Midentity: Exploring the Effects of Self-Regulated Learning on Math Identity Development in a secondary math classroom.

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Abstract

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Looking to bridge gaps in math education for nine students in their eleventh grade year with varied levels of success in math, I based a self-regulated learning model for math study on studio art principles (Winner, Hetland, Veneema, Sheridan, & Palmer, 2008). The impact of SRL on identity as negotiated experience, community membership, learning trajectory, nexus of multimembership, and relation between the local and the global (Wenger, 1998) was examined through a case study of four students over two years through a combination of self-reports and online tools. Results indicated that while students felt more self-efficacious about process, beliefs about math-ability saw little change. Wenger's (1998) concept of identity as *learning trajectory* points to the quality of content students engaged and the importance of deeper connections across the conceptual landscape of mathematics for positive identity development. Examples of student data and implications are discussed.

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Chapter 1. INTRODUCTION

The majority of jobs in the future don't yet exist, and accordingly, current education must teach adaptability in addition to requisite skills for citizenship. One must learn to regulate her movement through the world as it changes quickly. Winne and Hadwin (2008) note "adaptation or change" as the defining characteristic of Self-Regulated Learning, and this paper seeks to explore how teaching a high school mathematics course for students who had not experienced much math success using SRL may have enhanced students' self-perception to adapt when faced with challenge (303).

Remedial education courses (as well as non-AP or non-IB courses in settings where AP and IB are offered) tend away from the dynamic, thought-provoking, rich curriculum offered in more advanced courses. Labeling of remedial math courses as 'slow-paced' or 'regular' can be significantly influential in a student's identity formation with negative impacts on future study, depending on how students interpret their placement (Wenger, 1998, p.150). Years before Wenger's (1998) published work on identity formation, Bandura (1977; cited in Corno, 2008) theorized that students' beliefs in their own talents and ability to succeed preceded effort that may produce such success. Corno (2008) takes this idea further to suggest a curricular focus on *learning itself* in order to build confidence and adaptability in high school students.

Learning is the practice of membership in a math classroom, and becoming a more skilled learner may impact efficacy views in all areas of personal study. John-Steiner (1997), in a large ethnographic work interviewing approximately one hundred prominent creative individuals, found that many composers, poets, scientists, and engineers, among others, experienced a freedom to choose their path within each respective discipline, and consequently aligned themselves with the field. The space to play and discover eventually led to field-relevant views of self that sparked careers. Hersh and John-Steiner (2011), mathematics professor and Vygotskian creativity theorist, respectively, looked for themes in the life-stories of mathematicians to see what principles may apply to math education today. The correlation between concentration and math-related attitudes with success in mathematics quickly emerged as two salient features of young mathematicians (Cornell, 1999; Hersh & John-Steiner, 2011). These ideas across literature led me to wonder how *choice* and *play* might effect student motivation in a remedial setting towards participation in mathematics, to build confidence, and form one's own sense of identity within a specific domain.

1.1 LITERATURE REVIEW

1.1.1 *Identity*

Wenger (1998) defines identity in five ways that I believe will be helpful for our discussion (*italics in original*): Identity as *negotiated experience*: defining the self as the self is experienced through participation; Identity as *community membership*: defining self by what is familiar or unfamiliar; Identity as *learning trajectory*: definition by past and perceived future; Identity as *nexus of multimembership*: reconciling various forms of multimembership; Identity as *a relation between the local and the global*: negotiating local ways of being to broader discourses (Wenger, 1998, p.149). Below, I intend to show how *self-regulated learning* as defined previously may relate to each of these constructs of identity in their formation.

1.1.2 *Identity and Self-Regulated Learning*

Malcom S. Knowles (1982) defines "self-directed learning" as "a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes" (18). While subtleties exist between *self-directed learning* and *self-regulated learning*, I would like to view self-regulation as an aspect of the broader term self-direction, denoting the process in which "people organize and manage their capacities," including "their thoughts, emotions, behaviors, and social-contextual surroundings" (Reeve, Ryan, Deci, & Jang, 2008, 223). Self-directed learning is an older concept with more specific references to activities outside of school, while self-regulation has more of a home in school settings with a more central role for a teacher and students in a classroom.

1.1.2.1 *Negotiated experience*

A student forms identity as "experience and its social interpretation inform each other" (Wenger, 1998, 151). In a mathematics setting, actions such as solving a problem correctly or incorrectly, going to the blackboard, and scoring a certain way on a test, all may have significant meaning and influence on this aspect of a student's identity. Through self-direction, the student can create her own learning goals and assessment, and accordingly, has increased agency in interpreting concepts like progress and success.

1.1.2.2 *Community membership*

"People aren't born disliking math, they learn to dislike it in school" (Hersh & John-Steiner, 2011, 305). What if this was not the case? What if a community's defined success centered on setting goals and reaching them instead of getting one answer right? Wenger (1998) summarizes this community aspect of identity as a form of competence. Clearly, a feeling of low competence may eclipse a student's view of himself as part of the community of those who can do math. In a class setting where each student is defining her own goals, a space is created to appreciate the strengths that each brings to the table. In this space, students may shine in more ways than finding right answers alone. Opportunity for leadership, creativity, and discovery can empower students to see themselves as math learners at any stage or ability.

1.1.2.3 *Learning trajectory*

Wenger (1998) identifies five trajectories of identity: peripheral, inbound, insider, boundary, and outbound (154). In a self-regulated classroom, where the student identifies learning goals and resources, a student who has grown tired of a certain topic can turn what was a non-participatory, outbound trajectory into a participatory one by merely jumping to a different topic of greater interest. Even the recognition of waning interest is a successful move by the learner as s/he shows the ability to self-assess and re-focuses elsewhere. Self-regulation in curriculum opens many doors for the formation of new trajectories to see oneself as a productive learner.

1.1.2.4 *Nexus of multimembership*

Identity as multi-membership acknowledges each learner as a complex member of many communities that follow different practices. Some named aspects of this nexus may include race, ethnicity, beliefs, interests, family, class, and others. Opening the curriculum to student voice allows space for members of the learning community to see traditionally unrelated aspects of themselves as connected to mathematics. Trajectories may be shaped for the individual and affirmed in a group setting.

1.1.2.5 *Relation between the local and the global*

Even while working on algebra, merely opening the door to the rest of mathematical possibilities may help students see themselves as part of a larger whole. In addition, through pursuing their own resources, students may engage a broader mathematics and cultural community with agency about their own learning. They can learn what it feels like to analyze their world with math.

With math adaptation and confidence as central goals for my students, I wanted to see if self-regulated learning - setting learning goals, implementing effective learning strategies, monitoring and assessing goal progress, establishing a productive environment for learning, seeking assistance when it is needed, expending effort and persisting better, adjusting strategies, and setting effective new goals when present ones are completed (Zimmerman & Schunk, 2006, 1) - as a method for studying mathematics would empower students to see themselves as a capable learner of mathematics, thereby strengthening them for whatever opportunities may lie ahead (Corno, 2008). The purpose of this study is to look at how facilitating this course in a self-regulated format fosters identity development in relationship to mathematics.

1.2 CONTEXT OF THE STUDY

The class is an option for eleventh-graders in the math curriculum of a Seattle independent school with both rigorous academics and a strong arts program. Students take the class with the intention to fill in gaps in their prior math education by self-selection or teacher encouragement. The gaps may result from moving towns/schools at inconvenient times, significant family events, lapses of motivation/engagement, or other reasons. Regardless of the route, all who take the class come to strengthen their math skills. Approximately every eight weeks in the course's running, I discussed its format with the students and made subtle changes based on the affordances and constraints we had observed for the prior grading period. In this way, a responsive fluidity was maintained within the initial structure. The diversity of learning profiles and potential gaps in prior understanding created a deeply interesting group of ideas and backgrounds for collaborative work.

1.2.1 *Portfolios*

Twice per grading period, students turned in a "Portfolio", which included 1) A body of work based on their topic of choice (e.g. factoring polynomials, solving systems of equations, etc.), 2) A cover letter analyzing their own learning strategies, successes, and areas for improvement, and 3) A visual representation of their topic.

1.2.1.1 *Body of work*

Van, Morton, Liu, and Kline (2006) conducted a study to examine the effects of web-based instruction on math anxiety for undergraduate math students and found that in general, web-based tools served to reduce math anxiety in their test subjects. While the data was not analyzed for differences in gender or age, for some students, online discussion forums, assignments, and other aspects of the system were advantageous. Additionally, one of my main goals was to teach students how to find and use online resources to answer their own questions and in ways that made sense to them. For these reasons, for roughly 75% of the course, online resources (Khan Academy: http://www.khanacademy.org/, Wolfram Mathworld: ttp://mathworld.wolfram.com/, Purple Math: http://www.purplemath.com/, etc.) were available to for any who found them helpful. The problem sets, many of which were skills focused could be constructed through any of these means.

1.2.1.2 *Cover letter*

Each cover letter answered reflective, metacognitive questions about the student's own learning and processes (see appendix). Research about self-theories in students' learning (Dweck & Master, 2008) has revealed that students' beliefs about their abilities to improve through effort can open them to succeed and take ownership of their own progress. I hoped that through self-evaluation and requiring that students state their objectives and strategies, students might participate in their own goal stating to see themselves with agency, control, and direction as they endeavored to re-learn algebra topics. After the fact, some students stated goals relating to grades, while others to learning, and this laid an interesting foundation for conversation about self-efficacy beliefs.

1.2.1.3 *Visual Representation*

John-Steiner (1995) addresses various modes of representation through the idea of *cognitive pluralism*, "the multiplicity of semiotic means and their formation through cultural practices," (John-Steiner, 1995, 5). Based on the Vygotskian notion that "a single word is so saturated with sense that many words would be required to explain it in external speech," (as referenced in John-Steiner, 1995, 6), extending the notion of cognitive pluralism to representation in mathematics can have interesting implications for modes of potential engagement. I often hear mathematics compared to a language to be learned, with its own syntax and vocabulary. However, the abstract nature of mathematical symbols has the potential to remain divorced from students' experience. One study by linguist Daniel Everett (as cited in Hersh & John-Steiner, 2011, 49) in the Amazon with the Pirahã tribe revealed a language devoid of arithmetic or numerical vocabulary. Most recorded conversations were based almost entirely based in the present moment. It seemed that economical development and cultural openness may be requisite aspects of society to facilitate common experience with numbers. The study suggests that though mathematical symbols, like written alphabets, are human creations, a certain departure from present experience assists in the wielding of mathematical symbolic tools.

I encouraged students in Math Analysis to think of relationships and metaphors that may also represent the relationships they saw at work in their topic. Given the abstract nature of mathematical language (symbols, numbers, etc.), I hoped to present the students with a forum to make sense of their mathematical processes however they chose in parallel to their mastery of the cultural-historical tool of 'math-speak'. This process was inspired by the thinking of Vygotsky's idea that "it is the meaning that is important, we can change the sign, but retain the meaning" (as quoted in Van Oers, 1997). I hoped to develop methods to connect students' cultural understanding of language to the meaning of mathematics. John-Steiner (1997) explores several aspects of thought (Verbal Thinking, Visual Thinking, Scientific Thinking, and the Languages of Emotion) and extends an already established discussion of *internal speech* to "stretch across several modalities." (p.215). She supports the idea that thought in any 'language' may blur into others within the mind, and that successful creative individuals found ways to extend this thinking into the physical realm. I hoped to encourage this with my students. When connections are not made between the symbols placed before them from history and the ideas in their minds, I encourage my students to represent their thinking in ways that do make sense. That said, we also discussed clarity of communication for pieces of work that will be shared with others, as covered later in this section. The majority of my first year's class flourished in artistic disciplines, and this seemed like an especially appropriate tool for connecting their other worlds to their math world. *Examples of "successful" visual representations are attached in the Appendices*.

1.2.2 *Class structure*

The structure of the class facilitated different ways of engaging with other classmates around the study of math. Much of my investigative approach can be seen about how students would best develop missing math skills in this structure. Most of the course was spent on individual studies with one to two days a week centered on discussion.

1.2.2.1 *Path and Studio Days*

While working on these assignments, the class fluctuated between three different days: Studio Days, Path Days, and Crossroads Days. *Studio days* (as well as *path days,* a term we eventually discarded) were designed after Winner, Hetland, Veenema, Sheridan, & Palmer's (2008) *Studio Thinking: How Visual Arts Teaching Can Promote Disciplined Habits of Mind* article, which emphasized transferable aspects of a studio arts class to other disciplines. These eight principles, *Develop Craft*, *Engage and Persist, Envision, Express, Observe, Reflect, Stretch and Explore,* and *Understand Art World* (we said *'Math World'*) are perhaps not surprisingly reminiscent of the SRL principles like goal-setting, finding appropriate resources and questions, and following through. I liked to think of the class in this way, as a studio art class in which students make progress and critique each others' approaches. *Crossroads Days* (a specific kind of day in class) functioned similarly to a seminar, rich with feedback and the opportunity for anyone in the community to pose questions or present on recent successes.

1.2.2.2 *Crossroads Days*

Crossroads Days occurred once or twice every two weeks when the class took the form of an open forum. Students had the opportunity to pose questions to the entire class about problems they were working through. This not only would provide space for various students to teach (an often empowering experience), but for students to see each other as resources for their questions. I encouraged students to anticipate the next step in their peers' work at the board and to approach these days with "a mindset of constructive criticism, that we come with different strengths and backgrounds, and we all will learn from each other" (from the course syllabus). Students could also share recent successes in understanding from their work and publically affirm the fruits of their efforts.

Chapter 2. THE STUDY

2.1 DATA COLLECTION

Qualitative research methods were most appropriate. I am interested in preserving the dynamic perspectives of students, their narrative accounts of their journeys as learners, and the emotional quality of their relationship with mathematics. While a quantitative study may be useful for measuring students' growth through test scores and other related measures, and I will reference such data as part of my studies, the emotional and perceptive qualities of each journey may be eclipsed when seen only through the lens of numerical data.

> "Think of interviewing as the process of getting words to fly."
> – Corrine Glesne (Glesne, 2011, 102)

I am interested in the story of my students, and their personal reflections on the course, and accordingly have chosen interview as a primary method of data collection. I facilitated twenty-minute interviews with each of the four students selected for the study. I asked respondents questions primarily regarding the five aspects of identity from Wenger (1998): *negotiated experience, learning trajectory,* and *nexus of multimembership*, followed by questions relating to *community membership* and *relationship between the local and the global* as they apply to students' math learning. These two parts were separated by a question Each interview was recorded and transcribed. Additionally, all questions were written and checked with Patton's (2002) suggested questions for qualitative research (as cited in Merriam, 2009, 96-97) and tested in order to avoid leading the respondent toward a certain desired or expected result.

2.1.1 *Coding*

I transcribed all interviews and performed member checks with interview participants.

Once interview transcriptions were confirmed, I coded interviews, portfolio cover letters, and end-of-year surveys for the presence (or lack) of *self-efficacy* and changes in feelings about math. In order to obtain a sense of the effectiveness of the math curriculum, since assignments (based on time spent in the site) were frequently given in Khan Academy, I checked students' progress in KA, as well as their visual representations for accuracy. Table 2.1 below describes specific codes.

Table 2.1 Codes

Code	Meaning	Examples
SE+	Positive statement of self-efficacy	Statements that focused on one's ability and possibilities e.g. *I thought about success every day, I've gotten better, I can figure it out*
SE-	Negative statement of self-efficacy	Statements with a limited view of one's own abilities e.g. *I can't, I haven't studied enough to know, I was never good at it*
Positively oriented changes in feelings about mathematics	Positively oriented changes in feelings about mathematics	Statements showing a change in how one felt about math, e.g. *now I think statistics is amazing, I've opened my mind to think about more than one approach*
P+	Personal adoption of process, adding strategies	Statements wherein a student reported growing as a learner, e.g. *I started asking my neighbors questions, I worked at home to practice skills used during the SAT, I chose to work alone to focus*
Energy points	Khan Academy's metric for measuring effort	I added up totals for students' entire years, and looked for specific instances of logins with more than 1000 points, which correlated to 30 minutes or so of intense effort

2.1.2 Sampling

The students in the study were chosen intentionally: a boy and a girl from each year of the study, one white and one person of color (the school is predominantly white). Though these measures were not central to the study, I thought it was important to have some variance of background in the stories told.

I chose these five elements of data with the intention of seeing a well-rounded picture of each student's participation in the course. While the data in this course was longitudinal, qualitative data was analyzed cross-sectionally to see a picture of each student through five lenses. Interviews and end-of-year surveys took place at the end of the year in reflection. The cover letters (part of the portfolio) were sampled from various parts of the year to see how different students analyzed their work at different stages of the year. I observed overall language trends in the cover letters, and think that a more longitudinal study of this data may provide further insight. However, it is worth noting that proficiency in the language of self-regulation over the course of the year (writing responses for the sake of the grade rather than the reflection) may also cloud the accuracy of this measure.

2.2 DATA ANALYSIS

In this section, I will detail what I looked for in each of the five instruments used, including end of year surveys, interviews, cover letters, visual representations, and Khan Academy progress.

2.2.1 End-of-year surveys

When I analyzed the end of year surveys, I looked for signs of self-efficacy and changes in feelings about math. The two main questions informing these results were *#2,3,and 4 (survey in Appendix C).*

Student A reported increased enjoyment and confidence in math at the end of the year, with an active statement about filling in her own gaps in math. However, evidences of *fixed mindset* (Dweck, 2006) around mathematics were still present. She perceived that successful students in math earned "good grades" and "caught onto things quickly." She also stated a binary perception of her comprehension in math, from no understanding to total understanding. This result was inconsistent with the learning methods discussed in the course and perhaps points to perceptions about learning mathematics founded earlier in childhood.

Student B also reported increased enjoyment and self-efficacy in math at the end of the year, and stated that choice in the curriculum was helpful since he knew what areas in math he was "weak in." I see this self-awareness as a sign of self-efficacy in analyzing the needs that are often diagnosed by a teacher or third-party agent, like a standardized test. Though this is a different realm of self-efficacy than I had originally thought about, the result makes me think about the benefits of co-creating curriculum with students to create a realm for the student to begin making decisions about their learning. Again, when asked about signs of a successful math student, Student B reported that a successful math student "already know[s] a formula to figure out the problem efficiently." I wondered if more emphasis on *process* in the course would have helped shift this perception of success.

Student C reported that at successful math student has "a little knowledge of a lot of topics," as well as "good explanations/step processes for everything." and "is able to help other students." She described herself as "enjoying" math though she thought she could "focus more" at various points in the year. She reported wanting to do more "group teaching assignments." Additionally, she reported increased confidence and enjoyment of math as a result of the course.

Student D described a successful student as "doing math" and "getting the question right."

As a math student, he said he forgets what he already learned at times, but works well with others. His ideal *Studio Day* would include a "group activity that ties into a discussion afterward," showing an interest in collaborative work. Since most of the work in the class was independent, this made me wonder if he and other students were interested in more group work and hesitated to express this during the course. He reported higher confidence and enjoyment in and of mathematics as a result of the course.

2.2.2 Interviews

I interviewed each student for 20 minutes about their experience in Math Analysis to obtain a sense of how they saw themselves as math learners in an open-ended discussion. Again, I looked for signs of self-efficacy and signs of changes in feelings about math. Interview questions may be found in Appendix B.

Student A (9 SE+. 4 SE-, 3 positively oriented changes in feelings about mathematics) effectively used the structure of the course to her advantage. She reported in her interview that earlier in life she had accepted that "math wasn't [her] thing," but a year after taking Math Analysis said, "I am doing a lot better in math…now." She described herself as a "self-motivated person," who would "just do [her] work, and if [she] needed help, just ask." This is a core component of the syllabus she adopted into her work flow. Student A started the year motivated by goals for her SAT Test Score, and over the course of the year with the freedom to work on SAT practice and related concepts, she raised her Mathematics Score by 150 points. She attributed this gain in her score to the work she put in on her review, a sign of accomplishment if not retroactive self-efficacy. Overall, her interview showed nine SE+, four SE- and three positively oriented changes in feelings about mathematics. This description is a faint backdrop for the positive influence and drive she demonstrated in the course. What transformation she experienced regarding self-efficacy seemed to still waver in the interview by the thought of college math courses.

Student B's interview (4 SE+, 2 SE-, 8 positively oriented changes in feelings about mathematics) showed much more about the role of representation in the course as presenting alternate means for engaging in mathematics. While the student responded only intermittently about self-efficacy, his view of math changed altogether through the lens of representation and approaches to problem solving. He said he had "opened his mind a lot more than to think of solely one strategy," and discussed math as a means of communication, and multiple perspectives as a gateway to understanding the problem. This student seemed to value the collaborative aspects of the course, and found that the individualized structure gave him a gateway to understand math in a way that was culturally and personally relevant. He described collaborating with other students and hearing their views as a "fulfilling experience," that helped him prepare for a year of Statistics, where bias analysis is a key theme of the course.

Student C (4 SE+, 1 SE-, 2 positively oriented changes in feelings about math) described herself as a "constructive, challenged, and persistent" math learner. Like Student B, she valued multiple ways of approaching a problem. She expressed interest in topics in prior math courses coupled with a conception that she could "get it" or not based on the simplicity of the "equation." She cited her speed in learning probability during a prior course as a success in mathematics. This follows in line with much of what was heard in the rest of the study, relating speed with success. That said, she explained her success as a result of comprehending the "logic of it" first, thus she was easily able to fit in the "math" of probability after. For me, this points to a conception of mathematics as deeper than the numerical symbols. Student C described getting into college and feeling successful on the SAT as her central goals for learning in Math Analysis.

Like Student A, she spent much of the year doing SAT preparation and worked with a tutor to this end for the majority of the year. The interview took place toward the end of her year in Math Analysis, and "[she] definitely gained skills this year," stating that the idea that everyone should work in the same way or at the same pace "really is a trick."

Student D's interview (2 SE+, 1 SE-, 3 positively oriented changes in feelings about math) showed an appreciation of the applicability of mathematics. In seven instances, Student D expressed enthusiasm about how math could be used to predict elections, betting scenarios in sports, and casino games. One example he cited came from our class investigations, and the rest he researched on his own or in other courses. Like other students, Student D's view of a successful math student included prior knowledge of equations, arriving at conclusions quickly, and knowing how to calculate an answer before other students. He told a story about being rewarded earlier in schooling for knowing the answer to a multiplication question that was complex for students in his class. When asked about the self-regulated format of the course, he shared that he could have used the time more effectively, and at certain points chose to disengage on purpose based on his current feelings about the work. This is a key component of conclusions about SRL to be discussed later in the piece.

2.2.3 Cover Letters

As mentioned, cover letters were a space for students to reflect on process and their manner of engagement with the topics they chose to study. Students turned in cover letters every three weeks, starting in October of the school year. I analyzed a cover letter from each student for changes in feelings about *self-efficacy* through statements with a first-person active verb referring to successful math-related tasks. I also looked for words/phrases pointing to a personal *adoption of process* as students studied.

Student A's cover letter (4 SE+, 4 P+) was turned in during the month of March. For this portfolio, she took a break from purely working on SAT Math sections to focus on angle relationships and problems involving similar triangles. She described a positive change in *self-efficacy*, having the space to work through geometry concepts and SAT problems in a "less stressful environment." saying that once she returned to full SAT sections, she cut out wasted time spent double-checking her answers due to lack of confidence. She mentioned that working without a timer made her less focused, however, and at times the work researching methods went later into the night. Overall, she mentioned that she was "pleased" to "learn a little bit more and then bring that to the SAT so [she] didn't have to rely on their tricks." Student A tried a new *strategy* to work toward her overall goal, and experienced success.

Student B's cover letter (4 SE+, 1 SE-, 5 P+) was turned in during February. He reported four explicit strategies for success on the SAT (plugging in numbers, drawing pictures, working backwards, and skipping problems if they are taking too long), three of which were strategies that could be applied in non-SAT math contexts. He described "finding success" through "practice" and identified "struggles" with more "complex algebra." Student B also reported that he "enjoyed" our discussion of Vygotsky's Theory of the Zone of Proximal Development. Occasionally, when we discussed educational psychology theories, Student B's reflections on learning moved our discussions in meaningful ways.

Student C (4 SE+, 3 P+) turned her cover letter in November of her year in the course. She assessed topics she "felt [she] needed more time with," started using a textbook resource and eventually finished her work in Khan Academy. She described that working on skills that may help her be a resource for her peers was a key motivation for her studies. This relational component emerged as significant for many of the students in the course. She described becoming “more vigilant in self-study,” and developing a sense of “ways [she] could improve.” Processes she adopted included choosing topics in common with her classmates to promote collaboration, using online resources such as Khan Academy, choosing a family of topics that relate to each other in order to build more effectively on prior knowledge, and making the most of our ‘speed dating’ days, which include becoming an expert on a problem and then assisting classmates with that problem in changing pairs.

Student D (6 SE+, 7 P+) turned his cover letter in during the fall of his year in the course. His affinity for real-world applications of mathematics was a theme in his letter as a means for “enforcing the validity of opinions.” He described his own improvements interpreting/critiquing graphs, using feedback and collaboration to gain understanding, learning more efficient ways to solve problems through listening to other perspectives, and persevering in his use of Khan Academy. His reports of growth in self-efficacy included effective use of Studio Days to learn math as well as develop a rhythm for his learning, listening to and processing feedback, and engaging in the problem-solving process. Student D’s social successes and curiosity about the world fueled much of his independent work in the course, and he continued to be a key collaborator during the year

2.2.4 Visual Representations

As stated earlier, visual representations were included in the course as a means of sense-making with math in non-traditional ways. Students could decide whether to go in a more metaphorical direction or more literal, a range we will see below.

Student A’s visual representation, as with many of hers, was a well-constructed diagram that could have come from a textbook. She used color-coding and the coordinate plane to show various angle relationships (vertical, complementary, supplementary, congruent). She also included that the sum of all angles in each of the four quadrants add to 360 degrees, superimposing a circle onto the x- and y- axes. While it did not venture into the realm of metaphor as many others did, this representation, highlights these relationships in a nonlinear (and perhaps nontraditional) fashion through the use of color and placement on the page. I appreciated the clarity of this representation as she employed it for instruction of her peers.

Student B's visual representation shows the student on a path. It is a perspective drawing, and the student in the drawing faces a glowing set of buildings in the distance labeled "college". Two books lay in the foreground, one labeled "SAT" and the other labeled "Portfolio". The one labeled "SAT" may be a reference a preparation booklet, and the other may highlight a central tool for evaluation in the course, the portfolio. The drawing is simple, with very few terms to distract from the image of the student in what appears to be a path from his study tools toward his goal. I observe this as a key indicator of motivation, of math as a means toward an extrinsic goal, rather than a steeping of the mind in math concepts to play with metaphor.

Student C's visual representation included an intricate design that seemed to be inspired by floral and paisley. She drew eight identical 'leaves' that met in the middle, producing a kind of spiral. She shared that this design showed how each part was identical, and thus the entire shape is symmetrical on several axes. She cut each piece out of the 'flowered' shape and used the pieces to show equivalence in fractions (e.g. four eighths is equal to two fourths is equal to one half). This was the first of her visual representations for the year. I encouraged student to think about further ways to communicate entirely without words or other shared symbols. Student C's representation was a key beginning for our discussion about the affordances and constraints presented by more experiential, malleable representations.

Student D's representation visualized a rate problem wherein plankton moved to the surface of a body of water at six hundred meters per hour. The drawing has mostly been drawn in with color using a blue marker. Drawn is a house that appears to be like an igloo and an arrow tracing the plankton's path of travel. In all, a distance of twelve hundred meters is marked out on the plankton's path. This representation, like many in both years of the course, employed multiples of ten or one hundred that evenly divide into one another. This method of communication may be useful when a learner is still grasping a concept. Student D did not outline a problem, as the situation is self-contained with nothing left to the imagination. The secondary school viewer likely looks at the diagram, makes sense of it, and leaves without needing to think deeply about rates. Student D was not alone in this style of representation.

Reflecting on all four examples, Students B and C came to the class with more extensive experience in the arts, while Student A was more focused on sports, and Student D politics. I wondered if there was any meaningful connection to be made here, how deeper thinking in math with metaphor could be facilitated in future years, and think this implies room for further research.

2.2.5 Khan Academy

Students in both years used Khan Academy as a significant curricular tool. It attracted students and myself through its many topics, problem sets, and instructional videos that gave us flexibility and ease of use. Students in the course employed other resources for their independent work, such as SAT preparation websites, a textbook, and various worksheets, so not all skills progress from the year will appear in the Khan module. However, since Khan Academy uses periodic cumulative assessments (called 'Mastery Challenges'), some progress over time may be observed, and I will analyze these results for skills mastered below. Khan Academy uses a metric called *Energy Points* that are awarded when a student puts forth effort *and* when they are successful in an exercise. Energy points and skills mastered will be listed as explicit points of reference in the discussion below.

Student A (1784 energy points, 0 skills mastered, 4 videos watched) made use of Khan Academy as an instructional tool and little more. As stated, her goals for the year were mostly centered around preparation for the SAT, and as other students worked on Khan Academy, Student A could be found with an SAT or ACT preparation booklet. Khan Academy may not be the most accurate tool for measurement. She shared that she improved her SAT Math score by over one hundred and fifty points.

Student B (4266 energy points, 0 skills mastered in KA) seemed to spend time on Khan Academy and pursued many skills, but none beyond an introductory understanding. He preferred to use worksheets and the textbook many days. Additionally, it should be noted that I often assigned homework through the website based on time and not skills mastered, assuming a baseline level of engagement. This method of evaluation may not have served this student well. Toward the end of the year, he clearly had Khan Academy open, but did not take any assessments, hinting at login time that was not used effectively.

Student C (17 instances of >1000 energy points, 43 skills mastered) made effective use of Khan Academy as a learning module. In class, she focused quickly and reported spending time at home to supplement her work in class. The graph of her participation by time over the course of the year goes up, nearly doubling by-instance at the end of the year. Fifteen other skills were attempted and not mastered.

Student D (6 instances of >1000 energy points,1 skill mastered, several others at varying degrees of progress), as stated, was far more interested in politics and the economy than working on skills. He used Khan Academy often, and grew stuck on certain problems with relative frequency working on his own. Working in pairs and groups where explanation/discussion with another human was possible, he experienced much more success. Many of his Khan Academy login times lasted less than twenty minutes.

Table 2.2 Data Analysis Chart (Part 1)

Student	Survey	Interview	Cover Letter	Visual Represent.	Khan Academy
Student A	Increased enjoyment, confidence Success: "knows right answer quickly"	9 SE+. 4 SE- , 3 positively oriented changes in feelings about mathematics 3 words: "slow" "needy" "formula oriented"	4 SE+ 4 P+	Display of angle relationships. Clear, explicit, descriptive with diagrams	1784 energy points, 0 skills mastered, 4 videos watched
Student B	Increased enjoyment, confidence Success: "already knows a formula to figure out the problem efficiently"	4 SE+ 2 SE- 8 positively oriented changes in feelings about mathematics 3 words: "receiver" "thoughtful" "slow"	4 SE+ 1 SE- 5 P+	Student on a path toward college next to books titled 'SAT' and 'Portfolio' (a key tool for assessment in the course)	4266 energy points, 0 skills mastered

Table 2.2 Data Analysis Chart (Part 2)

Student	Survey	Interview	Cover Letter	Visual Represent.	Khan Academy
Student C	Increased enjoyment, confidence Success: "good explanations" "little knowledge of many topics" "able to help"	4 SE+ 1 SE- 2 positively oriented changes in feelings about mathematics 3 words: "constructive" "challenged" "persistent"	4 SE+ 3 P+	Design using symmetry to show equality of fractions and a pattern	17 instances of >1000 energy points, 43 skills mastered
Student D	Increased enjoyment, confidence Success: "getting answers right"	2 SE+ 1 SE- 3 positively oriented changes in feelings about mathematics 3 words: "capable" "tentative" "Semi-engaged"	6 SE+ 7 P+	A visualization of a rate problem with plankton and an igloo	6 instances of >1000 energy points,1 skill mastered, several others at varying degrees of progress

2.3 RESULTS/FINDINGS

2.3.1 Self-Efficacy

Students as a whole reported an increase in self-efficacy over the course of the year, as well as positive feelings about mathematics. In each interview, I was surprised by the array of words in response to the question *Describe yourself as a math student in 3 words.* While students' cover letters and end-of-year reflections had an air of strong belief in self, this question, which was placed right at the beginning of the interview, seemed to point to *peripheral learning trajectory* and perhaps a form of *community membership* that centers more on the relationships in the class rather than adopting a sense of agency in mathematics. Looking back, it is important to ask why, after many efforts to build a positive view of students' own abilities, a disproportionate number of responses still showed a narrow view of success in mathematics and what success in the field means.

2.3.1.1 *Structure vs. Content*

While the structure of this course was likely new for incoming students, the content itself tended to be dry, or repetitive at the least. Khan Academy, worksheets, skill reviews: in isolation and without further investigation, these all neglect the deeper questions of mathematics. *What is math? How do quadratic functions relate to linear functions? Why do we study math? How do the representations that already exist within traditional mathematics – graphs, formulas, tables – show the relationships at play in a function?* We scratched at the surface of these questions, but often stayed in the confines of problem sets with little connection to other topics that may have led to more meaningful impressions.

To ask a deeper question takes time. It requires multiple approaches with time to reflect. Self-regulation cares less about the actual learning that occurs and more about the process – setting goals, developing strategies, following through. All students in some ways were successful self-regulated learners. Not all students had successful experiences with true mathematical thinking. In future classes, I plan to scale back the SRL component to make room for projects, richer problems, and varied experiences that may promote real engagement with mathematics.

2.3.1.2 *Community membership*

Pursuit of more modes for community membership is another reason I proposed this class format. I had seen classes with limited opportunities for success, especially for students who had not been successful in mathematics. Between representation, discussion leading, self-reflection, and choice in curriculum, I hoped students would find more modes of participation, and therefore more ways to positively develop identity around mathematics.

If a student will see his- or herself in a community of math learners, however, it is paramount that the students share experiences *doing math and thinking mathematically*. Students who join the class already motivated with specific math-related goals may find community with others who share those motivations. However, for those without a strong sense of direction, or even the self-awareness to know what s/he doesn't know, one may form community around tertiary goals of the course, and leave without exploring the conceptual landscape that may support and inform future choices studying math.

2.3.1.3 *Identity*

Lastly, I want to ask, *what is the 'it' that students identified with?* My goal was to provide students space to develop positive identity as math learners. Responses in interviews and end-of-year surveys showed that little had changed in how students saw themselves through the course. We read articles about learning. We discussed reflection and evaluation strategies. Students encouraged one another to make an effort, to believe in their abilities. These all may have been about their learning, but the students were most often applying their new mentalities to activities that reinforced old beliefs about math: divorced from daily experience, a right or wrong answer, something that is known or not, a hurdle on the way to college, and on.

While the aims of building community and providing students with multiple ways to engage content seemed to improve the course experience, it is important that the 'what' of the experience also challenges student perceptions. Positive talk must accompany and not replace the hard work of exploration, justification, and understanding the structures beneath the formula.

2.3.2 *Strategies*

Some of the strategies adopted by students using an active voice included asking questions of peers and the teacher, seeking out multiple perspectives, working without a clock, working on families of related mathematical concepts, drawing diagrams, and persevering. The *negotiated experience* in Math Analysis - self-regulated work, reflection, discussion, representation, and assessment – may facilitate deeper learning in mathematics, and yet do not necessarily produce an *inbound trajectory* toward math learning, as they can be viewed as tasks to themselves. While a student could develop a vocabulary of strategies, the math skills required to do the problem at hand using these strategies may obstruct progress that would facilitate a more efficacious view of self as a math learner.

2.3.3 Skills and Accuracy

The more immediate and obvious question than identity development regarding success in the course may be: Did the students get better at math? Of all the instruments listed, Khan Academy reports are the most telling of skills progress, and student C appears to be the only student who employed it with any consistency. Student A spent most of the year focused on SAT Math, and made clear progress in that realm. Students B and D employed worksheets, projects, and other media to work, which led to more difficult to trace evidence of progress in their studies. For these students, my impressions of their progress could be solely based on how I saw them engage a series of topics of increasing difficulty. Given that Khan Academy was to be a primary instrument in the formation of the course, it would appear the students directed themselves toward other means of study for reasons to be explored. A learning module that students find useful and intriguing may be one of the first steps for promoting engagement.

2.4 CONCLUSION/DISCUSSION

2.4.1 *Implications*

The data in this case study of four specific students (out of eighteen total between the two years) revealed areas where interest berthed and self-efficacy shone through in reflective statements. It also showed what some would consider unimpressive, or loosely traceable at the least, mathematical results. I will discuss what the implications of this study on i) structure of the course ii) formal instruction iii) tools/resources students may use.

2.4.1.1 Structure

Some students made use of the open-ended structure of the course to their advantage. It is possible that those who entered the class with less refined study skills could have been better served by a more rigid structure or guidance in self-direction at the least. In future classes, I plan to increase the amount of check-ins with me and to design more continuous and consistent ways for students to record their own progress.

2.4.1.2 Curriculum

The self-regulated design of this course was true for 80% the first year, and almost as much the second year. As I hoped to respond to student needs/wants, I planned more varied lessons in the second year, with approximately 20% less time for individual study or path/studio days. In the future, I will modify instruction so there is a thread of common experience of curriculum throughout to supplement the large portions of self-regulated time. My hope is that this will supplement the amount of conversation students may have and provide a reference point for the work students do on their own. One challenge this may bring with it includes an interruption of the otherwise continuous threads students may create for their learning. Careful planning and making connections to current material seem necessary for a successful integration of this kind.

2.4.1.3 Tools/Resources

Khan Academy, an algebra textbook, and popular websites served as the main tools for learning during both years of the course. As you have read, certain students chose to work mostly in ACT or SAT preparation books, or worksheets that I generated. I found that these tools focused mostly on core skills and provided few opportunities to advance students' deeper problem solving abilities in mathematics without discussions and group activities that pushed the students' thinking in these ways. In the future, I plan to integrate deeper, richer problems from algebra concepts that relate to skills the students work on at the time in order to develop opportunities for individuals in the class to share expertise and enrich pathways for *community membership* that reside not only in our SRL discussions but also in more advanced problem solving.

2.4.2 *Limitations*

It must be acknowledged that all students in the case study were either (a) familiar with me from previous years at the school and in this class where I was the teacher, (b) in a previous math class where I was the teacher, or (c) both. Additionally, the class is set in a school culture (independent, elite) that by context is strikingly different than the majority of schools in the country. Student/teacher relationships are less formal, and the idea of self-advocacy is already in the language of students' coursework from the beginning of their school career. The class only had nine students both years of this study, yet another difference with average class sizes across the country and world. The affect in our class was generally positive, supportive, and calm. I wonder how these responses and stories may change in a different setting.

4.3 *Closing Thoughts*

This study was helpful for my practice at the least, and I humbly share it as an example of how a self-regulated curriculum looked in a secondary classroom with students who have previously not experienced much success in math. The model provided opportunity for some students, and not as well for others, however, at the end of two years, even the limited success stories and new forms of confidence in mathematics reinforce my belief in negotiating student agency in the curriculum. I wonder if the chance to make active statements about the content of our class opened inbound trajectories that may not have existed. Though there are too many acknowledgeable factors to name in one's development, it seemed that prior formats of class and the students I taught had missed each other somewhere in a way that motivated this endeavor to try something new and see how it would serve them. One day, each one will make new, important decisions and have to teach themselves new concepts and skills. Through this process, I grew in the skills I hoped to impart to my students as well – self-assessing, reevaluating, developing new strategies, and finding new tools. As a teacher who hopes to respond to future students whatever their background, perhaps the study was as valuable for me.

I encourage future research in the area of SRL for secondary students to see what other models and philosophical approaches may positively impact students' identity development as learners in the content area. I would like to reemphasize a point made in the Results/Findings section, that in any model I encourage a focus on deep, rich content and taking the necessary steps to support student engagement with that content. If we want students to see themselves in a different light, we must not merely change the light bulb, but help them find a new landscape that requires a different interaction, one from which the new learner is formed.

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APPENDIX A – OPENING SCRIPT

Hello, and thank you so much for meeting with me. My name is Steven Wilbur and I am a graduate student in Educational Psychology at the University of Washington. Some people refer to *self-directed learning* as a process by which someone takes initiative, sets goals for his/her learning, finding resources, and evaluating his/her own progress. I am studying the effect that self-directed learning opportunities have on learner's view of themselves as math students, and I am interested to know more about how you would say your experiences have shaped your belief in your capability to do math. Your identity in relation to what you say will remain anonymous, though I may share some or all of your responses for the purposes of my research. If you agree, we can meet again so you can see my notes and make sure your thoughts are represented accurately in my report. Please feel comfortable to share candidly about the course. I am interested in your honest reflections on your experience, and no response will have any bearing on your grade in the course.

APPENDIX B – INTERVIEW QUESTIONS

1. Describe yourself as a math student in three words.

2. Where have you gone to school?

3. What are your favorite and least favorite topics in math?

4. Tell me a story about a success you had in math class.

5. Please tell me about your learning experience in Math Analysis this year.

6. What does learning mean to you?

7. How has your definition of learning related to your school experience?

8. What are math concepts you would like to learn about that may have practical implications for your life?

9. So some people define or refer to Self Directed Learning as a process by which someone takes initiative, sets goals for his/her own learning, finding resources, and then evaluates his/her own progress. Take a second to think of a time when you directed your own learning in any subject. (*pause)* What were some challenges with that?

10. How did that process make you feel?

11. How did that experience compare with other learning experiences?

12. How do you see yourself as a math learner now?

13. Please tell me anything else you would like to about the Math Analysis course.

APPENDIX C – END OF YEAR SURVEY

1. About how much time have you spent on Math Analysis homework each week?

2. Circle the word that best fits your attitude about your learning in math:

- I am (more/less) confident as a math student than I was at the beginning of the year.

- I am (more/less) confident as a learner of all subjects than I was at the beginning of the year.

- I enjoy math (more/less) than I did at the beginning of the year.

- I have found it (more/less) enjoyable to be able to choose my topics of study.

- I have found it (very helpful / inconsequential / very challenging) to be able to choose my topics of study. How so? Please answer here:

3. Think of someone you know who is good at math. What kinds of things to they do that make you think they are good at math?

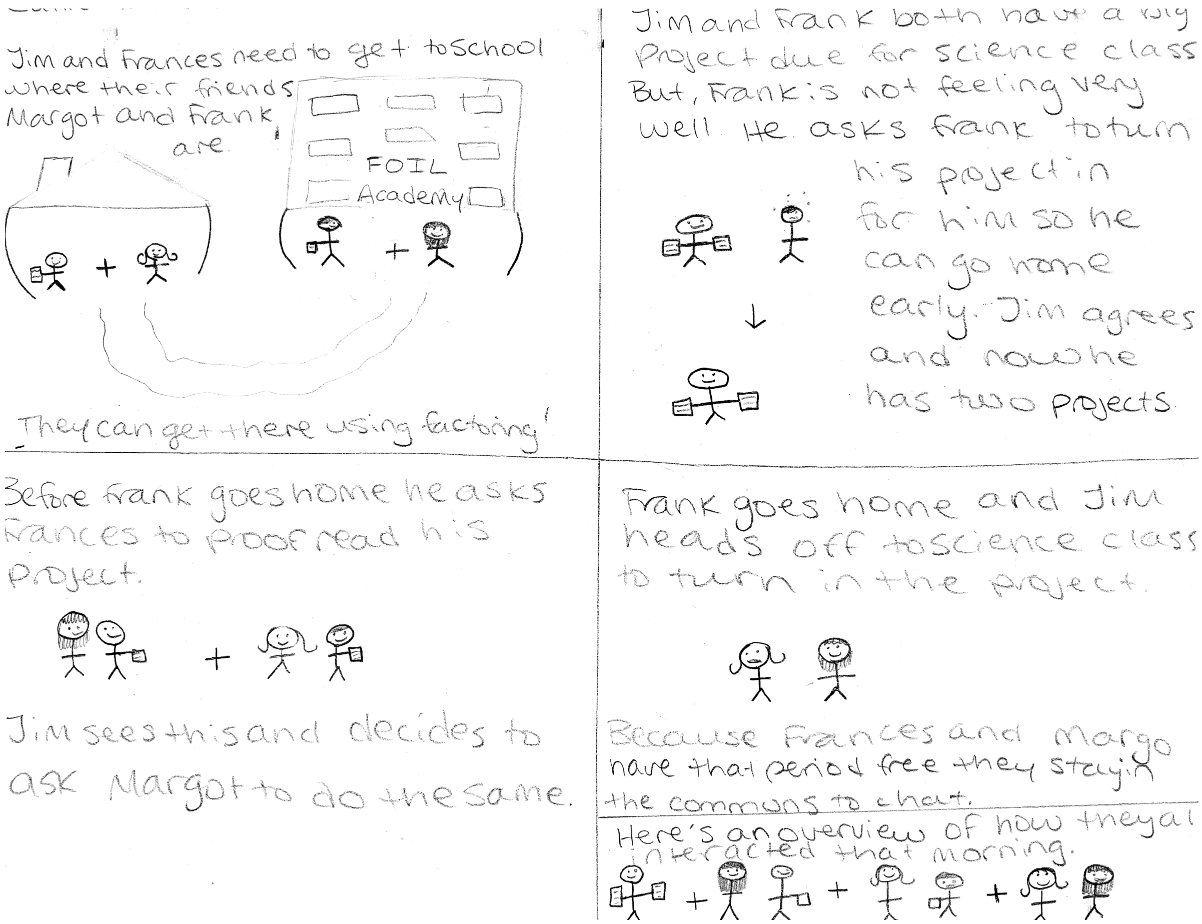
4. Describe yourself as a math learner. Please include both strengths and challenges as you see them.

5. Describe your ideal Studio Day. *This can be the activity the kind of activity, the kind of question, individual vs. group work, location, ..., anything!*

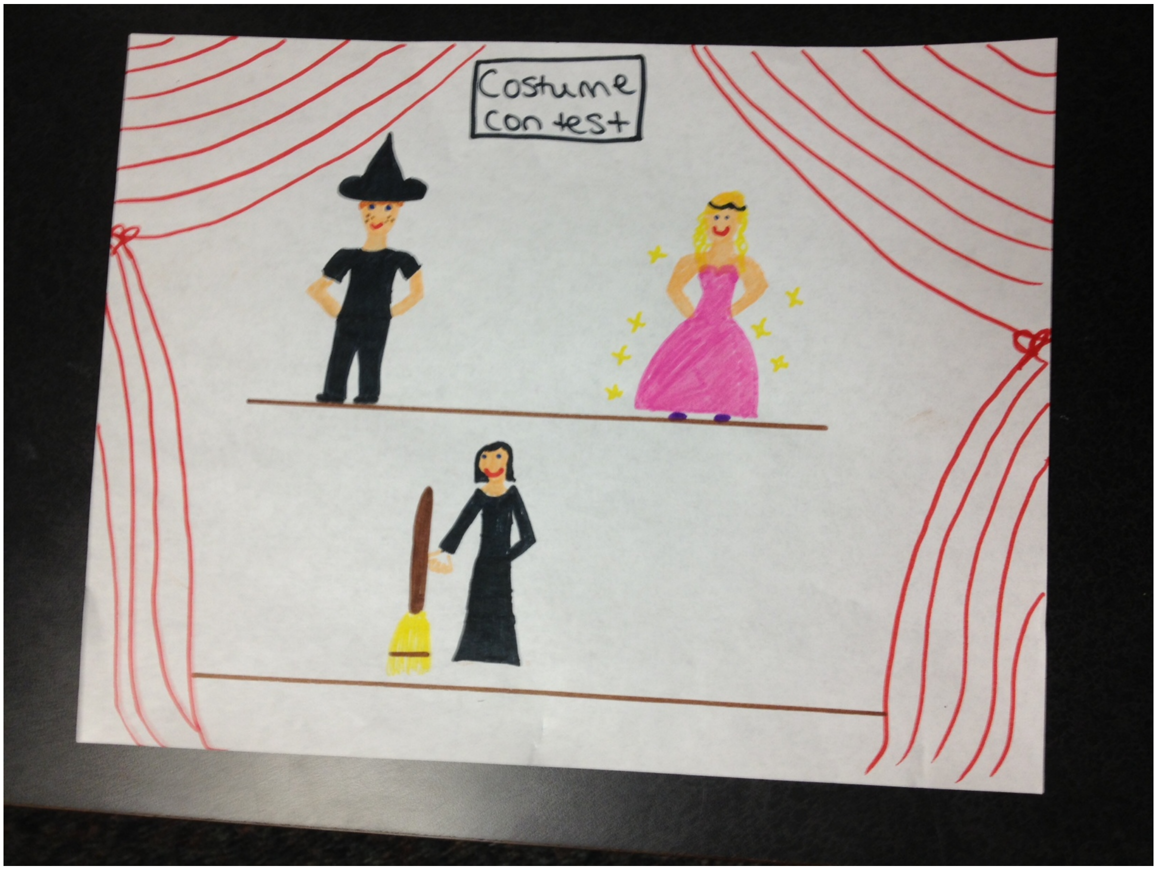
6. Lastly, what assignments do you feel most motivated by? (can be from this class or other classes)

7. What do you think it means to be a mathematician?

APPENDIX D – VISUAL REPRESENTATIONS



A story of four students who exchange two papers in such a way that each student touches each paper, much like the expansion of two binomials (commonly known as FOIL method)



Simplifying rational expressions by cancelling factors in the numerator and denominator

APPENDIX E – SAMPLE PORTFOLIO GRADE SHEET

portfolio 4.2 grade sheet **name** ____________

cover page ____ / 20

Statement of your goal _____ / 5
What topics? Why did you choose these topics?

Description _____ / 5
The skills you learned,
The strategies you used to learn

Your cover page should answer these questions: _____ / 10
What did you like about your study?
What do you still have questions about?
How did you use the Studio Days to help you?
How did you use feedback and collaboration to accomplish your goal?

assignments ____ / 25

Minimum of 6 unique problem sets or other exercises
Should cover a range of topics and be mostly flawless
as we will have worked out problems in class.
for instance, if studying linear functions one should include
point-slope form, slope-intercept form, graphing, etc.
These can be from the book or elsewhere as long as we agree
on your choice of resources.

visual representation (due 4.9.14) ____ / 5

We will work on this April 7 and 8. This is a diagram/drawing to represent what you learned.
It should clearly show a relationship(s) and/or process(es) that you studied
during the three weeks your portfolio was in progress. While working out
problems is the way we mostly focus on to show our math thinking,
I would like for this representation to use analogies, drawings,
and re-conceptualizations of the material. Show off your creativity!

total ____ / 50

other notes: