On Self Regulation in College-Level Mathematics Classes

Jenny Lee

Dagan Karp, Advisor

Luis A. Leyva, Reader

HARVEY MUDD COLLEGE

Department of Mathematics

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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.

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Chapter 1

Motivation

1.1 The need for change

I politely ask you to consider: a typical child grows up being told over and over again to "be quiet" and to learn the materials presented in front of them; there are no stupid questions as long as they are relevant to the material at hand. As they progress into higher education (if they do), they find themselves often sitting in a large lecture hall, questions left unanswered "in the interest of time," and wondering whether the lecturer knows their name, or even cares if they show up at all.

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. Despite advances in research in education, classroom instruction has not changed significantly in a typical college in the last five to ten decades, if not more. Students are still attending large lecture-style classes assessed via exams accompanied by weekly, graded assignments. With an increasing number of individuals pursuing a higher education, it seems naive to think that the current systems of education are still suitable or equitable to all students. With the diversifying population of students, it is just as crucial to bring sensible change to promote an equitable learning setting.

1.2 Mathematics is not fair

The current nature of mathematics education in the US provides an extremely different experience for a student who is Asian American versus African American versus white. Starting from achievement gaps between African American and Latino/a students and white students to the extremely stereotypical belief that “Asians are good at math,” there is abundant evidence for the unfair nature of mathematics education (Flores (2007)).

Specifically, there exists a large socioeconomic difference between ethnicities. The 2007-2011 census provides enough quantitative evidence of the 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 (Suzanne Macartney and Fontenot (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 et al. (2018)).

With income gaps this big, opportunity gaps are not so different. In 2013, enrollment percentages in postsecondary education showed about a near 10% difference between white (42%) and black (34%) students (Musu-Gillette). 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.

Exactly what perpetuates these depressing statistics rests deeply rooted in racism that has lined all of US history. To be more specific, it is absolute ignorance to think that any part of education is void of racism, whether outwardly intentional or not. From the 2005 study conducted by the American Mathematics Society, 80% of full time mathematics professors with PhDs are white, compared to 1% black and 2% Hispanic.

Yet, mathematics is historically not a unique subject to white Europeans; rather, prominent advancements were made by individuals from all over world. Yet, if we ask ourselves the names of famous mathematicians, what we hear are not Srinivasa Ramanujan, Hypatia, or Dorothy Vaughn but rather Euler, Pythagoras and Fermat. The problem in question lies exactly here–whiteness is rarely questioned in this context of mathematics. Without having stood in the shadow of an individual that society pictures to be the “model mathematician,” it is extremely difficult to understand the place of inequality in the education of our students. It is the not the white teacher but the student of color who has the sole responsibility to succeed through societal oppression. It is no different than asking an ugly duckling to be something other than what he sees in the reflection.

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 et al. (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.

The solution is not clear either. There are many variables and factors in any classroom environment that either cannot be controlled or are unknown. There is no magic wand that turns poverty-stricken neighborhoods into more privileged ones, nor is there one that removes racial inequality within a school, never-mind school districts across a nation. One important example of an unexpected factor that aggravates the situation is 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.

In particular, this happens in subjects like mathematics, widely believed to be a neutral subject. First, neutrality on its own deserves to be revisited. Statements such as "all lives matter" made as a counter to the Black Lives Matter movement, describe a harmful form of using neutrality to deny racism exists. In a similar vein, stating that "mathematics has no color" contains as many subliminal messages. As Rochelle Gutierrez, notable for her advocacy in equitable education, writes:

> [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)).

It is not to say that finding a derivative is promoting white supremacy. Rather, the way in which we teach a mathematical concept and the myriad of assumptions we make in the process shape the role mathematics takes in our society. 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.

Thus, I propose to look into establishing self-efficacy in students. The status quo continues to marginalize students, undermining their abilities and discouraging them from the simple thought that they can succeed in mathematics. By letting students believe that they are capable and entrusting them with their own capabilities, classrooms will no longer be a place for oppression but a place for opportunity for everyone. Building self-efficacy will hence build supportive environments that can empower students with independence and trust in themselves.

While I believe such an ambition can be achieved in various ways, not excluding political and administrative actions, I think fostering self-regulation is a promising first step. in the next chapter, self-regulation is defined and detailed, showing how it can build an equitable classroom.

Chapter 2

Self-Regulation

2.1 Definition

This is a definition 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 and Boekaerts).

Adopting a focus on self-generation of thoughts and actions that are expected to lead to attaining personal goals is a statement of power. There is an obvious power dynamic which is centered at the instructor, given control over a group of powerless individuals and their actions and knowledge. Promoting self regulation empowers students to have more control and independence in their learning experience, thereby shifting the locus to the student.

Much of the core ideas behind self-regulation in classrooms come from mastery based learning. 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 (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 a foreign skill in traditional instruction. Thus, self-regulation does not come easily to most students today. For a large part, if not all, of a young student's life in education, 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 this status quo, it is unthinkable to "personalize" a course to meet a particular student's needs. The best attempts so far include remedial classes, which further reduce self-efficacy in underachieving students (Martin et al. (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.

2.1.1 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 in learning.

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 (**?**).

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.

A section below outlines more specifically what kinds of self-assessments 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.

2.1.2 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 and Schroeder (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 et al. (2000)). 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.

2.1.3 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 (L K Dunalp (a)). 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 (L K Dunalp (b)).

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.

2.2 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 et al. (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 3

The case study

3.1 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.

3.2 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.

3.3 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.

Bibliography

Badger, Emily, Claire Cain Miller, Adam Pearce, and Kevin Quealy. 2018. Extensive Data Shows Punishing Reach of Racism for Black Boys. *The New York Times* URL https://www.nytimes.com/interactive/2018/03/19/upshot/race-class-white-and-black-men.html, https://www.nytimes.com/interactive/2018/03/19/upshot/race-class-white-and-black-men.html.

Bradley, Kirk. 2017. *Evaluating the effects of mastery learning in postsecondary developmental mathematics*. Ph.D. thesis, ProQuest Information & Learning, US.

Burris, Joanna S., and Lee Schroeder. 1972. Developmental Mathematics: Self-Instruction with Mathematics Laboratory. *The Two-Year College Mathematics Journal* 3(1):16–22. doi:10.2307/3026792. URL http://www.jstor.org/stable/3026792.

Busato, Vittorio V, Frans J Prins, Jan J Elshout, and Christiaan Hamaker. 2000. Intellectual ability, learning style, personality, achievement motivation and academic success of psychology students in higher education. *Personality and Individual Differences* 29(6):1057–1068. doi:10.1016/S0191-8869(99)00253-6. URL http://www.sciencedirect.com/science/article/pii/S0191886999002536.

Flores, Alfinio. 2007. Examining Disparities in Mathematics Education: Achievement Gap or Opportunity Gap? *The High School Journal* 91(1):29–42. URL http://www.jstor.org/stable/40367921.

Gutierrez, Rochelle. 2012. Embracing Nepantla: Rethinking "Knowledge" and its Use in Mathematics Teaching. *Journal of Research in Mathematics Education* 1(1):29–56. doi:10.4471/redimat.2012.02. URL http://hipatiapress.com/hpjournals/index.php/redimat/article/view/191.

L K Dunalp, G Dunlap. ????a. Self-Monitoring: Customized Math Self-Correction Checklists | Intervention Central. URL http://www.interventioncentral.org/academic-interventions/math/self-monitoring-customized-math-self-correction-checklists.

———. ????b. A self-monitoring package for teaching subtraction with regrouping to students with learning disabilities. URL https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1286182/.

Lage, Maureen J., Glenn J. Platt, and Michael Treglia. 2000. Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment. *The Journal of Economic Education* 31(1):30–43. doi:10.2307/1183338. URL http://www.jstor.org/stable/1183338.

Martin, Kimberly, Molly Goldwasser, and Eugenia Harris. 2017. Developmental EducationâĂŹs Impact on StudentsâĂŹ Academic Self-Concept and Self-Efficacy. *Journal of College Student Retention: Research, Theory & Practice* 18(4):401–414. doi:10.1177/1521025115604850. URL https://doi.org/10.1177/1521025115604850.

Montague, Marjorie. 2007. Self-Regulation and Mathematics Instruction. *Learning Disabilities Research & Practice* 22(1):75–83. doi:10.1111/j.1540-5826.2007.00232.x. URL https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1540-5826.2007.00232.x.

Motlagh, Shahrzad Elahi, Kourosh Amrai, Mohammad Javad Yazdani, Haitham altaib Abderahim, and Hossein Souri. 2011. The relationship between self-efficacy and academic achievement in high school students. *Procedia - Social and Behavioral Sciences* 15:765–768. doi:10.1016/j.sbspro.2011.03.180. URL http://www.sciencedirect.com/science/article/pii/S1877042811003594.

Musu-Gillette, L. ???? Status and Trends in the Education of Racial and Ethnic Groups 2016 188.

Suzanne Macartney, Alemayehu Bishaw, and Kayla Fontenot. 2013. Poverty Rates for Selected Detailed Race and Hispanic Groups by State and Place: 2007âĂŞ2011 20.

Thevenin, Melissa K. 2007. *Mentors, role models, and differences in self-efficacy and motivation among construction management students*. Thesis, Colorado State University. Libraries. URL https://dspace.library.colostate.edu/handle/10217/88608.

Zeider, Pintrich, and Boekaerts. ???? Self-Regulation: A Characteristic and a Goal of Mathematics Education - Handbook of Self-Regulation - Chapter 21. URL https://www.sciencedirect.com/science/article/pii/B9780121098902500500.

Zollinger, Steven. 2017. The Impact of an Online, Mastery, and Project-Based Developmental Math Curriculum on Student Achievement and Attitude. *Walden Dissertations and Doctoral Studies* URL http://scholarworks.waldenu.edu/dissertations/4120.

1 Appendix A

References

[AI11] Benjamin O. Abakpa and Clement O. Iji. Effect of mastery learning approach on senior secondary school students achievement in geometry. *Journal of the Science Teachers Association of Nigeria*, 46(1):165–177, 2011.

> Study conducted on students in a secondary school mathematics course on geometry. Quantitative results show massive improvements after mastery learning methods. Gender differences were also analyzed, but there was no significant differences in achievement between male and female students with mastery learning approaches.

[AW14] Laura Ariovich and Sad A. Walker. Assessing Course Redesign: The Case of Developmental Math. *Research & Practice in Assessment*, 9:45–57, 2014.

> This study uses modular (mastery based) curriculum with the assistance of computer software. The problems that arose included computer software issues, but were not restricted to those. The workload of the class was far heavier than traditional settings, which students showed dissatisfaction for.

[Blo68] Benjamin S. Bloom. Learning for Mastery. Instruction and Curriculum. Regional Education Laboratory for the Carolinas and Virginia, Topical Papers and Reprints, Number 1. *Evaluation Comment*, 1(2), May 1968.

> This is one of Benjamin Bloom's original and first papers officially on the subject of learning for mastery (LFM). The paper begins with the current problems that exist in the status quo method of instruction, in particular regarding the use of the normal curve in assessment. Bloom discusses variables that determine "mastery" in students: aptitude, quality of instruction as well as ability to understand instruction, perseverance and the time allowed for learning. This paper broadly describes the ways in which learning for mastery can be incorporated into the classroom setting, and shows a little bit of evidence of the success of LFM.

[BMPQ18] Emily Badger, Claire Cain Miller, Adam Pearce, and Kevin Quealy. Extensive Data Shows Punishing Reach of Racism for Black Boys. *The New York Times*, March 2018.

[BPEH00] Vittorio V Busato, Frans J Prins, Jan J Elshout, and Christiaan Hamaker. Intellectual ability, learning style, personality, achievement motivation and academic success of psychology students in higher education. *Personality and Individual Differences*, 29(6):1057–1068, December 2000.

[Bra17] Kirk Bradley. *Evaluating the effects of mastery learning in postsecondary developmental mathematics*. PhD thesis, ProQuest Information & Learning, US, 2017.

> The study looks at community college students in intermediate algebra under a mastery learning environment. Results showed fewer dropouts and failed grades, as well as higher test scores for students that underwent the modified classes.

[BS72] Joanna S. Burris and Lee Schroeder. Developmental Mathematics: Self-Instruction with Mathematics Laboratory. *The Two-Year College Mathematics Journal*, 3(1):16–22, 1972.

[CC16] Cheng-Huan1 Chen and Chiung-Hui1 Chiu, cchui@ntnu.edu.tw. Collaboration Scripts for Enhancing Metacognitive Self-regulation and Mathematics Literacy. *International Journal of Science & Mathematics Education*, 14(2):263–280, March 2016.

[CMS18] Kwok-cheung Cheung, Soi-kei Mak, and Pou-seong Sit. Resolving the attitudeachievement paradox based on anchoring vignettes: evidences from the PISA 2012 mathematics study. *Asia Pacific Education Review*, pages 1–11, March 2018.

> This short paper looks into the paradox between attitude and assessment in students' mathematics performance across various countries in East Asia. There is little discussion of why the paradox may exist, and discusses more about a new way to identify the paradox.

[FK14] Carlton J. Fong and Jaimie M. Krause. Lost Confidence and Potential: A Mixed Methods Study of Underachieving College Students' Sources of Self-Efficacy. *Social Psychology of Education: An International Journal*, 17(2):249–268, June 2014.

> This study looks at the differences of self-efficacy between underachieving and achieving groups of students. Results showed no statistically significant differences. Factors that may have led to this result include the fact that underachievers received more positive, verbal feedback. Furthermore, the study pointed toward mastery learning experiences as one of the more influential reasons that

boosted self-efficacy in the underachievers. One caveat of this study is that they students are coming from a relatively high-achieving university, so self-efficacy could likely have carried over from past experiences in high school.

[Flo07] Alfinio Flores. Examining Disparities in Mathematics Education: Achievement Gap or Opportunity Gap? *The High School Journal*, 91(1):29–42, 2007.

[FTWC18] Teukava Finau, David F. Treagust, Mihye Won, and A. L. Chandrasegaran. Effects of a Mathematics Cognitive Acceleration Program on Student Achievement and Motivation. *International Journal of Science and Mathematics Education*, 16(1):183–202, January 2018.

[Gut12] Rochelle Gutierrez. Embracing Nepantla: Rethinking "Knowledge" and its Use in Mathematics Teaching. *Journal of Research in Mathematics Education*, 1(1):29–56, February 2012.

[Her11] Michele Lynn Heron. *How Does Self-Regulation Impact Student's Use of Mathematical Strategies in a Remedial Mathematics Course.* PhD thesis, ProQuest LLC, January 2011.

[HH18] Anesa Hosein and Jamie Harle. The relationship between students prior mathematical attainment, knowledge and confidence on their self-assessment accuracy. *Studies in Educational Evaluation*, 56:32–41, March 2018.

[KE09] Sahin Kesici and Ahmet Erdogan. Predicting college students' mathematics anxiety by motivational beliefs and self-regulated learning strategies. *College Student Journal*, 43(2):631–642, June 2009.

[Len15] Laurie Lenz. Active Learning in a Math for Liberal Arts Classroom. *PRIMUS*, 25(3):279–296, January 2015.

An experiment utilizing POGIL (Process Oriented Guided Inquiry Learning)

[LH16] Chiu-Lin Lai and Gwo-Jen Hwang. A self-regulated flipped classroom approach to improving students learning performance in a mathematics course. *Computers & Education*, 100:126–140, September 2016.

[LPT00] Maureen J. Lage, Glenn J. Platt, and Michael Treglia. Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment. *The Journal of Economic Education*, 31(1):30–43, 2000.

[LZH10] Andju Sara Labuhn, Barry J. Zimmerman, and Marcus Hasselhorn. Enhancing students self-regulation and mathematics performance: the influence of feedback and self-evaluative standards. *Metacognition and Learning*, 5(2):173–194, August 2010.

> This study looks at a particular self-evaluative methods that take into account individual versus social comparative feedback playing a role in improving self-efficacy. Predicted results would be that receiving individual feedback that is not affected by competition factors would do better to improve self-efficacy. Actual results showed that students who received individual feedback were actually the most dissatisfied with their performance. Possible reasons included the fact that social comparative feedback gives context to what are realistic and achievable goals that motivate both over-confident students and well-achieving students to have a more solid grasp of what is expected in their performance.

[MAY+11] Shahrzad Elahi Motlagh, Kourosh Amrai, Mohammad Javad Yazdani, Haitham altaib Abderahim, and Hossein Souri. The relationship between self-efficacy and academic achievement in high school students. *Procedia - Social and Behavioral Sciences*, 15:765–768, January 2011.

[McQ16] Dr Fiona McQuarrie. Changes in K-12 Education. page 20, 2016.

> Regarding changes made in k-12 education. Not pertinent necessarily.

[MG] L Musu-Gillette. Status and Trends in the Education of Racial and Ethnic Groups 2016. page 188.

[MGH17] Kimberly Martin, Molly Goldwasser, and Eugenia Harris. Developmental Educations Impact on Students Academic Self-Concept and Self-Efficacy. *Journal of College Student Retention: Research, Theory & Practice*, 18(4):401–414, February 2017.

[Mon07] Marjorie Montague. Self-Regulation and Mathematics Instruction. *Learning Disabilities Research & Practice*, 22(1):75–83, February 2007.

[MS15] David Miller and Matthew Schraeder. Research on Group Learning and Cognitive Science: A Study of Motivation, Knowledge, and Self-Regulation in a Large Lecture College Algebra Class. *Mathematics Educator*, 24(2):27–55, 2015.

[Mui08] Krista R. Muis. Epistemic profiles and self-regulated learning: Examining relations in the context of mathematics problem solving. *Contemporary Educational Psychology*, 33(2):177–208, April 2008.

[noa] Self-Regulation: A Characteristic and a Goal of Mathematics Education - Handbook of Self-Regulation - Chapter 21.

> This chapter is a thorough overview of self-regulation in the context of mathematics, and is probably the best starting read to understand the scope of self-regulation in mathematics, in particular in the classroom setting. Multiple intervention studies are taken into consideration and analyzed, and subjects of the studies are varied in demographics. Common successful components were identified and significant evidence suggested that fostering self-regulation skills were possible. The sort of self regulation implemented in classrooms were more related to problem solving skills than self-regulated assessment.

[PSK+16] OiYan Poon, Dian Squire, Corinne Kodama, Ajani Byrd, Jason Chan, Lester Manzano, Sara Furr, and Devita Bishundat. A Critical Review of the Model Minority Myth in Selected Literature on Asian Americans and Pacific Islanders in Higher Education. *Review of Educational Research*, 86(2):469–502, June 2016.

[SAD+15] Rebecca A. Simon, Mark W. Aulls, Helena Dedic, Kyle Hubbard, and Nathan C. Hall. Exploring Student Persistence in STEM Programs: A Motivational Model. *Canadian Journal of Education*, 38(1), January 2015.

> The study looks particularly into the effects of supporting student autonomy in order to increase the feeling of self-efficacy. In particular, it looks into STEM fields and differences in gender. Results showed that the effects were more visible and positive in male students, but not so much in female students. In addition, the study confirms that a mastery based approach was beneficial to developing intrinsic motivation, despite lower performance.

[SOLTR04] Tara Stevens, Arturo Olivarez, William Y. Lan, and Mary K. Tallent-Runnels. Role of Mathematics Self-Efficacy and Motivation in Mathematics Performance Across Ethnicity. *The Journal of Educational Research; Bloomington*, 97(4):208–221, April 2004.

[The07] Melissa K. Thevenin. *Mentors, role models, and differences in self-efficacy and motivation among construction management students.* Thesis, Colorado State University. Libraries, January 2007.

[TS00] Nan L. Travers and Barry G. Sheckley. *Changes in Students' Self-Regulation Based on Different Teaching Methodologies.* May 2000.

[WYLZ17] Wenlan Wang, Hongbiao Yin, Genshu Lu, and Qiaoping Zhang. Environment Matters: Exploring the Relationships between the Classroom Environment and College Students' Affect in Mathematics Learning in China. *Asia Pacific Education Review*, 18(3):321–333, September 2017.

[Zol17] Steven Zollinger. The Impact of an Online, Mastery, and Project-Based Developmental Math Curriculum on Student Achievement and Attitude. *Walden Dissertations and Doctoral Studies*, January 2017.

> This is a detailed literature review and research conduced on online, mastery and project based learning, specifically in mathematics in college level classrooms. Research needs for each learning style are outlined. In particular for mastery based learning, qualitative research is needed, in particular because of contradictory results on student stress levels and engagement. Research questions explored quantitative data on content knowledge as well as qualitative input on things like student attitude.