices.

Maria noted that she had "always loved math and loved teaching it to anyone who would sit still, including my brothers." She recalled a fifth grade teacher who had suggested to her she was gifted: "Mrs. Sitwell said I would be a good 'math mom' and could raise lots of kids to be good in math if I became a teacher." Maria's decision to become a teacher felt like "a calling, you know, like I can do it and can help others to love math too." Meanwhile, a tutoring experience with middle school students during her pre-service teacher program led her to "realize now that sometimes people can do math great, but they don't *want* to do it, they don't enjoy it like I do."

Leo identified a key point in the decline of his perceived mathematical potential 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.*

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 1991." 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.*

Jon, 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." 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.*

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.

DISCUSSION: One valuable result of asking students about their personal mathematical histories is that we can be aware that by the time most students leave high school, their readily recalled memories of mathematical experiences are likely to be evenly split between positive and negative. As one student put it, "every encounter with mathematics carries a risk" – a risk that for many has no more than a 50% likelihood of being associated with a positive outcome.

Students bring to their college mathematics courses the perception that intentional engagement with mathematics is externally driven by factors like grades and the behavioral expectations of instructors. Also, mathematical experiences appear to be related to an intimately felt and emotionally powerful collection self-evaluations about relative ability, efficacy, and potential that are connected to decision-making patterns (including long-term decisions about career).

AFTER COLLEGE, AMONG TEACHERS: Since the report on undergraduate experiences summarized here, I have continued to assign activities like the one in the appendix in undergraduate and graduate courses as well as in professional development with practicing K-12 teachers. For most in-service teachers, writing a mathematical autobiography has turned into writing *two* mathematical autobiographies – one about self as student and one about self as teacher. For a few, all with five or more years of classroom experience, there is a kind of splitting and rejoining of self-as-student and self-as-teacher that occurs in creating the essay. Among these educators, most have made remarks similar to something Pat, a veteran elementary and middle school teacher, wrote,

> *When I was making lists of math experiences, at first the only way I could organize it was to have my experiences as a learner and then my experiences as a teacher, kind of in a timeline. Then I realized that some of my learning experiences were actually teaching experiences, like when I tutored a classmate in junior high school. And some of my biggest "aha!"s about understanding mathematics came in my first two years in the middle of teaching or planning to teach, or reflecting on something that happened in class.*

Similarly, teachers with degrees in mathematics, or many years of advanced mathematical learning, have often echoed Belinda's reflection on her goals for students in her sixth and seventh grade mathematics classes:

Though it still sometimes happens, I don't get that math discovery feeling while I'm teaching much anymore. Nowadays, it comes when I take a class or go to a conference presentation. When I put myself in the role of "student" is when it feels most natural to expect to learn some mathematics. At t his point, after 12 years in the classroom, I'm more interested in contributing to students "owning" the math for themselves than I am in creating particularly flashy memories.

Also, experienced teachers frequently offer synthesizing thoughts at the end of their mathematical autobiographies that are like Antonio's thinking, after six years as a teacher at an alternative high school:

I know it may sound cold, but I'm sure I accumulated a whole lot more good mathematical thinking from experiences I don't remember in detail, from the unremarkable yet effective day to day teaching I was lucky enough to experience for most of my schooling. I own my knowledge and I own my ignorance now, which means I am the one who can learn AND teach myself. I think that's the direction I'm going with my math teaching too, helping my students know themselves as learners of mathematics so they can make good decisions about how they learn. So they can be informed consumers about what they take away from what others offer to them in the name of "teaching."

NOTE ON USING THE MATHEMATICAL AUTOBIOGRAPHY ASSIGNMENT: 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). The results of student interviews and journaling reported by some (Borasi & Rose, 1989; Carlson, 1999; Davis, 1997; Millsaps, 2000; Nimier, 1993; Yow, 2012) 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). The mathematical autobiography assignment used for this report included prompts for reflective memory searching and was part of the course grade.

Does the use of the mathematical autobiography as a curricular extension activate useful self-reflection? The answer seems to be: "Yes, for some students." The mathematical autobiography is an expressive writing exercise and appears to foster a useful sense of perspective. Half of those interviewed remark on feeling more self-control around mathematics by allowing themselves to write about and feel emotions without getting tangled up in them.

Instead of seeking to rid students of their reactions to mathematics, a mathematical autobiography allows students to acknowledge their responses and build reflective awareness of them. Self-regulation may come in many forms: from response to the anticipation of consequences of behavior choices (Boekaerts, 2000), to self-aware constructing of goals (Locke & Latham, 1990), to beneficial inner-speech.

However, it must be noted that such self-regulation requires an appropriately supportive classroom. 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; Borasi & Rose, 1989; Brandau, 1988; Pajares & Schunk, 2002).

Developmentally, the kind of self-reflection and recollective thought called for in the assignment is only deeply possible among late adolescents (Rubin, 1996). While younger students can benefit from such an assignment, it may be most productive for students in middle school and higher. At all age levels, the teacher can learn plenty from reading what students write! Can the assignment harm rather than help? Research on expressive writing 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!?!").

What people 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 thoughts and emotions, and interacts with others.

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APPENDIX

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.