Addressing Math Anxiety Using Alternative Assessment

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Abstract

Math anxiety impacts student achievement. Having taught for nine years, I have observed its effect on students in my class every year. While studies show that a number of factors contribute to a student's math anxiety, the use of traditional assessment is a leading cause. The purpose of this action research, in turn, was to examine the effects of alternative forms of assessment and feedback structures on students' math anxiety. During the assessment and feedback cycle, students participated in a series of oral formative assessments, lessons and activities involving self-regulated learning, and an oral summative assessment during which they received oral feedback. Data collection included pre- and post-intervention surveys and focus student interviews, observation data, and a researcher reflective journal. Findings from the data suggested that the use of alternative assessment and feedback structures does lower students' math anxiety and has other positive benefits as well, including shifts in mindset. Yet, there are potential limitations, such as insufficient time and resources to effectively implement alternative assessments in all classrooms, leaving room for future research about how teachers can most effectively use oral assessment to identify and close gaps in students' understanding.

Introduction and Context

Assessment is an integral part of teaching, providing invaluable information about students' strengths and areas for growth. Yet research shows that traditional assessment structures are a major contributing factor to students' mathematical anxiety (Geist, 2010; Henrich and Lee, 2011; Beilock and Willingham, 2014), which ultimately affects their performance (Geist; Beilock and Willingham, 2014; Black and Wiliam, 1998). Not surprisingly, in turn, educators are paying increasingly more attention to the use, structure, and purpose of assessment, especially given its high stakes nature, which has implications both in and outside of the classroom.

At places like Lighthouse Community Charter School, a public K-12 charter school in Oakland, California, assessment scores can mean the difference between remaining open and closing its doors due to sanctions imposed by No Child Left Behind. Predominantly serving low-income students of color, Lighthouse is founded on the mission of preparing students for college and a career of their choice. Though 85% of Lighthouse students qualify for free or reduced lunch and roughly 90% are non-native English speakers and/or the first in their families to attend college, 87% of Lighthouse seniors are accepted to four-year colleges, and of those students, 89% have remained in college or graduated with a degree. Despite this success, only one-third of Lighthouse's high school students earn proficient math scores on standardized state tests, including the California State University math entrance exam, which determines whether students need to take remedial coursework in college. It thus becomes important for Lighthouse math teachers to reexamine their use of assessment, especially given that preparing students for college is at the core of the school's mission.

During my eight years at Lighthouse, I have taught four different high school math courses, including Algebra I, Geometry, Algebra II, and, most recently, Math Analysis. I conducted this research with all 63 of my Math Analysis students, the vast majority of whom are eleventh graders I taught last year in Algebra II.

Problem of Practice

One of the reasons why I enjoy teaching so much is its dynamic nature. I love that each day, each year, and each student is different. Yet, after nine years, one thing has remained stubbornly the same: every year I meet students who say they "can't" do math. When prompted to elaborate, these students often shrug their shoulders and tell me that they have never been good at math and don't think they ever will be. After these conversations, I have often wondered what experiences have led my students to develop this mindset and the degree to which the curriculum, grading system, and teaching strategies of my school (and in particular of my own) have influenced these students' attitudes towards math.

In the past, one frustration I have heard some students voice is that, in math, there is only one "right" answer and seemingly only one "right" way to get that answer. Not surprisingly in turn, I have observed many students completely disengage from a problem and withdraw from class altogether after making a mistake, or after they believe they have made a mistake. I have often seen students tossing their writing implements aside and saying, "I give up," if their answer does not match mine or a peer's. This response is troubling for many reasons, not the least of which is that this experience only seems to reinforce these students' beliefs that they are not good at math and that they never will be.

Only recently did it come to my attention that I was sending mixed messages about the importance of getting the "right" answer to my students. In class, I would tell students that I cared more about whether they included evidence of their problem-solving process and whether they could explain the reasoning behind their steps than whether they got the right answer. But in fact, when grading the majority of their formative and summative assessments, I checked the accuracy of their work. Students could not pass an assignment if they got a wrong answer. Although my formative assessments required students to explain their ideas and understanding of the solutions, I offered little to no feedback during class about how to develop and communicate the mathematical thinking needed to arrive at the answers. My actions in short undercut my words.

This revelation emerged during one of my coaching cycles last year when my director of instruction asked me what skills I wanted my students to develop. I responded by rattling off a list of things, none of which had anything to do with the content standards, but instead included behaviors such as asking good questions, persisting in the face of challenge, and explaining mathematical ideas. She then asked me how my assessments reflected these values. I sat in silence for a little bit as the reality of her words sunk in. At that moment, I realized that I had to develop assessments and grading standards that reflected my values more effectively and transparently to students.

My school's recent adoption of Common Core Math standards has fortunately granted me the opportunity to develop a curriculum that more clearly aligns with the skills I want my students to cultivate as lifelong learners. No longer do I feel compelled to teach 15 skills in two-week periods to ensure that my students have been exposed to all possible problems they might see on a standardized test at the end of the year. Instead, I am able to integrate inquiry-based activities that give students the opportunity to construct their own meaning of a skill, as opposed to my showing them the "right" way to solve a problem and giving them a worksheet with 20 practice problems. This year, I have also been more deliberate about including classwork activities that emphasize the importance of finding multiple ways to solve a problem, in order to communicate to students, especially those who are easily discouraged, that there is no one "right" way to solve a problem. In this way, I have seen the math practice standards come alive more meaningfully than in years past. By creating experiences that allow students to take ownership of their own learning, they inevitably "make sense of problems and persevere in solving them" (Common Core Math Practice Standard 1) in order to understand a skill.

Despite these changes to my curriculum, I recognize that I still must develop formative and summative assessments that reinforce these beliefs in order to send a clear message that I do in fact value creative problem solving, persistence, and clear communication of ideas, and that accuracy is not the only criterion that matters. This need became all the more apparent during a test day early on in the school year. Shortly after a student walked in and remembered we were having a test, he tossed his backpack on the table and declared that he wasn't going to pass – even though just the day before, he diligently (and accurately) completed a set of problems similar to the ones on the test. I was surprised by how many other students expressed similar anxiety. Right before I was about to pass out the test, another student yelled, "I give up," even though she too had confidently and methodically solved similar problems the day before.

I am struck then by the dissonance in my students' self-perceptions of their mathematical abilities and of what I believe they are capable. I am not sure if and to what extent this mismatch is rooted in a fixed math mindset. But based on these observations, I have concluded that **many of my students inaccurately assess their skills and consequently lack confidence in their ability to perform on traditional summative assessments, such as tests or quizzes.** Until I provide my students with alternate ways to be assessed and with feedback to help them address gaps in understanding, I do not think that my students will develop the confidence needed to overcome a fixed mindset.

Literature Review

Introduction

California's recent transition to Common Core has ushered in a new wave of standardized testing that has major implications for high school students. In the fall of 2016, state colleges and universities will begin using high school test scores to determine what type of coursework incoming freshmen will take upon entering their undergraduate studies (Smarted Balanced, 2014). Because Lighthouse's mission is to prepare students for college and a career of their choice, the college readiness of our high school graduates is of utmost importance. Unfortunately, recent data suggest that our students are not adequately prepared for college math courses. Given the link between academic performance and anxiety (Kulm, 1994; Beilock and Willingham, 2014), addressing students' math anxiety, in turn, becomes an increasingly important issue. Research shows that a variety of reasons can account for a student's lack of mathematical confidence: family, past educational experiences, as well as traditional assessment and grading structures (Geist, 2010; Henrich and Lee, 2011; Beilock and Willingham, 2014). Timed tests and a competitive grade-centric classroom environment, in particular, seem to increase a student's anxiety and consequently affect achievement (Geist; Beilock and Willingham, 2014; Black and Wiliam, 1998). In this review, I present literature related to math anxiety, traditional and alternative assessment, feedback, and the role self-regulation plays in a student's learning and performance on such assessments. I argue that changing the way I assess and coach students to use feedback and self-regulated learning strategies on formative assessments will impact students' mathematical confidence and ultimately their academic achievement on summative assessments.

Mathematical Achievement

Data about my school and the U.S. lead me to believe that students are not adequately prepared for college math coursework, suggesting that more needs to be done to address these achievement gaps.

Based on their performance on the Standardized Aptitude Test (SAT) and California State University (CSU)'s college placement exam over the past several years, the majority of Lighthouse graduates are not prepared for college math courses. In order to place out of remedial math courses at CSU, students must earn an SAT math score of 550 or pass the CSU's placement exam, the Entry-Level Mathematics (ELM) test. For the past six years, the average math score for outgoing

Lighthouse seniors has hovered below 500 (Lighthouse, 2014). Scores from the CSU's placement exam uncover similar results. In the fall of 2013, 67% of Lighthouse students did not pass the ELM and were subsequently required to take a remedial math class, compared to 29% of students system-wide (CSU, 2013). Lighthouse's 2013 percentage was slightly higher than those of past years – in 2012, 50% of students were not proficient in math, and in 2011, 57% students had to take a remedial math class – but significantly lower than that of 2010, when four-fifths of college-bound students were not proficient in math (CSU, 2010-2012).

Data related to the U.S. as a whole reveal similar trends. Over the past decade mathematics achievement in U.S. schools has trailed behind that of most other industrialized countries (Greene and McGee, 2012; National Center for Education Statistics, 2012). When compared to 25 developed countries using state, national, and international exams, 94% of all school districts in the U.S. scored below the 67th percentile in math, based on data collected between 2004-2007 (Greene and McGee, 2012).

Despite having the fourth largest per student expenditure (and spending 35% more per student on elementary and secondary education than the average per pupil expenditure) among Organization for Economic Cooperation and Development (OECD) countries in 2011 (OECD, 2014), the U.S. ranked 27th out of 34 OECD countries (National Center of Education Statistics, 2012). Moreover, mathematics achievement in the U.S. seems to be stagnant. Over a nine-year period, the average math score hovered between 474 and 487, reaching its peak in 2009 before most recently dropping slightly to 481 in 2012 (National Center of Education Statistics, 2012).

From this data, I conclude that mathematical achievement, as it relates to college readiness, is an important issue for both my school and the U.S. Many suggest that anxiety plays a crucial role in determining students' attitudes towards math and consequently their academic success (Geist, 2010; Beilock and Willingham, 2014; Black and Wiliam, 1998; Henrich and Lee, 2011).

Mathematical Anxiety

Based on my research, I argue that anxiety is one cause of poor mathematical achievement (Beilock and Willingham, 2014; Geist, 2010). It limits a student's ability to engage with challenging tasks (Martin and Marsh, 2003) and thus fails to push thinking forward (Masters, 2014) and to allow for academic progress (Stiggins, 2002; Black and Wiliam, 1998). A number of reasons may explain why students develop math anxiety, but given my inability to influence most of these factors, I argue that focusing on assessment is the most effective way I can influence my students' relationship with math and their academic success therein.

The aforementioned college-ready statistics call into question the factors accounting for such low achievement, not only at Lighthouse but more broadly as well. According to Beilock and Willingham (2014) and Geist (2010), anxiety is one potential cause, as it compromises a student's ability to solve problems (Beilock and Willingham, 2014) and prevents students from developing academic resilience, which is defined as "the ability to effectively deal with setback, stress, or pressure in the academic setting" (Martin and Marsh, 2003, p. 1). Students who lack resilience thus lose the opportunity to learn effectively, since "learning is most likely when students are given challenging tasks just beyond their comfort zone" (Masters 2014, p. 4). If students, lacking resilience, do not even attempt these challenging problems, they miss the chance to learn (Stiggins, 2002; Black and Wiliam, 1998). It is not surprising, in turn, that Beilock and Willingham (2014) suggest that the relationship between a student's anxiety and academic achievement is inversely proportional.

To address this issue, it thus becomes necessary to examine the most common causes of math anxiety. Several sources claim that low math confidence can begin before a student even steps foot into a classroom (Geist, 2010; Henrich and Lee). Students from low socioeconomic backgrounds are particularly at risk of developing negative attitudes towards math (Geist, 2010). Given the correlation between income and level of education, Geist (2010) states that a parent's level of education is often the primary risk factor affecting a child's attitude towards math since parents with less education tend to have their own negative attitudes about math, which they then pass on to their children.

Classroom experiences also play a role (Beilock and Willingham, 2014; Geist, 2010; Henrich and Lee). Beilock and Willingham (2014) note that at the elementary level in particular, a teacher's own math anxiety often transfers to students, intentionally or not, calling attention to the need for ample professional development to ensure that teachers are not only knowledgeable about the subject matter but are also properly equipped for *how* to teach mathematical concepts.

Even more important perhaps are the structures teachers put in place in shaping a student's feelings about math. Teachers who emphasize "right" answers, employ algorithmic ways of problem solving, and use timed tests lead many students to develop math anxiety (Geist, 2010; Kulm, 1994; Pappon, 2014) and a fixed mindset toward math (Lee, 2009). According to Segool, Carlson, Goforth, von der Embse, Barterian (2013), students exhibit even greater anxiety when it comes to high-stakes testing. Additionally, the use of letter-based or percentage grades often creates a competitive culture that further exacerbates students' math anxiety, especially among older students, who often use and rely on grades as a measure of self-worth (Covington, 1992).

Based on this research, I conclude that a variety of factors account for mathematical anxiety. While I cannot change a student's family background or past math experiences, I can change how I assess students summatively and how I coach them to use feedback from formative assessments to inform their learning. For this reason, I argue that a focus on assessments (and the feedback and self-regulation thereof) will help address my students' lack of mathematical confidence. Not only does assessment have a profound influence on students' motivation and self-esteem (Foster, 2009; Covington, 1992), but Gibbs (1999) argues that it "is the most powerful lever teachers have to influence the way students respond and behave as learners" (p. 507).

Assessment

Based on my research of assessment, I argue that traditional summative assessments do not effectively meet the needs of students, and that alternative forms, as described below, are needed (National Council of Teachers of Mathematics (NCTM), 1995; Stiggins, 2002; Kulm, 1994). Because performance on formative and summative assessment is linked, I believe that a focus on the former precedes a shift in the latter. To improve learning outcomes, I argue that oral exams, in particular, are a potential solution in decreasing students' anxiety on summative assessments (Huxham, Campbell, and Westwood, 2012; Iannone and Simpson, 2012).

Though there is no clear consensus about the purpose of assessment, there is common language used to describe it. Masters (2009) states that assessments at their core provide information about a student's level of understanding at a given moment. When teachers use this information to modify their practice in order to better serve the needs of students, then the assessment is considered formative (Black and Wiliam, 1998). Summative assessments, in contrast, are generally used for the purpose of assigning grades (Leite and Torres, 2014). In the past (and even today), teachers often used assessment at the end of a unit (Leite and Torres, 2014) to measure whether students learned the material that was taught, providing students with little to no feedback about the progress they made (Masters, 2009). In this way, educators have come to associate traditional assessment with measuring skills or processes (Lowery, 2003; Kulm, 1994), often in the form of tests or quizzes with problems that have one answer and one way to solve them (Wallace and White, 2014). It comes as little surprise, in turn, that Kulm (1994, p. 5) states, "Test anxiety is perhaps the greatest factor in producing poor attitudes towards mathematics."

Within the past few decades, however, a number of educators have redefined the purpose of assessment, suggesting that its traditional forms do not best serve the needs of students (NCTM, 1995; Stiggins, 2002; Kulm, 1994). One such concern is that traditional assessments train students how to take tests rather than how to think (Kulm, 1994). Testing students in this way provides a limited view of what a student actually understands and ultimately limits the subsequent feedback a teacher can offer, which Kulm (1994) identifies as a critical purpose of assessment. Furthermore, on these tests, students generally receive letter grades, which provide little information with which students can self-monitor their own progress and make subsequent improvements (Masters, 2009).

Alternative assessments thus differ from their traditional counterparts in several key ways. They deemphasize the importance of a single "right" answer (NCTM, 1995; Schulman, 1996), provide opportunities for feedback (Masters, 2009), and, perhaps most importantly, empower students to become active participants in monitoring and making informed choices about their own learning (Stiggins, 2002; Schulman, 1996). Though my research did not reveal a universally recognized definition of alternative assessment (which others also refer to as informal, authentic, and performance assessment (Schulman, 1996)), Fernandes (2006) describes it as "participative, transparent, integrated in teaching and learning, and aimed at regulating and improving. It is a procedure that focuses mainly on processes, without ignoring the products" (cited by Leite and Torres, 2014, p. 16).

Assuming a variety of forms, alternative assessments generally adopt an "open-ended" structure (NCTM, 1995) and allow for multiple possible answers and multiple ways of finding these answers (Wallace and White, 2014), thus reducing students' anxiety by devaluing the importance of finding a single "right" answer (Kulm, 2013). Journals, debates, investigations, oral presentations, portfolios, and oral exams are just a handful of examples (Kulm, 1994; Iannone and Simpson, 2012; Huxham et al., 2012; NCTM, 1995).

According to two empirical studies led by Iannone and Simpson (2012) and Huxham et al. (2012), oral exams are a promising form of alternative summative assessment that may lead to decreased anxiety and greater academic achievement. Because of the observed benefits of oral communication noted by Kulm (1994), Fiori and Boaler (2004), and Chapin, O'Connor, and Anderson (2003), this type of assessment is of particular interest. "Listening to students talk about mathematics reveals aspects of their understandings and dispositions towards mathematics that written work alone does not disclose… Such knowledge is crucial for assessing individuals in the classroom, and can be used to help meet goals of effective, equitable teaching" (Fiori and Boaler, 2004, p. 1). Additionally, Chapin et al. (2003) argue that talking about math often leads to deeper understanding and reveals gaps in understanding to both teachers and students that the latter may never have realized had they not been asked to express their ideas clearly.

In their respective studies, Iannone and Simpson (2012) and Huxham et al. (2012) examined the use of one-on-one oral exams as a way to decrease students' anxiety. Though some students reported feeling more anxious about taking an oral vs. a written exam, Huxham et al. (2012) state that these feelings may have stemmed from a lack of overall familiarity with the type of format and could subsequently be improved with coaching. Iannone and Simpson (2012) also observed an initial increase in anxiety before students took the exam, but noted that afterwards students reported feeling more positive. These findings ultimately suggest that oral exams can be a viable assessment tool to decrease students' overall anxiety, especially given the additional benefits noted by these studies, including the opportunity for students to receive immediate feedback and to practice and develop their communication skills (Iannone and Simpson, 2012), as well as improved performance (Huxham et al., 2012). Many students who participated in the oral exams also reported studying more than they traditionally did for written ones, which may account for why students in this study did better on oral exams than written assessments (Huxham et al., 2012). All these factors, in turn, suggest that oral exams can have noted, beneficial impacts on students' anxiety and achievement.

To adequately prepare students for a shift from traditional to alternative summative assessment, it is essential that I modify the formative assessments I offer as well, given that the two forms of assessment are "mutually reinforcing" (Adabor, 2013, p. 1) and thus "cannot be completely separated" (Qu and Zhang, 2013, p. 338). To increase the impact of summative assessments on student learning, Harlen (2005) thus argues that teachers must design summative and formative assessments with similar goals in mind – a point reinforced by Adabor (2013), who states that "both formative and summative assessments should be aligned in a meaningful way to effect success in mathematics understanding and proficiency" (p. 1).

These findings lead me to believe that assessment – both formative and summative – is the primary means by which I can influence my students' participation in the learning process. Modifying current assessment structures will be critical to my students' development of mathematical confidence. Because the use of traditional summative assessment is a major contributing factor to the mathematical anxiety my students experience and the one over which I have the most control, it is imperative that I rethink how I design assessments in order to incorporate the open-ended, formative, and self-regulative nature that have come to characterize alternative assessment. As Kulm (1994) acknowledges, "(o)ffering alternative assessments can send a powerful message to students, showing them that the test is not necessarily the most valid or even the best evaluation of their abilities" (p. 33). Oral exams are a particularly promising alternative to explore, largely because of their observed impact on student anxiety and their inclusion of feedback and reflection opportunities.

Feedback

Based on my analysis of literature related to feedback, I argue that feedback and assessment are inextricably linked (Brown, 2004). Effective feedback serves many purposes, which I will outline below, but ultimately informs both the student and teacher of any gaps between a student's current and desired understanding (Hattie, 2012; Nicol and Macfarlane-Dick, 2006; Sadler, 1989). Given the difficulty teachers face with providing this information in a timely, comprehensive, and comprehensible fashion, I argue that self-regulated learning is one way to increase students' access to meaningful feedback (Nicol and Macfarlane-Dick, 2006; Zimmerman, 2002).

Though assessments are important, feedback is ultimately what makes them meaningful (Brown, 2004). By equipping students with the necessary information to set appropriate goals for continued learning (Hattie, 2012), feedback is the means by which educators can "influence the extent to which our assessment practices are developmental, rather than solely judgmental" (Brown, 2004, p. 84). The type of feedback teachers provide is especially important because, as Dweck (1999) notes, "External feedback has been shown to influence how students feel about themselves (positively or negatively), and what and how they learn" (Nicol and Macfarlane-Dick, 2006, p. 199). Because judgmental feedback fails to give students a clear sense of their current level of understanding and most importantly steps for how to improve, it is far less effective than its developmental counterpart (Hattie, 2003). Knowing the "difference between what we know and can do, and what we aim to know and do" (Hattie, 2012, p. 115) is at the root of increasing achievement and is what Hattie (2012) ultimately acknowledges as feedback's purpose. For this reason, Hattie (2012) argues that effective feedback addresses three questions with respect to the student's product, process, and self-regulation: "'Where am I going?'; 'How am I going there?'; and 'Where to next?'" (p. 116). The more students are aware of the answers to these questions, “the more students can help to get themselves from the points at which they are to the success points, and thus enjoy the fruits of feedback” (Hattie, 2012, p. 115).

Nicol and Macfarlane-Dick (2006) also acknowledge the importance of using feedback to set appropriate goals and to close gaps in knowledge and conclude, based on their research of different models, that good feedback:

1. Helps clarify what good performance is (goals, criteria, expected standards);
2. Facilitates the development of self-assessment (reflection) in learning;
3. Delivers high quality information to students about their learning;
4. Encourages teacher and peer dialogue around learning;
5. Encourages positive motivational beliefs and self-esteem;
6. Provides opportunities to close the gap between current and desired performance;
7. Provides information to teachers that can be used to help shape teaching. (p. 205)

In order for feedback to be useful, in turn, many agree that the person providing it must know the expectations of the assignment, possess the ability to compare the student’s current progress with these expectations, and know what must be done to close any existing gaps between where a student is at a given point and where the student is expected to be (Hattie, 2012; Nicol and Macfarlane-Dick, 2006; Sadler, 1989). Traditionally, teachers have been the gatekeepers of such knowledge (Sadler, 1989; Schulman, 1996; Nicol and Macfarlane-Dick, 2006). Yet, it is often difficult for teachers to provide feedback that is timely, comprehensive, comprehensible, and thus meaningful to students. If the feedback doesn’t provide a clear picture of what the student needs to do when the student needs it in a way that makes sense, it is difficult for a student to make any progress. Given the obstacles teachers face, this feedback system thus fails to meet the needs of students (Sadler, 1989) and makes students overly reliant on the teacher (Hattie, 2012). This breakdown in communication ultimately surfaces the need for students to become more active participants in monitoring their own learning (Nicol and Macfarlane-Dick, 2006), so that they can be the ones to recognize gaps in current and desired progress and subsequently "take corrective action" (Zimmerman, 2002, p. 65).

These findings lead me to believe that feedback is a critical component of assessment. If I am going to change the way I assess students, then I must also pay attention to the feedback that accompanies it. Ultimately, students are most likely to achieve when they are aware of the learning goals, are able to identify gaps between their current understanding and their desired outcomes, and are active participants in monitoring their own learning.

Self-regulated Learning

Like feedback, self-regulated learning plays a crucial role in assessment, particularly formative assessment (Black and Wiliam, 1998). In order for students to be able to effectively use feedback, however, students must first be aware of the desired learning goals, as well as where they stand in relation to those goals; otherwise, students cannot take the necessary steps to make academic progress (Black and Wiliam, 1998; Clark, 2012). This awareness initiates the process of self-regulated learning and thus enables students to make sense of feedback, suggesting that feedback and self-regulated learning are intertwined and mutually reinforcing. Not only does feedback invite students to begin the self-regulation process, but it can also improve their ability to participate in this process (Labuhn, Zimmerman, Hasselhorn, 2010). According to Clark (2012), feedback is what makes a student's learning goals and a teacher's expectations clear. Based on my analysis of the literature, I thus argue that self-regulated learning is critical for all students because it provides them with the tools necessary to use feedback effectively and consequently make academic progress and become lifelong learners (Nicol and Macfarlane-Dick, 2006; Kistner, Rakoczy, Otto, Dignath-van, Büttner, Klieme, 2010). To maximize the effects of self-regulated learning, I argue that teachers should explicitly teach how to participate in this process (Kistner et al., 2010; Pintrich, 2002).

According to Pintrich and Zusho (2002), self-regulated learning is an "active constructive process whereby learners set goals for their learning and monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the contextual features of the environment" (p. 64). This definition is particularly useful because it calls attention to the role self-regulated learning plays in a student's cognition, motivation, and behavior, while also underscoring the role teachers must play in designing tasks and assessments to promote self-regulated learning (Nicol and Macfarlane-Dick, 2006).

Zimmerman (2002) breaks self-regulated learning down into three phases: planning, practice, and evaluation. Each phase places the student at the center of the learning experience, as outlined below:

> **Planning**: Students analyze academic tasks, choose strategies that best address their specific learning challenge, set identifiable goals, and make self-efficacy and self-evaluation judgments to assess the accuracy of their level of understanding and content mastery.

> **Practice**: Students implement their plans, monitor their progress, and make real-time adjustments to their learning plans.
> **Evaluation**: Students assess the strategies' effectiveness based on teacher feedback, build on the successful strategies, and/or modify or replace less effective ones. (Hudesman, Crosby, Ziehmke, Everson, Isaac, Flugman, Zimmerman, Moylan, 2014, p. 3)

By providing opportunities for students to reflect on their strengths and areas for improvement, self-regulated learning enables students to set and monitor goals based on their behaviors (Zimmerman, 2002). Citing research from Zimmerman (2002), Hudesman et al. (2014) state that "(s)tudents begin to understand that learning is directly related to experimenting with different strategies, a notable shift from the more common notion that achievement is simply a function of innate ability or some other external factor" (p. 109). In this way, Zimmerman (2002) argues that self-regulated students perform better and have a more optimistic outlook about their future. By making the process of learning transparent, self-regulated learning allows students to see the iterative process of improvement, thus dispelling the myth of intrinsic intelligence (Hudesman, 2014), improving students' attitudes towards math (Kulm, 1994), and helping boost their confidence (Masters, 2009).

In order for students to become effective practitioners of self-regulated learning, teachers must provide ongoing opportunities for students to practice it (Pintrich, 2002; Labuhn et al., 2010; Zimmerman, 2002). Otherwise, potential gains from the use of self-regulation and feedback will not be realized (Labuhn et al., 2010). Teachers can create this experience for students in several ways. Providing opportunities for students to evaluate either their own or that of their peers "enables learners to develop self-assessment skills and gap-closing strategies simultaneously, and therefore to move towards self-monitoring" (Sadler, 1989, p. 140). To ensure that students are accurately self-regulating, it is important for teachers to then provide feedback on this process (Labuhn et al., 2010). Zimmerman (2002) furthermore suggests that teachers ask students to set academic goals, provide choice with respect to the tasks that students can do and to the people with whom they can work, as well as model the self-reflective strategies teachers want students to use. All these recommendations place students at the center of the decision-making process, making it all the more critical to develop students' ability to self-regulate accurately.

To guide students in this direction, researchers have made clear the need to explicitly teach self-regulated learning strategies (Kistner et al., 2010; Pintrich, 2002). An empirical study conducted by Kistner et al. (2010) found that it is important for teachers to explicitly rather than implicitly teach the importance of self-regulated learning and the effective use of self-regulated learning strategies, concluding that implicit coaching of self-regulated learning strategies was not as effective as explicit teaching when it came to tackling more challenging tasks, such as understanding mathematical proofs (Kistner et al., 2010). One possible explanation is that by making students aware of self-regulated learning strategies, teachers equip students with the language needed to reflect on their learning (Pintrich, 2002). If a student does not know how to talk about their strengths and areas for growth, in other words, then they are less likely to participate in this reflection (Pintrich, 2002).

Based on this review, I conclude that explicitly coaching students on how to use self-regulation strategies will enable students to use feedback effectively and to become more active participants in their learning. To increase the chances of my students being able to use this practice accurately and meaningfully, I must provide ongoing opportunities for students to set goals, monitor their progress, and determine next steps to close any gaps between what they currently know and what they want to or are expected to know.

Conclusion

Given the proven impact of self-regulation strategies on academic achievement (Kistner, 2010) and its ties to feedback and assessment, my analysis of the literature makes it clear that any intervention I implement incorporate all three. Research shows that mathematical anxiety affects mathematical achievement, and that providing alternative forms of assessment, in conjunction with feedback and self-regulated learning strategies, is one way to decrease anxiety and improve confidence and thus performance. In order for feedback to be useful to students, however, teachers must pay careful attention to how it helps students establish goals, monitor their progress with respect to these goals, and determine next steps to close any potential gaps in current and desired progress. By explicitly teaching students self-regulated learning strategies, teachers can involve students in the feedback process and set the stage for ongoing learning.

Based on my analysis, I propose that changes to assessment, feedback, and self-regulated learning structures will decrease my students' anxiety and improve their overall academic achievement in math. Specifically, I plan to conduct two assessment cycles with all of my students, during which I will align formative assessments with a summative oral exam, offer timely, specific feedback about students' progress with respect to desired learning goals, and explicitly teach self-regulated learning strategies.

This proposed intervention stems from my belief that the sooner students are aware of (and the more accurately they can diagnose) gaps in their understanding, the sooner students can address them before or as part of an assessment. In order to make this process effective, I argue that a couple of key factors must be in place. First, the tasks and assessments I provide must give students the opportunity to participate in the self-regulated learning process, which means that I must design the tasks so that they are accessible to and appropriately challenging for all students. (An open-ended assessment would be ideal.) Second, I must support students by giving them clear and timely feedback not only about their work, but also about their ability to self-regulate, so that they can do so accurately.

Theory of Action

Problem of Practice	Literature Review	Intervention	Expected Outcome	Research Methods/Data Collection
Many of my students inaccurately assess their strengths and areas for improvement. Consequently, they lack confidence in their ability to perform on traditional summative assessments, such as tests or quizzes.	• Family, past educational experiences, and assessment methods all contribute to math anxiety • Alternative assessment (particularly oral exams) is a promising avenue to address anxiety	• Oral formative and summative assessment • Cycle of feedback and self-regulated learning • Explicit coaching of self-regulated learning	• Students will be able to identify their strengths and growth areas • Students will report feeling less anxious about summative exams	• Pre and post-intervention surveys and interviews about anxiety • Observations of my class • Research journal

Intervention and Data Collection Plan

Research shows that assessment is both a major contributing factor to students' mathematical anxiety and the principal means by which a teacher can affect a student's attitude and behavior in class (Gibbs, 1999). For this reason, I chose to redesign the assessments I used and to modify my instruction accordingly. More specifically, I implemented alternative forms of assessment (both formative and summative), provided immediate oral feedback based on their formative assessments, and coached students on how to use this feedback to prepare for the summative exam – all in service of reducing the mathematical anxiety my students experience. By focusing on assessment, feedback, and self-regulated learning, it was my hope that students would become more active participants in their learning and ultimately more confident mathematicians and learners.

At the start of my three-week intervention cycle, I spoke with each of my three blocks of students, communicating the rationale behind these changes, so that they had a sense of why I was drastically shifting my form of assessment and instruction. That same week, I delivered a 20-25 minute lesson, outlining the three phases of the self-regulated learning process, and kept a poster on a whiteboard in my classroom as a visual reminder of the three phases. I then showed students a short video of a teacher solving a math problem I had assigned to them several days before and asked them to identify when and how the teacher used the three phases to make sense of and solve the problem. After debriefing the three-phase self-regulated learning process together as a class, I provided each student with a handout that included a list of sentence frames students could use at each phase and asked students to apply these strategies to their own problem solving (Appendix A).

Because research shows that students' performance on summative assessments is linked to their performance on formative assessments, it seemed logical that a shift in formative assessment would precede that in summative assessment. Consequently, I assigned four formative assessments during the first two weeks of the intervention cycle, three of which included an oral explanation component, designed specifically to prepare students for the oral summative exam (Appendix B). After each of these formative assessments, I provided students with immediate oral feedback about their progress.

After this two-week cycle of coaching students to use self-regulated learning strategies, offering them immediate, oral feedback, and implementing three oral formative assessments, I then administered the oral summative exam. The format I used was modeled after the ones discussed in my literature review and consisted of one-on-one conversations generally lasting 10-15 minutes with students during which I asked them to walk me through a problem from our current learning target. Unlike problems found on past written exams, the questions posed in the oral exam were open-ended, meaning they had multiple possible answers and/or multiple possible ways of solving them.