On Self Regulation in College-Level Mathematics Classes

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Abstract

This thesis investigates the need for improvement in mathematics education at the college level in the US regarding equitable practices in instruction. In particular, it 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 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.

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Chapter 1

Introduction

1.1 Motivation

Before I begin, I ask you, reader, to consider my abbreviated description of my experience of mathematics education: I sit in a classroom full of students, all who are told to practice and memorize the materials presented by the teacher. I have questions about why a formula looks the way it does. My teacher does not answer; he thinks it's not relevant to the class. In college, I again find myself sitting in a classroom full of students, my questions left again unanswered "in the interest of time." I wonder sometimes whether the lecturer knows my name or even cares if I show up at all. I go on to take an advanced toplogy course. There are three women, including me, and at least ten men, in the first class. By the end of the semester, I'm the only woman left, with at least ten other men.

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. In my college math lectures, professors cover proofs of some theorems and write down some definitions. If at any point I were to doze or be distracted, I would have a harder time following for the rest of the lecture, trying to play catch-up from one point to the next. If I don't make the necessary connections and absorb the important concepts right then and there, I feel behind and lost. In worries that I'll fall even further behind, I dare not look around to see how my peers are doing, or to question

the validity of what I'm being taught.

In stark constrast, I've never fallen asleep or felt like I was behind in classes that are participation-based or seminar-based. Even the way students sit in the class is different. As opposed to rows and columns facing the board, desks are arranged in rough circles that have everyone face one another, so as to encourage voices from all directions, not one.

I am therefore as baffled as I am frustrated with how traditional lecture-based classes seem to prevent effective learning. Forgetting for a moment that, personally, lectures are simply difficult to be interesting for over an hour, I, a woman and 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 woman 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 at my pride and love of my ethnic identity.

I find that this system of learning which disregards the students in the picture is highly ineffective. The social, historical, and economical contexts in which mathematics takes part in for people especially 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 look into self-regulatory methods in teaching, and in particular, I study self-paced assessments as a tool for equity in mathematics education. Using a case study done at my own institution to see the outcomes of self-paced assessment, I raise some points of discussion about future applications.

1.2 Background

1.2.1 The status quo.

The classroom setting that I described in the introduction 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 emphasizes 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. 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 need for improvement in the traditional systems, change has been slow going, in large part due to the 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. In many respects, postsecondary mathematics in America has not changed since a century ago. For instance, white male instructors still teach lecture-based courses with weekly homework assignments and two or so exams.

1.2.2 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

Inquiry-based learning (IBL) describes a broad area of educational methods that focuses on student-driven instruction in the classroom. Most notably, IBL looks into how students can learn actively through questioning and creating arguments independently (Yoshinobu, 2013). Though IBL has been experimented on and researched at many different institutions for varying disciplines, it has also been involved in improving post-secondary mathematics.

One way IBL is used in postsecondary mathematics is the Moore Method, or Modified Moore Methods. In short, the Moore Method looks to have students prove theorems from scratch with minimal instructor intervention (Parker, 1992). Created by Robert Lee Moore, this method saw fallbacks in courses other than introductory topology (which is where the method was used initially), and Moore himself received a lot of criticism for forbidding African-American students to take his classes and holding misogynistic and anti-semitic viewpoints, perhaps suggesting that his method would specifically benefit white men (Ross, 2007). Modified Moore Methods were developed and introduced in an effort to reduce some of these points of improvement (Cohen, 1982).

In 2014, a study conducted across multiple institutions with a focus to evaluate the benefits of IBL gave more insight into how students ultimately fared due to IBL (Laursen, et al., 2014). Results showed that IBL removed previously seen gender gaps that disfavored women. More recently, 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). While self-regulation in mathematics learning has not been explored as explicitly as the other two methods, elements of self-regulation are present and can be found.

Exactly how incorporating the ideas of self-regulation is possible is detailed in a later chapter. In specifics, this thesis proposes a possible way to change classroom dynamics using self-paced assessments, which attempts to alter one aspect of mathematics classes for a more effective and less stressful learning experience using self-regulative practices.

1.2.3 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 (1.1, 1.2) with data from the most recent 2015 survey conducted by the Conference Board of Mathematical Sciences (Blair, Kirkman, Maxwell, 2018).

What is most notable from the number of degrees awarded is the sharp

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

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

decline in the percentage of women receiving PhDs than men compared to the percentage of MAs and BAs awarded. Table 1.2 further shows there exist fewer women, regardless of ethnicity, in tenured faculty positions overall which diverge even more from the numbers of PhDs awarded. Underrepresentation in science and engineering as described by the National Science Foundation refers to a minority group whose number of scientists and engineers per 10,000 population of that group is substantially below the comparable figure for scientists and engineers who are white and not of Hispanic origin (United States Code, 2011). The numbers above show an example of underrepresentation of women in mathematics, a phenomenon that is important to take note of, but describing the reasons why such is the case is outside the scope of this thesis.

Looking specifically at ethnic groups, the numbers show an overall evidence of minoritization of non-white faculty for both genders. That the

presented data only respects the notion of binary genders also points to a possible lack of support and representation of genderqueer or nonbinary individuals. How this minoritization and underrepresentation could potentially impact mathematics education is explored in the next chapter where I discuss inequitable practices in mathematics education.

1.3 Self-paced assessment

There is no concrete, definite solution to the problem of how mathematics education has been unfair, benefitting only some and hence being ineffective for others. Yet, it is important to try to attempt and propose possible ways to alleviate and work towards what could better serve the current student population.

One attempt to do so is through implementing self-paced assessment, a method that takes from self-regulation and self-regulatory methods. Self-paced assessment takes elements from some non-traditional methods in postsecondary mathematics education that have been experimented on previously. Such include but aren't limited to mastery-based learning, flipped classrooms, and inquiry-based learning.

In describing how self-paced assessment can be run in a postescondary mathematics classroom, this thesis presents a case study conducted on a group of first year students taking an introductory linear algebra course at Harvey Mudd College, a small liberal arts college located east of Los Angeles. The results of the study propose a possible question of using self-paced assessments to take a step towards equity by trying to shift the locus of control to students and providing a more positive experience to reduce negative sentiments towards mathematics.

Chapter 2

Math is not fair.

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

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 additional context, both social and historical, outside of the classroom that definitely affects the way a student perceives and performs in mathematics, particularly in the college or university level. With biases and obstructions that exist in ways to curb student achievement, intentionally or not, mathematics education is not fair in various ways that I'd like to look at different levels of society.

2.1 Implicit Biases by Instructors

The one individual that interacts and directly impacts every student in a classroom is the instructor. 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 (Green, et al., 2007). 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 1.1, 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 face challenges that make it increasingly difficult remain in the field despite potential opinions being held against them.

For instance, if women are already minoritized in the status quo, it manifests a vicious cycle that likely feeds biases against them. Called "stereotype threat," consequences can result in lasting effects on the environment for women in mathematics (Spencer et al., 1999). In tests, women performed substantionally worse in tests when told that there were differences in achievement based on gender, compared to equally achieving men. Other experiments handling racial differences showed similar results; African-American subjects who were realized of how their race would perform prior to taking a test were more likely to perform worse than white subjects (Steele and Aronson, 1995). Procedures in both experiments included both explicit (direct, verbal delivery) and implicit (diagnostic surveys that served as stereotype-activation) ways of priming subjects of their identities and

related stereotypes. Regardless of procedure, subjects who were threatened by stereotypes performed objectively worse. This points to the possibility of how instructors imposing certain biases can actively impact students' performances.

Another 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 (Sue, et al., 2007). 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.

2.2 Structural Biases in Institutions

To begin discussing how postsecondary institutions present biases against some students and privileges to others, 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, about 95% of college applications require SAT or ACT scores, which imply that this score is often used as a metric to determine admission into the school (Morse, 2008).

The problems associated with using this score have been firmly studied and confirmed in research; in particular, studies show how it tends to hold advantages for already privileged students (Buchmann et al., 2010). In mathematics, women and black students tend 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 affects their opportunities further down the road.

Even if students were to be admitted into such schools, they may face roadblocks in accessing or utilizing certain resources at the institution. More often then not, students are expected to be have financial resources that enables them to have not only important academic materials like textbooks and computers, but also life essentials like meals. Many students experience stress and pressure to afford certain amenities or at least have ways in which they can provide the necessary costs, be it through work or loans (Ross, et al., 1999).

This connects to a bigger problem in the context of racial identities and socioeconomic groups. 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 study 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. Stress from life-related sources negatively impacts students' achievements in school (Andrews and Wilding, 2004). Thus, this gives reason to believe that students with financial difficulties are probably more prone to experiencing academic difficulties than those without. 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, with about 11% fewer black students graduating.

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. In addition, 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). Societal and economical factors that relate to academic achievement in these ways means they cannot be ignored when considering equitable practices in mathematics education.

2.3 Cultural Obstructions

When stating that there are cultural obstructions that contribute to 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, how institutions teach a mathematical concept and the myriad of assumptions made in the process shape the role mathematics takes in classrooms and eventually our society.

2.3.1 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).

Kumashiro categorizes the approaches to anti-oppressive education, including understanding the need for education for the Other, the need for education 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 (Kumashiro, 2000). 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).

2.3.2 Mathematics education 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 show of underrepresentation in mathematics by analyzing literature that seems to promote mathematics education reform but also contributes to the agendas by not going into detail the key position race and racialization takes in the picture.

Furthermore, Martin argues that mathematics education itself has aligned with these agendas 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 have existed and continue to exist 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 2.1 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 check whether whiteness is being perpetuated, and how so. But understanding how mathematics has continued to be used as a tool of racial and ethnic justice can be achieved through an example. In particular, Nicole Joseph uses these characteristics to identify and recognize how white institutional spaces influence the mathematics learning of black women (Joseph, 2017). Martin's notion of white institutional spaces come from critical race thoery, which stems from legal backgrounds, serves to present a model that recognizes inequities in race and challenge existing predominant ideologies (Solorzano, et al., 2000). Joseph describes how critical race theory permits the claim that mathematical spaces are not neutral. Her identification of how mathematics education has been unfair toward black women presents a concrete way in which individual students and their educations are affected under white institutional spaces.

2.3.3 It is possible to change.

I've thus far presented a problem in which inequitable practices in mathematics education are real and impact students. Remodeling education to eliminate inequitable practices in mathematics seems a daunting task for any one single institution, let alone an entire nation, 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).

As it is with any kind of change, there is resistance from the presiding body of power.

But Rochelle Gutierrez tells us there is hope. In her quote earlier she describes how students are "stripped away" of their sense of wholeness in the mathematics classroom, hence addressing an issue of how students are dehumanized objects in the classroom (Gutierrez, 2012, 2017). In discussing possible ways to "rehumanize" students, she emphasizes the necessity to recognize hierarchies in classrooms and shifting the role of authority (Gutierrez, 2018).

More broadly, Gutierrez's ideas are grounded in her theory of two axes that cross in describing dimensions of equity: Access and Achievement make up the dominant axis, while Identity and Power make up the critical axis (Gutierrez, 2009). The dominant axis describes what would determine a student's ability in mathematics, while the critical axis describe what would measure a student's ability to think critically of mathematics, perhaps bringing change. Gutierrez contends all four are needed to build an equitable mathematics learning environment. In particular, she describes the Access dimension being a "precursor" to Achievement and Identity to Power, which implies the two former need to exist and establish before the latter.

Thus, her proposal that moving the locus of power is one way in which the critical axis is being used–she brings the students' identities into the conversation. In the next chapter, we explore a way in which this can be done via self-regulation.

Chapter 3

Self-Regulation

3.1 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 amount of control over the students' actions and knowledge that is only sometimes challenged.

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.

The use of self-regulation in mathematics learning can be a driving force in achieving a change in perspective of mathematics in society, both by institutions and students alike. As I discussed in the previous chapter, it is important to keep in mind that the goal of self-regulation lies in rehumanizing students and bringing more equity in a postsecondary mathematics classroom.

3.2 Origin and forms of self-regulation in history.

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 likely does not come to most educators immediately. 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 given to students is difficult to refute or debate, especially when individual attention is hard to receive. Moreover, it could be that chances to improve one's grades are really given only once or twice a semester after midterm grades are posted.

This problem arises because mathematics education is rarely in the form different from the lecture-recitation style classes. Seminar or discussion-heavy classes in mathematics are generally unheard of, let alone calling on students for participation aside from asking for answers. 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 below.

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.

3.3 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 some self-assessment and evaluation methods revolves 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 solved 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 (Ventista, 2018). 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-regulation which seeks to implement a fair way to provide student autonomy by encouraging self-assessment of skills and improving 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.

3.3.1 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.

3.3.2 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.

3.4 An example of self-regulation in the classroom: using self-paced assessments.

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 assess their learning 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 (Abouserie, 1994). Students are expected to cover a large amount 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 sounds naive to trust that traditional methods of assessment and instruction are fair and accurate ways to judge the complex

and multidimensional understanding of material students can have. In addition, since examinations often act as a tool to give grades, which means questions that demand the creative process (such as open questions in the field) are likely left out to avoid vague, subjective grading. Despite how critical creative thinking is for mathematical research and exploration, if exams avoid asking such questions, students aren't able to practice necessary skills for furthering knowledge.

Self-paced assessment seeks to remedy some of many issues with traditional methods of teaching. For example, instead of one large assessment instrument 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 reduces 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. In pop culture students are compared to prisoners, both groups of individuals under complete control, following a rulebook of a system set in stone. Students from a young age are praised for following directions and punished for acting out (Inbar, 2006). 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. This phenomenon aligns with the school-to-prison-pipeline metaphor, which may further perpetuate negativity (Crawley and Hirschfield, 2018).

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 imminent 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 4

The case study

4.1 Introduction

Before getting into the details of the case study, let me introduce you to my experience of the US College Education at Harvey Mudd College: projector screens, chalkboards, individual desks and syllabi stating exact dates to assignments and exams. Despite the numerous liberal arts colleges in the US, variety of student experience is hard to find. 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.

As mentioned in the earlier chapter, the focus of the study was to see if positive change could be brought about in the status quo via self-regulation– specifically, through the use of self-paced assessments. 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.

4.2 Method

This study focused on a mandatory introductory linear algebra course, listed as Math 40, offered as a part of the common graduation requirements. Math

40 is typically a 7 week course, and historically assign students about 10 assignments and two exams consisting of one midterm and one final. There were total 49 students involved being first year students, and students were split between 2 sections randomly, taught by the same instructor. One of the sections underwent the study. The other section remained unchanged as a control. For ease in distinguishing the two, I will refer to the test section as the "quiz section" and the unchanged section as the "control section."

The 24 students of the quiz section did not have any midterm or final examinations. Instead, these students were required to finish a total of 10 small, one or two problem quizzes by the end of the course. All 10 closed-book, closed-notes assessments consisted of questions that pertained to the knowledge of the material that was taught up to the day of release. Students were able to retake these quizzes without penalty, but the ultimate grade of the quiz would be determined by the attempt with the highest score. There were no deadlines to any of these quizzes except for the final deadline at the very end of the semester. Students were also expected to finish each within 15 minutes. In other words, all quizzes were self-paced and take-home, meaning students had autonomy over when, where, and how they wished to take these assessments.

The control section took one midterm and one final exam as traditionally done, appropriately scheduled around half way and at the end of the semester. Homework assignments remained identical to the other sections, and instruction was similar for the two sections under the same instructor. There were no extra or additional assignments, nor were there fewer assignments, in any one of the sections.

There were six other sections of Math 40 being taught at the same time by other instructors, but other than the same material being taught, had nothing to do with the study. Students were not given the choice to opt out of the study while in either the quiz or control section, but could choose to drop or switch into a different section not part of the study. No students in other sections were allowed to switch into either sections in study.

Students in both sections were asked to fill out a pre-survey during the first week of the course asking for information including demographics, high school math courses, and family backgrounds. This survey also asked for self-confidence and assessment in mathematic ability, belief in the need for certain elements in creating an intellectual environment, and level of comfort in asking questions.

After the course ended, students were asked to fill out a post-survey, which included questions about students' perceived growth in mathematics

ability and confidence. They were also asked to participate in a Focus Group session for qualitative feedback using questions presented by a non-interactive individual not part of the study (neither I nor the instructor were present in the room).

4.3 Results

During the pre-test, students were asked for information on their demographics. Below, table 4.1 gives an overview of the students' racial/ethnic identities.

Section	Asian	Black	Hispanic	White	AIAN/ NHPI*
Control	6	0	5	18	3
Quiz	7	5	8	16	0

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

Table 4.1 Number of students per each racial/ethnic group. Total is greater than sample size (accounting students of mixed race).

Overall, the pre- and post-surveys found little statistically significant evidence of differences between the two sections. Qualitatively, there were notable differences in descriptions of the experience in the course; in particular, many students in the quiz section noted a lower level of perceived stress.

Using $\alpha = 0.05$, two-tailed t-tests were run on the differences in averages were taken regarding student scores of self-assessment of math knowledge and self-perceived growth in confidence and knowledge of mathematics.

1. H_0: Students self-assessed scores their math did not change (before = after).

Students were asked to assess their own knowledge of mathematics in both the pre- and post-surveys. Table 4.2 shows the difference in averages of how students assessed their knowledge before and after the class.

In both sections, the hypothesis H_0 was not rejected.

Section	Before	After	Difference	p-value
Control	3.164	3.160	0.024	0.890
Quiz	3.136	3.208	0.0720	0.652

Table 4.2 Differences in average of how students rated themselves on self assessment of math knowledge (lower value indicating lower score).

2. H_0: Students perceived their growth in mathematical knowledge eqally in both sections (quiz = control).

Students were asked in the post-survey of their self-perceived growth in mathematical knowledge. With a p-value of 0.151, the hypothesis was not rejected.

3. H_0: Students perceived their growth in confidence in mathematics equally in both sections (quiz = control).

Students were asked in the post-survey of their self-perceived growth in confidence in mathematics. With a p-value of 0.482, the hypothesis was not rejected.

4.3.1 Focus Group

During the Focus Group session, students were asked to answer questions on the classroom atmosphere and give broad ideas and opinions of positive and negative things about the course. When asked for three words to describe the course, the students from the control section used words like "lots of proofs" and "solid linear systems" (in reference to course content), the quiz section students also shared some of these answers but also emphasized "fun" and "[having a] good time."

Similarly in the answers for the other questions, students in the control section were mostly focused on the intensity of the course and the material, students in the quiz section expressed opinions about the quizzes themselves and the overall lowered stress levels. In part, they discussed how the quizzes as a tool that "forced [them] to break up" the material as well as a way to test their learning of the material, knowing that they could retake it without penalty. Others noted the abundance of time there was to take a quiz, compared to its relative brevity, in particular to how midterms are traditionally given in a block of time. Some students mentioned how

quizzes could "pile up if [they] were not careful" and expressed a desire for a deadline for the first take of the quiz in order to help them not fall behind.

Furthermore, some students from the quiz section raised a question of fairness for their peers and friends from other classes, expressing how it was "hard to see them fail" after an exam while not being able to help or relate to them.

4.4 Discussion

The results of the study were showed no significant differences quantitatively in both sentimental factors and academic achievement between the two sections. Qualitatively, however, students experienced a much lower level of stress in the quiz section. Considering these two facts together, I contend that the study ended up having a positive impact on the students overall, since introducing this change could mean introducing better opinions of the learning environment while maintaining the academic rigor. That being said, the sample size and population of the study were not only small but also unique.

4.4.1 A (not so) brief note on Mudd

To understand how self-paced assessments fit into the classroom in this case study, it is critical to note the nature of the college in study as well. The college in this study is named Harvey Mudd College, housing 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. The introductory linear algebra course in this study, Math 40, is part of the Common Core. All students are therefore expected to take this course regardless of intended major. Moreover, 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 and

maintained by the student body and respected by all parties of the College. There are consequences to breaking the Honor Code that are decided by students; often, students at Mudd are willing to take on these consequences via self-reporting incidents that are caused, regardless of intention. 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.

The Honor Code plays a vital role in the practicality of self-paced assessments. It was expected for students to complete the assessments closed-book and independently. Another expectation was that there would be no discussion of the assessments with other students at any point in the semester so as to avoid benefitting students that may not have had completed them. To trust that students would follow these rules, which are impossible to enforce given the intentional absence of supervision, all parties involved must agree to promise integrity. Thus students need to be able to adhere to the Code, and instructors need to be able to trust that students will do so.

Therefore, I contend that a level of respect towards a code similar to that the Honor Code allows for self-paced assessments to maximize effectiveness. Without this, other measures can be taken to enforce integrity involved in the proposed method, such as having designated proctors or times for students to take assessments supervised, but this asks for further effort and resources that make the method harder to implement.

Class sizes, college demographics

According to the Harvey Mudd College website, the first year class of 227 students from which this sample was taken was composed of 22 percent Asian, 21 percent Latino/Latina, 5 percent African or African-American, 31 percent white and 14 percent multiracial students. 52 percent were women, which for a STEM-focused institution, Mudd as ranks one of the highest.

With a class this size, most courses have low student to faculty ratios that enable students access to professors more easily than perhaps at larger institutions. Furthermore, Harvey Mudd is an undergraduate-only institution, meaning there are no graduate students on campus who often take teaching assistant or recitation lecturer positions at larger schools. Professors are generally also expected to be dedicated to teaching as much as they are to research; again, this likely gives students a better chance at accessing a professor for help or advice than students elsewhere, and professors time to spend helping and providing for students directly. For

instance, the instructor of the case study done here had to hand-grade and come up with all of the assessments and retries, which is a large time commitment that would easily have been infeasible with a larger class size.

In addition, the math department faculty at Mudd is far more ethnically diverse than the statistics shown previously, with 5 women out of 15 total professors *[note to Dagan: not certain how to include more information without being insensitive]*.

Thus, it is very likely that there are definitely variables in the demographics of students and the school that may have affected the results of this study and method. This would then likely hinder predicting how effective it is at other institutions of different characteristics in population.

Mental Health and Wellness

At Harvey Mudd, awareness and improvement of mental health and wellness is actively advocated for by both academic and residential departments. Mudd is known for its intensity and rigor in curriculum; all students must go through three semesters of Common Core, which consists of 10 or so rigorous classes. During the semester in which most students take Math 40, students are also taking at least four other courses that have demanding amounts of homework and effort.

Not surprisingly, stress is a big factor that affects many students' lives. Whether from workload or academic difficulty, students are often sleep deprived or are burnt out from the consistent loads of problem sets. Math 40 is taught at a relatively fast pace than other classes, being a half-semester course, and homework tends to be focused on exercising many new definitions of terms. Thus, students often feel the need to learn the material more quickly than others, which can cause this course to feel more stressful. Since Math 40 is mandatory to graduate, there is a lot of pressure to do well in the class, whether or not it is a course of their liking.

Given the situation, it is the institution's responsibility to reduce student stress as much as possible. Thus, if there exists a method of learning that reduces overall stress but maintains academic effectiveness, this can be viewed as an overall success, particularly at high-stress institutions like Mudd. The qualitative results of self-paced assessments point towards that this style of learning was less stressful than receiving traditional midterm/final exams. Students who noted that they could avoid the pressure-filled environment of taking a timed exam felt the benefit of the experiment. Other students saw the quizzes as a learning tool rather than an assessment, which also

may have lowered stress and negativity. If similar institutions are looking to reduce stress amongst students and promote good mental health, this may be one way to go about doing so.

4.4.2 Self-regulation in action.

In examining the quotes from the Focus Group sessions, there are definite instances where students were unintentionally applying methods of self-regulation.

One student said, "I used the first quiz like a learning tool" beacuse they knew that they could see where they needed improvement and retake the quiz without penalty. This is not only a method of self-monitoring but also self-instruction; the student took upon themselves to assess their knowledge and take advantage of the fact that there was no penalty to trying again. In a broader scope, this is metacognition in action, where self-paced assessments are giving them a chance to understand how they learn and where to improve. This also means that the power is in the students' hands to control what they believe is a correct assessment of their learning, rather than a single examination taken at a time not of their choosing.

Some students pointed out possible areas where they wanted to take charge of what could have been done in the experiment better. One student said, they "wanted a deadline" for the first try of a quiz in order to avoid having them pile up. The only deadline to these quizzes were that they had to be completed before the end of the semester. By saying that they wanted more deadlines, the student is asking for what they wish would help them better their learning, particularly in helping them self-monitor their habits in completing assignments. On a similar note, another student pointed out that a "release date" for each fo the quizzes would have helped them keep track of when they were coming so as to help them prepare for it in advance. This is another mode of self-regulation where the student possibly tries to plan ahead and figures out what they need to do logistically for them to minimize cramming.

As mentioned before, Math 40 is a fast course. This was noted by both sections, but the control section was significantly more demanding of the need for more practice problems (particularly on proofs), while the quiz section focused on whether the quizzes were beneficial to keeping them in track through the course. The control sections' frustrations that there were not enough examples or practice problems seem not to have appeared in the quiz section perhaps becuase the quizzes themselves acted as a sort

of practice. How nothing was said of the lack of understanding on how to do proofs shows that the quizzes were able to perhaps achieve more academically than homework and lectures alone. Furthermore, students in the quiz section were actively noting their progress through the course; while a few students noted that they felt they had forgotten a lot of the first couple lectures, others noted that the quizzes forced them to return to these concepts. Self-assessment involves the realization of how one is doing in mastering or understanding a concept–students in the quiz section (no matter what they thought) had a general idea of how they were doing with the material, therefore exercising further metacognition.

While this was a small sample size, there seemed to be optimistic evidence towards how self-paced assesmsents could improve and engage metacognitive abilities and reinforce students' power in the classroom.

4.4.3 A question to consider

This case study proposes an open question: can self-paced assesmsents help to address inequitable learning environments?

I ask this question in hopes to get more efforts of gathering a larger data set to work with, both quantitatively and qualitatively. This study was a small example of self-paced assessments could be used in a mathematics classroom. Though the student sample and school demographics are unique, there is a lot that can be done to implement either a part of the method or change the method to cater the need of other institutions and students.

I think that more experiments done at either Harvey Mudd or similar, small liberal arts colleges could give more insight into how effective this method is, in particular focusing on how it could improve the power dynamics of the classroom setting and improve self-regulatory skills. A different focus could also be to see how this reduces stress related to academics without hindering curricula.

All in all, this study has opened up interesting possibilities to explore in a mechanism that ultimately seemed to help students at Mudd feel lees stress and understand their learning while not impacting their academic learning much.

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