On Self Regulation in College-Level Mathematics Classes

Jenny Lee

Dagan Karp, Advisor

Luis A. Leyva, Reader

Department of Mathematics

May, 2018

Abstract

This paper looks into need for improvement in mathematics education at the college level in the US regarding equitable practices in instruction. In particular, this paper focuses on understanding the role self-regulation can play in the classroom dynamics, and how self-paced assessment can be a way to empower students. Also included is a case study in an introductory linear algebra class at a liberal arts college and is meant to provide a investigation into self-regulation in this context. The appendix includes an annotated bibliography comprised of the most relevant studies in self-regulation conducted in the last two decades or so. An index of keywords and pertinent quotes are highlighted for the ease of the reader.

Contents

Acknowledgments

Chapter 1

Outline

1. **Introduction**

   (a) Background and motivation
   - personal background and lived experience, motivation (personal anecdote explaining the motivations behind why mathematics education needs reform, viewed and related in the perspective of a student)

   - background in postsecondary math education, including self-paced assessment (**cite the few things we have**)

      i. find literature of how mathematics is typically taught (citation needed, look Pedagogy of the oppressed by Freire [he calls this the banking model of education. explain this. then claim that banking model is being used in majority of education], Radical equations by Bob Moses)

      ii. pedagogical developments (flipped classrooms (Mudd math), IBL (talk about Moore method. cite Brian Katz) -> all specific to math)

         A. laying of the land of what nontraditional mathematics education looks like in postsecondary institutions

      iii. gender inequity and underrepresentation / minoritization in math (AMS, CBMS, Sean Harper specifically about black male students, An invisible minority specifically about asian americans, Ursula Whitcher for women)

   - intro to self-paced assessment

2. **Mathematics is not fair**
   rethink the chapter title, mathematics in the context is not fair, mathematics is not neutral. what implications does this title have?
   (a) implicit bias by instructors
      i. Harvard implicit bias study (ok if it's broad)
         -give disclaimer that this may or may not be related to mathematics
      ii. John vs Jenny (implicit biases from minoritized is equivalent to those not)
   (b) structural biases by institutions (colleges and universities)
      i. access to resources, meals (textbooks, computers), private tutors, work and work study, trips home
      ii. few faculty of color and women (role models and impact on students)
      iii. few students of color and women (point to same resources as in introduction)
   (c) reliance on SAT's, especially in mathematics (how that correlates to parents' incomes, relate that to how universities are reliant on this score)
   (d) cultural obstructions to academic success*
      mathematics culture specifically
      i. Alice and Bob
      ii. cultural norms being imposed in the classroom (music, art, speech, dress); constructions by cis-het white male supremacy in mathematics **Rochelle Gutierrez, Danny Martin, Nicole Joseph, Luis Leyva, Belle Hooks**
         A. Oppression / Anti-oppressive (specifically Kumashiro, Luis Leyva & Dan Battey - A Framework for Understanding Whiteness in Mathematics Education) - **Big idea: Current practice is biased against some and privilege others**
         B. Math education as a racial project / whiteness in math education - critical race theory, coming from legal practices (Danny Martin [racial project paper] as introduction, Battey/Leyva paper for specificity and giving framework; the checklist they provide, Nicole Joseph and her work on

white supremacy as a part of a foundation in the history of math education / intersectional approaches [feminism], brilliance of black girls as an axiom) - **Specificity on racial and ethnic justice**

C. Rehumanizing / decolonizing mathematics (Nepantla, mathematx from Rochelle Gutierrez, one way to say mathematics is unfair is to say current ways feel mathematics students and educators feel dehumanized, and how math education has been part of the settler colonialism project; hence can we shift the locus of control to do this?)

iii. Result – underperformance

- Societal norms and impact of socio-economical differences in US
  - use literature to substantiate this, do not create your own arguments (show causation, not correlation)
- Whiteness in mathematics, western mathematics (Kumashiro, Bishop)
- Implicit and/or systemic biases in action
  i. Microaggressions
  ii. Model minority myth
- Outdated practices
  i. Description of student demographics and historical changes/trends
  ii. Correlation between student performances and student demographics
  * need substantial evidence

3. **Self-regulation in mathematics learning**
   (a) Different types of learning
      i. Descriptions of mastery, inquiry (Moore method), flipped classrooms, group-based/active learning
      ii. Focusing on how each impacted student learning
   (b) Finding a commonality that can suggest a shift in the paradigm of learning
   (c) Suggesting how self-regulation can reduce unfairness in mathematics learning
4. **A case study in self-regulation**

(a) Introduction and description of self-paced assessments
(b) Qualitative description of setting and details of where and how the study took place
    i. Honor code, establishment of trust
    ii. Nature of course in study, number and demographics of students
    iii. Structural differences
(c) Data Analysis
    i. Tables and graphs of student backgrounds, performances
    ii. need to talk to Prof Williams
    iii. Qualitative student reports of differences in experience (Extremely important!)
    iv. in the context of health and wellness of students / describe Mudd
(d) Discussion
    i. Necessary adaptations and customizations that were
    ii. Scalability
    iii. Potential adaptations
    iv. Caveats and fallbacks of the case study
    v. What this suggests for us: a question to consider

5. Matias at SFSU, oral exams in Germany; thinking about scale

6.

Chapter 2

Introduction

2.1 Motivation

Before I begin, I ask you, reader, to consider my abbreviated description of my experience of mathematics education: a typical child sits in a classroom full of students, all who are told to practice and memorize the materials presented by the teacher; there are no stupid questions as long as they are relevant to the material at hand. As she attends her first classes in college, she again finds herself sitting in a classroom full of students, questions left unanswered "in the interest of time." She wonders whether the lecturer knows her name or even cares if she shows up at all.

Mathematics has always been a difficult subject for me. In large part, it is difficult because of how difficult it is to stay awake during lectures. Perhaps laughable, but it's true; I often joke that had it not been for my persistent parents' efforts and lifelong interest in the subject, I would have easily been an art major, which requires a lot more moving of body parts and far fewer listening to lectures. I am therefore not surprised when many of my peers express distress or dislike of math of any kind, or when in turn they express surprise to my liking of it. It is, in my experience, a difficult subject to learn to enjoy in the classroom.

I am therefore as baffled as I am frustrated with institutional traditions that exist as obstructions to effective learning, both of mine and my peers'. Forgetting for a moment that lectures are simply difficult to be interesting for over an hour, I, a female student of color, rarely see a figure for me to look up to or relate to. I have sat in numerous math lectures being the sole female student in the room, questioning where all of my fellow female math majors could have gone. I have shuffled through mathematics texts wondering when the last time I read a textbook from a female author of color was, never mind see a theorem named after one. Being Asian-American, I constantly question and face biases and stereotypes of Asian-Americans, many which make me take a second glance my pride and love for my ethnical identity.

This list can go on, and I'm not happy. I find that this system of learning which disregards the students in the picture is highly ineffective; the context in which mathematics lives in for people like myself is simply non-negligible in fostering a good learning environment.

This thesis is my attempt to bring some of the problems I see into light, as a way to expose the flaws and changes necessary in mathematics pedagogy, particularly in postsecondary education. Afterwards, I propose a question that takes into consideration a way that may solve a subset of these problems using a small case study at my own institution.

2.2 Background

2.2.1 The status quo.

The classroom setting that I described in the very beginning is an example of the "banking model" of education, named by Paulo Freire in *Pedagogy of the Oppressed* in 1968. Freire draws a metaphor between this style of education to a bank, where the teacher is the depositor and the students are depositories (Friere, 1968). The teacher's tasks are to "fill" the students of information, and the student's role is to simply accept this information, with no particular requirement to digest its contents further or apply additional context. Thus, under this model, a good teacher is one who can give as much as they can to as many students, and a good student is one who receives and regurgitates the most with precision.

Of the various problems Freire points out about this model, he particularly hammers down the notion that the banking model transforms students into objects that merely act as containers, devoid of critical or creative thought.

Friere is certainly not the only individual questioning the method of education utilized in classrooms today. Educator and psychologist Donald Bligh presents in his book, *What's the Use of Lectures?*, rationale for why traditional lecture style classrooms are ineffective and outdated, supported by an exhaustive collection of studies (Bligh, 1998). His ideas are not new either, compiling hundreds of studies conducted on this topic and relating theories from many other educators. Most notably, he cites the work of Benjamin Bloom, also a professor known for proposing and driving experiments on mastery-based learning (Bligh, 1998).

Despite the existing literature about the flaws of the traditional system, there have been resistance against change, in large part due to the impracticality and difficulty of bringing changes into fruition. Take for instance educator Bob Moses, who saw struggling students in mathematics and created a nontraditional way of teaching algebra, called the Algebra Project. In his book, he describes the experience in spreading this idea across middle schools in Boston as an "uphill slough" (Moses, Cobb, 2001). He was turned down by principals for reasons ranging from teachers claiming that student skills not being up to par to stating that it would be too difficult to transition from the traditional approach.

Moses' experience goes to show that there exists resistance towards change, and isn't uncommon in middle school classrooms. Thus it is unlikely that postsecondary mathematics in America has changed since a century ago. In fact, I claim this lecture-based, transmissive style of education still dominates mathematics classrooms today. A Google search for "changing higher education" returns a plethora of articles responding to recent student strikes advocating for change in policies regarding finances and other economic concerns. In contrast, a search for "changing K-12 education" returns a 20-page ERIC (Education Resources Information Center) document on curriculum reform and effect on entering post-secondary institutions. It was only in 2014 when an official committee by the name of Transforming Post Secondary Education Math was formed to in part discuss using a variety of instructive methods in the classroom (Holm, 2016).

In some ways, the formation and existence of this committee reflects the persistent push for change and experimentation of different methods of instruction.

2.2.2 Pedagogical methods

Throughout the 20th century, a variety of pedagogical methods came into trial across subject areas and institutions. Specifically in regards to postsecondary mathematics education, methods that have been explored include the following.

Flipped classrooms

This method of instruction involving an inversion or a "flip" in the classroom is best described as placing the students in a setting where the lectures are given outside of the classroom, and activities meant to be more meaningful for the learning experience take place inside the classroom (Zappe, et al., 2009). These activities, ranging from group work to solving tutorials to leading workshops, are often described as active learning and have been shown to significantly improve student performance in science and mathematics (Freeman, et al., 2014). There are ongoing studies on the effects of flipped classroom being done in undergraduate engineering and mathematics settings (Yong, et al., 2015).

Inquiry-based learning

The Moore Method of teaching, which departs entirely from lectures and turns to having student-led classes that required the work in proving theorems and concepts be done by the students, was both hailed for its innovative ways to foster learning and criticized for unaccounted fallbacks and impracticalities with broader audiences (Parker, 1992).

Seeing ways he could improve the method, David Cohen introduced and experimented with the Modified Moore Method within mathematics classrooms, where he looked to reduce the downsides of the Moore Method while maintaining its intentions and benefits (Cohen 1982). Inquiry-based learning (IBL) stems here, particularly relating how students can learn actively through questioning and creating arguments independently (Yoshinobu, 2013).

IBL in postsecondary mathematics have recently received attention as they appeared in discussions and examples presented in an issue of *Problems, Resources, and Issues in Mathematics undergraduate Studies* (Katz, 2017). Various examples that appear in this issue of IBL studies, which were run on various student bodies and subjects, bring up notable questions and results.

A focus on self-regulation

Educator and psychologist Benjamin Bloom developed mastery-based learning, which expects students to have complete or near-complete mastery of concepts before proceeding further into the material (Bloom, 1968). Over the years mastery learning has taken on many variations, some more successful than others, but all focus on individual pacing and developing autonomy in a student's ability to learn. The biggest takeaway from studies done in mastery learning is the positive impact it has on students despite how much it differs from traditional methods of teaching (Zollinger, 2017, Bradley, 2017).

Self-regulation is not a method but a vital piece of mastery-based learning that asks students to identify and understand their own progression in learning. A focus that requires and trains meta-cognitive skills in learning mathematics can be useful in enabling students to grow independence and attain ownership of their own learning. Furthermore, rather than introducing large stylistic changes to the classroom, bringing in a focus of self-regulation can be relatively easily accomplished compared to flipped classrooms or IBL (Montague, 2007). In mathematics, self-regulation has not been explored as explicitly as the other two methods, but

Incorporating the ideas of self-regulation, detailed further in a later chapter, this paper proposes a possible way to change classroom dynamics using self-paced assessments.

2.2.3 Inequity and Underrepresentation

Postsecondary mathematics also faces issues of underrepresentation in gender and race, in particular shown by the percentage of degrees awarded in mathematics. Below are tables (2.1, 2.2) with data from the most recent 2015 survey conducted by the Conference Board of Mathematical Sciences (Blair, Kirkman, Maxwell, 2018).

Department	Men	Women	Total
University (PhD)	3431 (68%)	1645 (32%)	5076
University (MA)	1436 (51%)	1365 (49%)	2801
College (BA)	2529 (51%)	2388 (49%)	4917

Table 2.1 Number of degrees awarded in all mathematics majors, categorized by gender and department during July of 2014 to June of 2015.

What is most notable from the number of degrees awarded is the sharp decline in the percentage of women receiving PhDs than men compared to the percentage of MAs and BAs awarded. Table 2.2 further shows there exist fewer women, regardless of ethnicity, in tenured faculty positions overall which diverge even more from the numbers of PhDs awarded. Exploring the reasons behind why such may be the case calls for a paper of its own.

Department	Asian	Black	Hispanic	White	AIAN/ NHPI*	Unknown
University (PhD)						
Men	15	1	3	55	0	2
Women	5	0	1	16	0	1
University (MA)						
Men	11	2	3	46	0	2
Women	6	1	1	26	0	1
University (BA)						
Men	6	2	1	53	0	2
Women	4	1	1	30	0	1

*American Indians and Alaskan Natives / Native Hawaiians and other Pacific Islanders

Table 2.2 Percentages of full time faculty members belonging to various ethnic groups by gender and by department as of fall 2015.

The facts here show underrepresentation of women is certain.

Looking specifically at ethnic groups, the numbers show an overall evidence of minoritization of non-white faculty for both genders. We explore how this could potentially impact mathematics education in the next chapter.

2.3 Self-paced assessment

Chapter 3

In context, math is not fair.

The title of this chapter may be confusing. What do I mean when I discuss fairness in mathematics?

Far too often, I grew up hearing and thinking that math was neutral; that unlike in literature or social studies, the instructions told you $1 + 1$ was always 2, no matter who you were or what you believed in.

As Friere discusses, the role a student typically takes in a traditional classroom is to act as a container that simply accepts information and regurgitates out appropriately (Friere, 1968). The system disregards fostering the capabilities of a student to process and apply independent thought, and the instructor is not expected to have their students be able to do so, either.

A student, however, is not a memorizing machine. There is always context outside of the paper that definitely affects the way a student perceives and performs in mathematics, particularly in the college or university level. With biases and implicit obstructions that exist in ways to curb student achievement, mathematics education is not fair in various ways that I'd like to look at different levels of society.

3.1 Implicit Biases by Instructors

If there is one individual that interacts and directly impacts a student, it is the instructor of a class. Hence, if an instructor were to hold preemptive opinions or biases that pertain to particular students, no matter how subconsciously, this may impact their preferences for or against certain students and their performances. Specifically, this proposition comes from the Harvard implicit association study, which essentially showed how people could hold biases or preferences without explicitly portraying them using a test that detected differences in reaction speeds to making adjective-subject associations.

Using this test, a study done in 2015 showed that male scientists had a tendency to associate science with males more than female scientists (Smyth and Nosek, 2015). In fact, this discrepancy was the greatest with associating males with engineering and mathematics, exceeding 0.8 standard deviations. This then possibly implies that male professors are likely to hold a stronger association between male students and mathematics. Referring back to Table 2.1, where the percentage of full time female faculty members was less than that of male members, this further suggests bias that a female student may be subjected to during her career.

In fact, a study conducted in 2012 showed that science faculty, regardless of gender and race, preferred male students over female students (Moss-Racusin, et al., 2015). The study involved using two nearly identical fictional individuals and seeing who was more likely to be hired as a laboratory manager. The only difference was their implied gender, deduced by the names "John" and "Jennifer." Despite all other attributes being identical, there was significant preference for hiring John; participants scored him higher than Jennifer on all marks on average.

These studies present a strong case for how instructors may hold presumed assumptions towards certain students in mathematics. Certainly what this implies is that if this were true, students subject to negative biases must work harder than their counterparts to impress or succeed and must have more discipline to remain in the field despite possible opinions being held against them.

Furthermore, if female students are already minoritized in the status quo, it manifests a vicious cycle that likely feeds biases against them, which in turn makes it increasingly difficult for such students to remain in the field. Called "stereotype threat," consequences can result in lasting effects on the environment for women in mathematics (Spencer et al., 1999).

An important example of stereotyping and implicit biases taking action is actions of microaggression, which describes any seemingly small behavior, including unvocalized assumptions, that relays hostility or prejudiced views towards a marginalized group, unintentional or not. When unnoticed or ignored, microaggressions towards ethnic minority groups feed racism, fueling a mindset that only continues to be confirmed as a correct one. As a result, impacted students fall further into the mindset of feeling less capable in the classroom.

3.2 Structural Biases by Institutions

To begin discussing how postsecondary institutions present biases against students, an understanding of how students are filtered into these institutions in the first place must be established. For a typical high school student in the US, a standard college application requires SAT or ACT scores that often are used as a metric to determine admission into the school.

The problems associated with using this score have been analyzed again and again; in particular, studies show how it tends to hold advantages for already privileged students (Buchmann et al., 2010). In mathematics, female and black students tended to score lower than male and white students, which also in turn pose more stereotype threats towards these students (Jencks, 1998). This means therefore that students admitted into notable colleges were subject to institutional biases before even setting foot on campus, which then affect their opportunities further down the road.

Even if students were to be admitted into schools, they may face roadblocks and unfairly provided opportunities at the institution. Far often then not, students are expected to be at some financial standing that enable them to have not only resources like textbooks and computers, but also essentials like meals. There exists an assumption that students can afford certain amenities or at least have ways in which they can provide the necessary costs, be it through work or loans.

This presents a bigger problem between racial identities and socioeconomic differences. The 2007-2011 census provides enough quantitative evidence of the existing, unequal distribution of poverty among different races. American Indians and African Americans came in the highest at about 26% of the population being in poverty, more than a double in comparison to the 11.6% of whites (Macartney, 2013). A 2018 New York Times article showcasing a megastudy conducted on white and black men showed that of the 5,000 white and 5,000 black boys who grew up in poverty, 48% of black boys grew up to remain in poverty and only 2% grew to be rich, while 31% of white boys remaining in poverty and 10% became rich (Badger, 2018).

Objectively, this means it is likely there are more non-white students thinking about and suffering from financial difficulties than their white counterparts. It's simply not fair to expect the same degree of achievement from students that need not think about running out of money by the end of the week to those that do. In 2013, enrollment percentages in postsecondary education showed about a near 10% difference between white (42%) and black (34%) students (Musu-Gillette, 2016). Graduation rates were similar, lowest for black students at around 41%. These numbers dip down further for STEM (Science, Technology, Engineering, Mathematics) degrees, about 11% apart.

The 2015 study conducted by the Conference Board of Mathematical Sciences showed that 71% of full time mathematics professors at PhD awarding universities were white, compared to 1% black and 4% Hispanic. 22% of total professors were women, of which 16% were white; approximately 0% were black and 1% Hispanic.

What this means for students of color sitting on the other side of the podium is a definite disparity in the number of professors that share their racial background. This lack of having a proper role model impacts the belief a student has that they can succeed, otherwise known as self-efficacy (Thevenin, 2007). With lowered self-efficacy comes lowered achievement, unsurprisingly (Motlagh, 2011). Once again, we see how the question of how these unfair societal norms factor into reducing the quality of education or effectiveness of education a student receives is rarely raised.

3.3 Cultural Obstructions

When stating that there are cultural obstructions that exist to contribute inequity in mathematics education, it is not to say that the action of finding a derivative is somehow racially charged or unfair to a specific group of people. Rather, the way institutions teach a mathematical concept and the myriad of assumptions made in the process shape the role mathematics takes in our society.

3.3.1 There is oppression.

Specifically, I contend that current practices in mathematics is biased against some and privileged against others. In his paper on anti-oppressive education, Kevin Kumashiro outlines ways in which oppression exists in classrooms today that works against "the Other," referring to traditionally marginalized in society, and discusses how to bring about anti-oppressive approaches to education, examining strengths and weaknesses of each (Kumashiro, 2000).

What Kumashiro discusses includes understanding the need for education for and about the Other, education that is critical of privileging and othering, and education that works to bring change in students and society. He points out that oppression in all four of these flavors comes from the underlying belief that "normal" equates to cis-gendered, heterosexual white men. Furthermore, a flawed and misleading understanding of the Other perpetuated by stereotypes add to further setting normalcy away from the Othered. In this way, he points to how whiteness has served in projecting mathematics as a "neutral" subject. As Rochelle Gutierrez writes on how mathematics assumes to have no "color" or cultural associations:

> [In] many mathematics classrooms, students are expected to leave their emotions, their bodies, their cultures, and their values outside the classroom walls, stripping them of a sense of wholeness (Gutierrez, 2012).

3.3.2 This is a racial project.

Mathematics is historically not led uniquely by white Europeans. Prominent advancements were made by individuals from all over world. But when I ask fellow math majors for names of famous mathematicians, what I hear are not Srinivasa Ramanujan, Hypatia, or Dorothy Vaughn; but Euler, Pythagoras and Fermat. The problem in question lies exactly here–whiteness is rarely questioned in this context of mathematics. Perhaps then a valid question to ask is, why has mathematics education been so predominantly white?

Danny Martin attempts to answer the question by discussing the deliberate and prevailing racial agendas that use mathematics education as a tool aligned with sustaining a white framework in society, particularly in attaining market-oriented goals (Martin 2012). He describes beyond what statistics describe of underrepresentation in mathematics; analyzing literature that is meant to promote mathematics education reform, including Friere's *Pedagogy of the Oppressed*, stays vague and removed from describing race and racialization in the picture.

Furthermore, he argues that mathematics education has aligned in keeping whiteness in control because it has been able to stay away and immune from possibilities of being racially charged or placed under racial politics. The way in which this was possible, he describes, is the existence of white institutional spaces that conform to particular characteristics:

> (a) numerical domination by Whites and the exclusion of people of color from positions of power in institutional contexts, (b) the development of a White frame that organizes the logic of the institution or discipline, (c) the historical construction of curricular models based upon the thinking of White elites, and (d)

the assertion of knowledge production as neutral and impartial, unconnected to power relations (Martin, 2013).

Many points made previously directly support how white institutional spaces exist and have existed in society today; domination in number by white professors, curricular concepts based on and named off of historical white mathematicians, and implications that there are no relations between mathematics in societal and racial constructs. If these four points do manifest in reality, Martin's claims suggest the deep-rooted locus of power residing in whiteness and calls for the need to critically analyze institutions.

While these points of indication are clear, they are broad. Thus in fulfilling the need for specificity and examples, Dan Battey and Luis Leyva describe these characteristic indicators of such spaces by breaking down into specific areas:

Dimension	Elements
Institutional	Ideological Discourses
	Physical Space
	History
	Organizational Logic
Labor	Cognition
	Emotion
	Behavior
Identity	Academic (De)Legitimization
	Co-construction of Meaning
	Agency and Resistance

Table 3.1 Framework of Whiteness in Mathematics Education. A more detailed breakdown of each dimension is detailed in their paper (Battey and Leyva, 2016).

This table outlines a way in which institutions can use to check whether whiteness is being perpetuated, and how so. But an even better understanding of how mathematics has continued to be used as a tool of racial and ethnic justice is through an example. Nicole Joseph uses these characteristics to identify and recognize how white institutional spaces influence the mathematics learning of black female students (Joseph, 2017).

In particular, she describes how critical race theory permits the claim that mathematical spaces are not neutral. Critical race theory, which stems from legal backgrounds, serves to present a model that recognizes inequities in race and challenge existing predominant ideologies (Solorzano, et al., 2000).

3.3.3 It is possible to change.

In this light, remodeling education to eliminate inequitable practices in mathematics seems a daunting task for any one nation, let alone an institution, to tackle. For all four educational approaches presented in his article, Kumashiro argues that there needs a prominent desire for change for any change to even occur (Kumashiro, 2000).

Chapter 4

Self-Regulation

4.1 Definition

This is the definition of self-regulation provided by Zeider, Pintrich and Boekaerts' *Handbook of Self-Regulation*:

> Self-regulation refers to self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals (Zeider, et al., 1999).

This can be broken into two parts. First, it focuses on self-generation, indicating the necessity for an individual's own efforts and thus emphasizing power in the self. That way, the generated thoughts and actions can be structured to their own goals and needs, not those of the society or instructor. The word "cyclically" should be underlined here, as it points out how the process can be a self-sustained one, reinforced by practice and initial support.

Adopting a focus on self-generation of thoughts and actions which lead to attaining personal goals is a statement describing the achievement of power. In a typical classroom setting composed of a single instructor and a group of tens to hundreds of individuals, there exists a power dynamic. The instructor is given an unchallenged amount of control over the students' actions and knowledge.

Thus, promotion of self-regulation will accomplish two parts for students: one in which the process of self-generating their own thoughts and actions will shift the locus of power away from being centralized at the instructor, and two in which the learning experience can be shaped to fit personal needs and goals, instead of generalized versions often presented in traditional classes.

To begin looking into how the core ideas of self-regulation came about, mastery-based learning is a fit place to start. Simply put, mastery learning seeks to incorporate individualized pacing of progression through the course material. Developed by Benjamin Bloom, mastery-based learning expects students to have complete or near-complete mastery of concepts before proceeding further into the material (Bloom, 1968). Over the years mastery learning has taken on many variations, some more successful than others, but all focus on individual pacing and developing autonomy in a student's ability to learn. The biggest takeaway from studies done in mastery learning is the positive impact it has on students despite how much it differs from traditional methods of teaching (Zollinger, 2017, Bradley 2017).

As shown with the many studies done of the impact of mastery learning, self-regulation is a foreign concept in traditional instruction. Thus, how or why self-regulation should be a part of school does not come easily to most educators, nevertheless students, today. For a large part, if not all, of a young student's life in academics, the classroom is where they are instructed to do one thing or another. Report cards and other assessments and evaluations are the only sources of feedback.

For college and postsecondary education where classroom sizes go upwards to hundreds and even thousands of students, the feedback received is rarely refutable, with chances to improve given once or twice a semester when a midterm is returned.

In particular, mathematics education is rarely in the form different from the lecture-recitation style classes. Seminar or discussion-heavy classes are generally unheard of, let alone calling on students for participation in any shape or form. With bigger classes, asking questions in itself becomes a challenge, often perceived as being a waste of lecture time; practically impossible if the lecturer spares zero opportunities for questions. Truly, the conversation is one-sided, with little or no reception from the students' in their understanding.

In this status quo, it is unthinkable to "personalize" a course to meet a particular student's needs. More so, students have few chances to champion for themselves what they were lacking in the education they received. It is hardly reasonable to claim that one form of learning is the best way for every student to achieve success, as will be discussed in further detail later in this paper.

Looking only in terms of providing individual attention for academic achievement, attempts so far include remedial classes. Unfortunately, these often further reduce self-efficacy in underachieving students, as the students are singled out and required to take these extra classes under the description that they are struggling or behind, increasing both physical and mental stress factors (Martin, 2017).

Nevertheless, self-regulation takes many different forms and can be adapted to any type of classroom. In both methodology and focus, self-regulation can be incorporated at small or large scales. Detailed below are some (but certainly not all) ways in which self-regulation can take place in instruction (Montague, 2007). In addition, self-regulative strategies will often encompass a mix or overlap of the listed forms, thus none are mutually exclusive of another.

4.2 Self-Assessment and Evaluation

Self-assessment and evaluation can be pertinent to either qualitative evaluations of cognitive skills related to work ethic and habits or quantitative assessment of knowledge on concepts. The goal of most self-assessment and evaluation methods circles around helping students practice independent realization of their own necessities and strengths in learning, and hence increase self-efficacy as well as a feeling of empowerment.

Evaluating work practices in mathematics can be achieved through a variety of ways, including worksheets that ask students to outline how they did certain problems, reflection assignments that encourage students to evaluate their own weaknesses and strengths, and checkboxes to ensure certain practices were done (Montague, 2007). Such metacognitive processes can help students find and understand for themselves where they can improve in a way that doesn't explicitly expose particular weaknesses to their peers or instructors.

In recent years, self-assessment of course material and knowledge recollection is sometimes found in form of online-based classrooms, which reduces the work load of instructors to grade and follow through with each individual's assessments, as well as prevent academic dishonesty. However, the nature of online based learning is that a computer and a reliable internet connection is a luxury that students should not be expected to have, especially when equitable practices are in concern, as mentioned before.

A section below outlines more specifically the kinds of self-assessments that can accurately aid student learning and provide ways the reduce unequal power dynamics. Moreover, the case study found in this paper describes one specific example of self-assessment that seeks to implement a fair way to provide student autonomy and improve self-efficacy in college mathematics. Once again, the goal of any method should be to increase empowerment of students and reduce inequitable practices, thus it is key to think about the benefits and fallbacks of everything discussed below.

4.2.1 Self-Instruction

Self-instruction looks into empowering students to learn the material on their own, thereby also instilling the belief that they are capable. Naturally, there is some risk associated to self-instruction, and therefore is often paired with supplementary activities or practices that solidify or clarify learning.

Examples of self-instruction cross an entire spectrum of student independence in the classroom, from full-autonomy where students decide what should be covered and how, to partial-autonomy that expects students to learn the material provided by an instructor (Burris, 1972).

Recently, self-instruction in mathematics has taken form via flipped classrooms, in which the learning of material is done outside of the scheduled class time through slides and recorded lectures (Lage, 200). This type of instruction reserves space and time for students to spend class time on group activities and more in-depth discussions of mathematics beyond the surface level of concepts, but also increases responsibility on the students to learn the material correctly on their own.

4.2.2 Self-Monitoring

Self-monitoring is similar in nature to the other self-regulation forms, but focuses more on providing immediate feedback. In mathematics, a checklist of commonly found errors are provided for students to check intermediate steps while solving problems (Dunlap, 1998). The checklist is subsequently personalized for each student as mistakes are made, and eventually they were removed as a form of assistance. Results from some studies showed an increase in achievement (Dunlap, 1998).

There are obvious challenges with this form of self-regulation, as it poses massive workloads realistically impossible for teachers or instructors. Furthermore, such a checklist is often difficult to formulate for mathematics classes above introductory, more computational courses. It is important, still, to see the benefits of introducing students to metacognitive methods such as creating a checklist on their own to aid their learning.

4.3 An example of self-assessment: self-paced assessment.

While all of the various ways self-regulation that takes place in the classroom has benefits, self-assessment of course material has tangible and scalable opportunities that touch upon self-instruction and self-monitoring as well. More specifically, self-paced assessment allows for the students to take control of the pace they are expected to learn the material.

The idea behind self-paced assessment is as simple as its name sounds. All assessments are conducted by the students on their own time and in their own choice of setting. Of the many stressful factors students are exposed to in college, examinations are one of the most prominent sources of stress. Students are expected to cover a hefty chunk of the course material and regurgitate it coherently within a set amount of time. In a traditional setting, all students in the course are asked to have the material digested by the time the exam is given to a level where basic concepts can be extended to applications. There is no chance or way to show that improvements can be made after exams are taken–in other words, a one-time assessment is the determining factor of a student's understanding of the material.

Described in this way, it is rather ridiculous as to how traditional methods of assessment and instruction are considered fair and accurate ways to judge the complex and multidimensional understanding of material students can have. In particular, examinations rarely ask for furthering of knowledge; in mathematics, the demand for using the creative process is simply left out in most exams despite how critical, creative thinking is necessary for mathematical research and exploration.

Self-paced assessment seeks to remedy a solution to some of many issues with traditional methods of teaching. For one, instead of one large assessment that covers weeks to months of material, multiple smaller assessments will ultimately achieve the same goal of checking the state of students' understanding while entirely removing the stressful factor of having to review and cram large amounts of material at once.

Second, students are relieved of the burden of having understood everything on a strict schedule. Individual styles and paces of learning is entirely ignored in the status quo, despite just how vastly spread out these can be (Busato, 2000). The only expectation is that students are to complete the set of assessments by the end of the course. It is expected that the assessments would be handed out on a timely manner when the material being assessed is covered, but it is not expected that the student would be prepared at that moment to be tested on it. Having the independence to be able to take the assessments at their own pace is essentially how self-regulation takes a role here.

Third, students will have a chance to retake these assessments if they feel as though they were not sufficiently prepared or think that they did not fully comprehend the material upon taking the assessment. Penalizing students who simply made an algebra mistake or could not finish an assignment that covered an important concept are simply unfortunate events that should not be deterministic of a student's achievement in the course. Rather, it should be encouraged for students to self-evaluate and test where they are in the course and use the retake opportunity to their advantage to figure out where they are lacking and where they are strong. This not only removes the unnecessary time spent on reviewing material a student may be already strong on, but also creates efficient study habits that builds metacognition.

Self-paced assessment as described here relies heavily on trust between students and teachers. Often in pop culture students are compared to prisoners, both groups of individuals under complete control, following a rulebook of a system set in stone. Though it sounds extreme, students from a young age are praised for following directions and punished for acting out. Eventually those who "succeed" in school are those students who were most obedient and studied what was given to them, without question. The snowball effect goes the other way as well, in which incriminating or humiliating students for some actions and grades lead to building further negative associations to school, reducing their desire to learn or participate.

Thus, giving students control over their own learning is essentially an action of giving students trust. If a snowball can form in one direction, the other direction is no different. Construction of trust in each other can work to flatten the strict hierarchy that exists today. Particularly for higher level postsecondary institutions, students are impending members of academia and society at a level of maturity that deserves trust, and subsequently, equity in power in the classroom. Trusting that students can be responsible for their own learning leaves greater individual impact that in turn affects how society views education.

As a more explicit example of how self-paced assessment can be implemented is explored in the case study.

Chapter 5

The case study

5.1 Introduction

Enter the US College Education: projector screens, chalkboards, individual desks, and syllabi stating exact dates to assignments and exams. Despite the 200 or so liberal arts colleges in the US, the variety of student experience is almost nonexistent. In any of these colleges, large lecture halls are ready to be filled with hundreds of students for them to watch a single professor or instructor. Whether a thousand-person introductory course or a ten-person advanced class, a student is expected to consume the material and spit it out, correctly. This is not to ridicule the efforts of certain colleges that are trying to actively reform education, but still the vast majority has remained stagnant.

The case study was designed as an attempt to show direct effects of making a small change and adding an element of self regulation in a mathematics course. To do so, self-regulated, self-paced assessments were put in place of midterm and final examinations.

5.2 A (not so) brief note on Mudd

To understand how self-paced assessment fit into the classroom in this case study, it is critical to note the nature of the college in study as well. Harvey Mudd College is a small liberal arts college with about 800 undergraduate students, located an hour from Los Angeles. The College focuses primarily on 6 departments in STEM, where all students are required to complete at least two semesters of coursework in each department, referred to as the Common Core. Particular traits of this school make the self-paced assessment ideal in achieving desired results in self-regulation.

The Honor Code

Mudd, short for Harvey Mudd College, places great importance on its Honor Code, which is maintained by students for students to be responsible for integrity in actions for all academic and non-academic affairs on campus. The Honor Code is not decided by faculty nor administration but created by the students and respected by all parties of the College. In many ways, it is a bridge to securing trust between one another that allows for more freedom and power for students as an active member of the College community.

As humans, students are not perfect abiders to the Honor Code. Violations are dealt with by students as well, determining consequences and punitive measures under student government. To further reinforce trust that may be lost with such violations, the practice of self-reporting is put in place such that students are able to admit their own fault, instead of being the accused.

This explanation is necessary to understand what ways trust can be placed in students. Of the various privileges that come from securing the Honor Code are take-home assessments, which are, as the name states, regular examinations that are typically handed out for students to take at their own leisure, "at home." Students are expected to take no more time than given, as well as not refer to any external materials if the exam is closed-book. This is all expected under no other supervision than the student's own consciousness.

The math department is no exception, either. Take-home exams are a part of nearly all courses, most professors see the value in not letting time or location be a factor in assessments. With the culture at Mudd, students who were asked to take take-home assessments, multiple times, were trusted to do the right thing.

5.3 Method

This study focused on a mandatory introductory linear algebra course, all 24 students being first year students. There were 8 total sections of the course across 4 different instructors, each who taught 2 of these sections. As a method of control, one of the sections from one instructor underwent the study, while the other section from the same instructor remained unchanged.

For ease in distinguishing the two, the changed section will be dubbed the "quiz section" and the unchanged section will be the "control section."

The 24 students of the quiz section did not have any midterm or final examinations. Instead, students were required to finish a total of 10 small assessments, or quizzes, by the end of the course. All 6 closed-book, closed-notes assessments consisted of one or two questions that pertained to the knowledge of the material, and students were expected to finish each within 15 minutes. All quizzes were self-paced and take-home, meaning students had autonomy over when, where, and how they wished to take these assessments.

Homework assignments remained identical to the other 7 sections, and instruction was similar for the two sections under the same instructor. Students were not given the choice to opt out, other than to switch into a different section. No students in other sections were allowed to switch into the section in study.

Students in both sections were asked to fill out a pre-survey during the first week of the course asking for information like demographics and high school math backgrounds. After the course ended, the students were asked to fill out a second survey and participate in focus groups for qualitative feedback.