Effect of Incremental Cognitive Messages on Mathematical Self-Concept Within Remedial and Grade-Level High School Students

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EFFECT OF INCREMENTAL COGNITIVE MESSAGES ON MATHEMATICAL SELF-CONCEPT WITHIN REMEDIAL AND GRADE-LEVEL HIGH SCHOOL STUDENTS

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Abstract

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Student self-concept, particularly within the mathematics discipline, is deeply rooted in student understanding of the control or lack of control (locus of control) that they might have over their potential for success. This understanding is tied closely with a belief in one's innate, fixed ability (or lack thereof) to learn and master mathematics, and often is already very well-defined early on in one's academic career. Research, alternatively, has demonstrated that students not only have substantial control over their intelligence, but that intelligence itself is not a fixed commodity.

In response, this study sought to evaluate the effectiveness of exposing students to relevant research to show them the control they have, and ultimately hoped to increase mathematical self-concept. Data from pretests (control and treatment groups) and posttests (treatment groups) was collected and compared both quantitatively and qualitatively to triangulate results; quantitative data was analyzed for statistical significance while qualitative was coded and sorted to note trends within the results. Further, the study evaluated both average grade-level students and struggling remedial students in order to compare any results that might highlight differences in the two groups in effectively addressing potentially unique needs related to self-concept, given that the remedial students had clearly experienced less success academically.

Quantitative results demonstrated only one significant impact, notably an impersonal understanding of the content covered, demonstrating that any real impact on self-concept must also include a personal application component. This was corroborated by qualitative results which also established that students' beliefs in abstract were altered, yet remained unchanged in their own views of themselves.

Keywords: Mathematical self-concept, locus of control, positive incremental cognitive messages, remedial, high school.

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This thesis is dedicated to two particular individuals who have influenced my path to seeking the degree for which this study was completed. First, though she may never know it, I dedicate it to Ms. Laura Kadlecek, my own mathematics teacher of 3 years during high school, who dedicated herself to deeply and comprehensively challenging and empowering students to reach for great heights—and achieve them. Under her mentorship, my own excellence in mathematics flourished and reached levels which would then stand out above my peers in college. This was not due to greater intelligence, but rather to the excellent equipping I received, and the consistent challenges I was trained to address with enthusiasm, perseverance and creativity. It is with this same enthusiasm and perseverance I now seek to enter the field as teacher myself.

Second, I dedicate this to my husband of 12 years, Nathan Orona, who not only became mother and family manager to free me from responsibility enough to dedicate myself to this endeavor, but who also placed his own career on hold for nearly a year to leave work early or miss out on business trips as needed. Without reservation or concern, he not only voiced his conviction that the financial expense was absolutely worth the cost because he so fully believed in this calling, but in fact insisted that I resign from my own job at the start of the program so that I would have the freedom to give myself 100% to my future career. No spouse could be asked to sacrifice more, and he not only did so, but did so with a smile and consistent encouragement. I cannot express my gratefulness.

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Introduction

Ask most adults how they feel about mathematics, and there is rarely hesitation: an adamant claim that they have never been good at math, or that they enjoy it. What causes this deep disparity? At what point do individuals decide they are "good at math" or "bad at math?" While general anxiety is not correlated to any particular causal factor, math-anxiety is unique in that subjects attribute failure specifically to lack of ability rather than lack of effort or external factors (Bandalos, Yates, & Thorndike-Christ, 1995; Furner & Gonzalez-DeHass, 2011; Hedl 1987, 1990). In fact, "because people generally are not math anxious before going to school, math anxiety is related to the teaching of mathematics and the notion that mathematics is something to be dreaded begin[ning] in the child's first years in school" (Furner & Gonzalez-DeHass, 2011, p. 229).

Combine this intrinsic fear of math developing at the start of one's schooling with the current global economy's reliance on science, technology, and mathematics (STEM), and the importance of addressing this concern in classrooms across the country grows daily, as our K-12 educational system continues to fall further behind (Furner & Gonzalez-DeHass, 2011). Additionally, the experience of anxiety or inadequacy (poor self-concept) on the part of students affects future career and life decisions, further complicating the nation's ability to compete in these arenas (Furner & Gonzalez-DeHass, 2011). Thus, "[m]any researchers posit that learners' attitudes and beliefs toward subject matter, especially mathematics, are as important as achievement… and attitude toward mathematics can determine the likelihood of continued study and perseverance" (Van Eck, 2006, p. 166). It is with this in mind that this study seeks to delve into these attitudes and beliefs as well as potential for addressing them, particularly with struggling students.

Literature Review

Math Self-Concept and Math Anxiety

The understanding and study of mathematical self-concept has developed as multiple fields of research have built upon one another. Original self-concept research began within the mental health field with the general concept of self-esteem (Marsh, Parada, & Ayotte, 2004), however it was education and social psychology fields that sought to break it down further into the distinct arenas in which personal self-image is developed: social, academic, physical and emotional (Marsh, Parada, & Ayotte, 2004). Gourgey then picked up this work formally within the academic arena, defining mathematical self-concept as

> "beliefs, feelings or attitudes regarding one's ability to understand or perform in situations involving mathematics. The self as capable or incapable of learning or performing in mathematics, rather than the subject of mathematics, is the object of the attitude" (Gourgey, 1982, p.4).

Thus an awareness grew of the need for deeper understanding of the interaction between self-concept and anxiety: to study the perception of one's ability, influenced by multiple factors, including the peer group in which the student finds herself (Bandalos, Yates, & Thorndike-Christ, 1995).

While the study of anxiety breaks down another level into two foci, test-anxiety and content-specific anxiety, the study of academic self-concept also breaks down into specific subject area anxieties. These self-concepts are often related to one's prior success in that particular subject, and potentially independent from one's self-concept in other subjects (Furner & Gonzalez-DeHass, 2011). As this study seeks to evaluate specifically the interactions of anxiety and self-concept within mathematics in particular, further references to these terms will directly relate to math anxiety and math self-concept.

Setting out to establish the interaction between math anxiety and math self-concept, Gourgey noted "it has frequently been observed that mathematically anxious people make disparaging remarks not only about the subject of mathematics but about their own ability to perform in mathematics" (Gourgey, 1982, p. 4). It is this phenomenon of attributing negative self-image along with a negative view of the subject that drives researchers to want to understand student perception of their own ability, particularly in mathematics. In nearly every correlation considered, math self-concept was more closely correlated with each factor than was math anxiety (Gourgey, 1982). This is significant in that addressing self-concept may have a greater opportunity to impact mathematics success than dealing directly with the anxiety component, and may also provide more insight into the obstacles preventing success in mathematics.

Success and Failure Attributions

Causal Attributions. In order to more fully understand the phenomena by which math self-concept is formed, Bandalos, Yates, and Thorndike-Christ (1995) added to the conversation by digging more deeply into the causal attributions of students, i.e. why they believe they succeeded or failed. Utilizing three factors previously identified by Hedl (1987, 1990) they specifically evaluated the correlations for Characterological factors (one's innate ability/disability or interest/disinterest), Behavioral factors (personal effort), and External factors (the teacher, the test, anything outside of student control). Unlike previous research had shown, they found no statistical difference in general anxiety level between the students who blamed their lack of ability and those who blamed their lack of effort. They did, however, find that those who blamed their lack of ability had significantly higher math-anxiety and lower math self-concept, providing further credence to the growing body of evidence demonstrating the sense of helplessness and hopelessness experienced with math anxiety and math self-concept above and beyond simple test anxiety (Bandalos, Yates, & Thorndike-Christ, 1995; Meece, Blumenfeld, & Hoyle, 1988).

Goal Orientations. While looking specifically at student goals, Urdan and Maehr (1995) (as cited in Van Eck, 2006) developed a similar set of factors to Hedl's (1987, 1990) that showed three different types of goals that motivate learners: performance compared to others, mastery of content, and social extrinsic rewards like praise or recognition (Van Eck, 2006). Furner and Gonzalez-DeHass (2011) built on this framework as they presented a well-articulated and well-supported argument with both qualitative and quantitative data gleaned from a wide body of others' research. They presented the two primary motivations for goal-setting: performance goals (concerned with proving ability) and mastery goals (concerned with improved understanding). They then evaluated which of four variable approaches (performance-approach, performance-avoidance, mastery-approach, and mastery-avoidance) were most correlated with mathematics anxiety. Their claim of correlation between reduced anxiety and mastery-oriented goals and expectations was clear, though the studies did achieve some variation in their results.

Interventions

Cognitive Messages. Early work in cognitive interference focused on how students perseverate on non-academic fears such as their own inadequacy, peer perception, and lack of control, ultimately reducing their potential for success through this negative focus (Arkin, Kolditz & Kolditz, 1983). Bandalos, Yates, and Thorndike-Christ's (1995) built on this, and proposed directly combatting these negative mental messages by providing tools to the student through a computerized coaching agent so that he can both recognize the behavior and address it before it hinders future success.

In her dissertation, Tami Im (2012) also utilized computer simulations to provide positive emotional support (affirmation) and positive cognitive motivational messages to combat the hopelessness of poor self-concept for GED students. As mentioned earlier, there are two dimensions to math anxiety, affective and cognitive dimension: "affective math anxiety refers to feeling[s] of nervousness, tension and fear of math. Cognitive math anxiety refers to negative expectancy of doing well in math" (Im, 2012; p.2). Thus the cognitive motivational messages serve to combat the negative expectancy, and improve self-concept. By presenting the possibility for continued improvement with positive statistics, Im (2012) reinforced the theory to the subjects in her study that intelligence is not a fixed amount, but can grow. Her study found that not only do positive messages reduce math anxiety and improve math self-concept from the pretest to the posttest, but also generate a significant improvement in actual math computation skill. This is powerful evidence: for these struggling and often insecure returning GED students, emotional support and confidence-building messages reduced math anxiety, increased math self-concept, and increased mathematical skill. This study seeks to build on this valuable insight into lower-performing high school students using similar cognitive messages.

Im (2012) cites several researchers (Carver et al., 1989; Folkman & Lazarus, 1980; Folkman & Lazarus, 1985; Gross, 1999) who have established the impact of coping-strategies that emphasize emotion-focused coping (seeking to alleviate negative emotions) versus problem-focused coping (seeking to fix the problem). This led Im (2012) to conclude that addressing both avenues would then have the greatest overall impact. Her study then built on Shen's (2009) work, which did not find significant improvement in self-concept or anxiety levels from the presentation of "entity beliefs," or cognitive messages aimed at the whole student self-perception (as cited in Im, 2012). Im, on the other hand, did find that by breaking the messages into more specific "incremental belief" messages, the student's perception of the opportunity for improved ability over time could effectively be influenced (Blackwell et al., 2007; Dweck, 1999; Im, 2012; Kennett & Keefer, 2006), and could ultimately build greater persistence and sustained effort. In other words, telling students "you really are smart" did not convince them, but telling them "research shows you really do have the ability to change your total intelligence by exercising your brain" did successfully impact them. "Once students have incremental beliefs, they tend to think of intelligence as a malleable construct which is able to be cultivated through effort and learning" (Im, 2012, p. 76).

Overall, the statistically significant results of Im's (2012) study were impressive: emotional support messages improved math anxiety and math skills, cognitive encouragement messages improved both math self-concept and math skills, and the combination of both had the greatest improvement in all categories. Her revision of previous research using cognitive messages that were incremental and specific rather than broad entity beliefs also proved statistically significant, confirming her hypothesis that hope must be tangible in order to improve performance (Im, 2012). Her work specifically with GED students with poor self-concept and high anxiety adds substantial understanding and quantitative credence to previous theory that both emotional anxieties and cognitive self-concept can be impacted with these tools.

Competition. Though Van Eck's (2006) study did show competition between students was effective in increasing motivation and decreasing anxiety, this is most likely due to the fact that several of his subject schools did not complete the study. The remaining population was only wealthy private school students who would clearly have extrinsic competitive motivation not relevant in a remedial student population, and therefore this particular factor of competition is likely not generalizable beyond the specific subject study (Van Eck, 2006).

Pedagogical Tools. Philosophical discussion by Furner and Gonzalez-DeHass (2011) proposed seven valuable and potentially effective means by which teachers could alter the classroom environment to reduce anxiety. The authors provided no evidence that these approaches had been tested for their impact on anxiety, nor were they directly connected to evidence that they promoted the mastery-approach previously shown to be significant (Furner & Gonzalez-DeHass, 2011). However, their proposed methods do provide thought-provoking options for pedagogical tools for use in the classroom. Of the seven proposals presented, three seem particularly pertinent to reducing anxiety and improving self-concept: 1) the more real-world significance authentically embedded in a lesson, the more the students are likely to succeed, 2) giving students big-picture problem-solving tasks rather than rote repetition or memorization inspires them to understand their own abilities and potential for the concepts' application, and 3) creating an environment where mistakes are accepted and even encouraged removes the fear of failure itself.

Intersecting with this proposal was Van Eck's (2006) use of computerized coaches programmed to influence student attitudes by seeking to motivate, praise success, maintain student focus, encourage perseverance, and most interestingly, commiserate with the student in attributing failure to external forces rather than blaming their own lack of ability. Though these approaches were actually implemented in the study, such a substantial amount of the sampled population dropped out or was disqualified that the results bear repeating in order to ascertain any significant evidence.

Quantitative Observations

Variable Interactions. The research highlighted in Marsh, Parada and Ayotte's (2004) article demonstrated the importance of using multivariate analysis to determine the interaction between self-concept and mental illness. Traditional single-dimension, single-variable analyses and interventions originally used in the mental health field are incomplete and outdated when held up to the multi-variable analyses utilized in other fields such as education. Im (2012) cites Hembree's (1990) meta-analysis that showed the effect size of different interventions on math anxiety. While standard proposed changes such as curriculum alterations, psychological intervention, and group counseling show effect sizes less than 0.10, the meta-analysis also found that behavioral interventions (to alleviate the emotionality of anxiety through systematic desensitization and relaxation training) and cognitive interventions (proposing confidence-building messages) both showed effects of over 1.00, with p-values less than 0.01. This is very convincing, both as to the uselessness of standard intervention and the value of behavioral and cognitive interventions. Thus this establishment of the hierarchy of math self-concept, math anxiety, causal attributions, and goal orientations is necessary in order to fully grasp the web of interacting phenomena.

Gender Influence. In 2010, a study of Turkish high school students inadvertently discovered a drastic difference between genders: "it was also obvious in the study that female students have significantly more negative opinions ($p<.001$) than male students" even when the female students were more successful (Ozyürek, 2010; p. 444). Though this will not be a central goal in this study, it will be considered as another interacting variable required to understand the broader picture at work.

Gaps in Existing Research

Though Im's (2012) study appears to be the first to embark on the study of traditionally unsuccessful students whose math self-concept is most effected by years of failure, her research focused on returning GED students who, by the time they were in her program, had already made a recommitment of effort in order to reach the extrinsic goal of a diploma. Though these students certainly exhibit high math anxiety with low math self-concept, they have a sense of determination distinct from the standard remedial high school student as well as a maturational difference, with the average age of the GED student being several years beyond traditional high school students. This leaves room for pursuing new research into understanding how and when poor self-concept develops in high school math students who have previously failed.

Furner and Gonzalez-DeHass (2011) also left the door wide open for further research into their proposed pedagogical tools for the classroom in order to substantiate their solutions and quantitatively or qualitatively connect the solutions to reduced anxiety. Bandalos, Yates, and Thorndike-Christ (1995) also proposed further study into the impact of goal-setting on causal attribution. Their results showed that students who have learning goals most often attribute success to behavior and those who do not attribute success to luck or uncontrollable factors. This presents an interesting link between intentionally and proactively pursuing learning versus the hopeless "whatever happens, happens" attitude.

Study Materials Development

Pretest and Posttest Surveys. As each study referenced a unique survey and set of survey questions used for establishing math anxiety or self-concept levels, it was clear there is no industry standard for studies. Two surveys were compared and found to have a good deal in common: the first more effectively measured attitude (Gourgey, 1982), while the second aimed at measuring physiological and emotional anxiety levels by building on Wigfield and Meece's (1988) Mathematics Anxiety Questionnaire (as cited in Im, 2012) and Fennema and Sherman's (1976) Mathematics Anxiety Scale (as cited in Im, 2012). The second also provided a model for assessing the subject's understanding of the theory of intelligence scale and the potential for growth of intelligence (Im, 2012).

Cognitive Incremental Messages Presentation. In seeking means of presenting the cognitive incremental messages, Im's method of using computer programs was not feasible given the setting for this study, thus other methods were considered. Ladd (2009) very effectively presents an essay through story-telling means which demonstrates the value of implementing goals as well as effective study habits. Blackwell et. al.'s (2007) work again provides valuable insight into the incremental nature of intelligence growth, while Driemeyer, Boyke, Gaser, Buchel, & May (2008) provide insight into the physiological changes which occur during learning. Both of these are critical for students to not only believe, but understand, incremental growth.

Additionally, in her non-academic public awareness article "Juggling Makes Your Brain Bigger", Nordquist, (2004) provides a scientific study in terms with which students can understand and connect. Her use of simple terminology in discussion of her study offered a clear connection between juggling and any other learning which requires one to challenge parts of the brain which are less developed. The study documented actual physical growth of brain matter as measured by multiple MRIs of those who learned to juggle by practicing versus those who tried to learn to juggle by watching. And finally, Jo Boaler, well known for her book for parents as well as math teachers, "What's Math Got to Do with It? How Parents and Teachers Can Help Children Learn to Love Their Least Favorite Subject" (2008) offers insight into the perspective of struggling students, and in particular their tendency to see mathematics as a ladder of steps to be memorized rather than a body of tools available for use. Both of these effectively present the foundation of cognitive incremental messages, yet via non-academic terminology conducive to use with lay persons and high school students.

Research Questions

Thus, this study seeks two objectives: 1) to qualitatively understand any consistent causal factors that broadly impact mathematical self-concept of grade-level and struggling remedial high school students including student identification of internal or external locus of control of circumstances leading to success or failure, and 2) to quantitatively assess the effectiveness of an intervention providing positive incremental cognitive messages on mathematical self-concept and math anxiety.

Methodology

Method and Rationale

This study was intentionally mixed-methods, with the objective of combining quantitative results with qualitative depth to achieve broader understanding. Before- and after-surveys provided a baseline and treatment comparison for quantitative measurement and comparison of the classes, while also providing a medium for asking more probing qualitative questions to highlight possible origins of reduced self-concept. The pretest survey, presented to all treatment and control classes, begins with open-ended questions moving on to guided response questions, and finally ending with quantitative assessments, seeking to provide students with the opportunity to suggest their own experience before they are influenced by the study's objectives. The posttest survey re-queries only three of the 5 open-ended inquiries into self-perception, but retains all 12 (as well as 2 original posttest) quantitative questions in order to measure as many potential effects on self-concept as possible that might have been influenced by exposure to cognitive incremental message theory.

Treatment. The quasi-experimental portion of the study isolated one independent variable which was applied to only the treatment classes: providing positive cognitive messages on studies which have demonstrated incremental growth in intelligence through short lectures and a fill-in-the-blank packet. Remaining classes were held as controls and did not receive the instruction. Though Marsh, Parada, and Ayotte (2004) provided convincing evidence of the importance of multivariate analysis, the inclusion of open-ended qualitative questions provides opportunity to triangulate results while digging further into the interactions of the variables. Because of its successful and significant impact on GED students, another struggling population, the treatment selected borrowed from Im's (2012) trial by providing encouraging reminders and evidence of the theories of incremental intelligence development.

The actual treatment consisted of the presentation of purposefully selected passages, chosen to highlight cognitive incremental message theory studies in language friendly to high school students. The passages, selected from Ladd (2009), Blackwell et. al. (2007), Driemeyer, et. al. (2008), Boaler (2008), and Nordqvist, (2004), were broken down into ten 5- to 10-minute lessons and presented to the students over approximately two weeks of daily classes, with the objective of identifying whether instruction on incremental growth of intelligence through cognitive messages could positively affect student self-concept (Blackwell et al., 2007).

Sampling Procedures

Sample Population. The classes selected for this trial were the 5 classes assigned to the researcher for a Spring 2013 student teaching experience. Two of these classes were grade-level Geometry classes. The other three were titled "Intermediate Algebra" and were populated with students who had been assigned to this class in lieu of moving on to second year Algebra. Assignments were made by the mathematics faculty if the student had either struggled with first year Algebra (defined as receiving a "D") or had failed to pass the end of course (EOC) exam required for graduation in Washington State.

The school itself is extremely diverse, reflecting the economically and ethnically diverse suburban/urban community in which it is located. The Geometry classes (participating students numbering 20 and 24 students) were a general reflection of the student body coming equally from low income housing and older apartments (predominantly East African immigrants and 1st generation Latinos) interspersed with upper-middle and middle-class single family homes of new construction (primarily white and 2nd generation Asian Americans), while the Intermediate Algebra classes (participating students numbering 18, 18, and 12 students) reflected even more of the non-white (particularly Latino) and low-income population.

Treatment Sample Selection. Two treatment classes were chosen randomly, one each from Geometry and Intermediate Algebra. These two classes received the treatment of instruction on cognitive incremental growth and studies on the causes of success and failure in mathematics. The data collected via the pretest survey (of all five classes) was then augmented by an additional posttest survey given only to these two classes following the treatment. No posttest analysis was completed of control groups.

Instrumentation

Survey Development. As no single pre-existing survey fully covered all goals of the intended research questions, the quantitative portion of the surveys used in this research was developed using a hybrid of the Gourgey (1982) and Im (2012) models, following their similar structure and borrowing from their question objectives. The qualitative questions were then developed to delve more deeply into individual experience, as well as serving as a triangulation measure to assess whether the quantitative responses reflected actual beliefs.

Starting with these two, a collaborative survey was formed which noted nuances gleaned from other studies. Among these considerations were the separate measurement of comfort with and perceived aptitude for math (Bandalos, Yates, and Thorndike-Christ, 1995), and gender (Ozyürek, 2010). Because this study works with already struggling or unsuccessful students, understanding external factors which the students believe may have influenced their failure is a key insight, as well as identifying each student's personal awareness of his or her interest in and desire for learning over the course of their academic careers. These points of qualitative interest were appended to Im's (2010) and Gourgey's (1984) quantitative questions which aimed at assessing students' beliefs regarding fixed intelligence, their own ability levels, desire/motivation and external factors throughout their student careers.

Similarly, the questions allow for assessing students' awareness of any differences between their math self-concept and their self-concept in other academic areas. As noted previously, within the general population, general anxiety and math anxiety do not necessarily correlate (Bandalos, Yates, & Thorndike-Christ, 1995), thus this study seeks to see if the same phenomenon of greater fear or lower self-concept within math is true of this lower-performing population as well.

Surveys. On both the pretest (Appendix A) and posttest (Appendix B) surveys, students were surveyed to quantitatively (via Likert-scales) understand and compare their understanding of what causes success or failure in mathematics and how they view their own success or failure. They were also questioned qualitatively (via open-ended questions) to assess 1) any specific experiences for the students as individuals which shaped their like or dislike of mathematics, 2) how they view themselves as a math student, and 3) at what grade level their like or dislike of math was strongest or first defined. The posttest survey sought to analyze for any statistically significant changes in response following the treatment, as well as any shifts in understanding apparent in qualitative answers.

Instruction Packet. A packet of ten passages to be discussed on ten separate days was created to highlight cognitive incremental message theory (Appendix C). Each day's passage was developed using studies in language friendly to high school students, or which were highly adaptable to the setting. Im's (2012) themes of helping students understand that intelligence is not fixed but can grow incrementally through positive cognitive incremental messages were augmented by student-friendly examples of Bandalos, Yates, and Thorndike-Christ's (1995) causal attributions theory: how focusing on one's own internal locus of control as the source of success (through goal-setting, self-analysis, hard work, etc.) brings greater success regardless of skill, whereas an external locus of control perspective results in lower overall success.

Breaking Blackwell's (2007) article, "You Can Grow Your Brain: New Research Shows the Brain Can Be Developed Like a Muscle," down into multiple sections over several days provided opportunity to delve into each of these loci of control issues. It also allowed time for enjoying Nordquist's (2004) vivid comparison of a non-juggler learning to juggle with a non-math person mastering math, and citing Driemeyer, et. al.'s (2008) study of gray matter brain growth through perseverance. This was also supported by Boaler's (2008) emphasis on perseverance itself being central to intelligence growth, and further, her extensive research demonstrating that regardless of skill level, struggling students benefit equally with gifted ones from attempting and persevering through difficult problems.

The final day of instruction in the packet included a longer passage adapted for high school students from Ladd's (2009) article and questions for college students. Provided with hypothetical situations of students who exhibited internal and external loci of control, students were to assess what scenarios reflected best potential for success. Together, all of these supported growth in student understanding of attribution of internal sources of success while demonstrating incremental growth of intelligence through cognitive incremental messages with the goal of positively affecting self-concept (Blackwell et al., 2007).

Treatment Administration. All surveys were administered directly by the researcher to each of the five classes, providing a copy to each student and as much time as they desired. The researcher also presented the content in the ten cognitive incremental growth studies and readings, one each day over a period of ten days, lasting 3 to 10 minutes each. Passages were introduced with a short summary of each study. For those with readings, students were encouraged to search through the readings to fill in the associated blanks. For those without readings, the researcher presented the content while filling in the blanks on a document camera projection, seeking student input on appropriate responses for each blank. Appendix C reflects the completed responses; all underlined items were replaced with blanks for the students to fill in as appropriate. During the final session, students read and answered the questions, but “correct” and “incorrect” responses were not discussed; all packets were then collected and completion and accuracy were noted to confirm engagement and understanding.

Validity of Data

Organization and Analysis. Quantitative data were grouped and sorted via three paths. First, for all 5 classes, pretest scores were entered and compared to confirm statistical similarity within Intermediate Algebra classes and between Geometry classes to validate the selection of one treatment class from each subgroup. Once statistical similarity was confirmed, both groups were compared to one another to note any differences between the grade-level Geometry students and the struggling Intermediate Algebra students. Within this breakdown was an additional sorting by topic and question so that each objective of the research might be separately analyzed. Finally, statistical analysis was completed comparing the pretest and posttest scores of the treatment classes to establish any significant changes in student perspective as a result of the treatment.

The qualitative data was then entered into a spreadsheet noting the question being answered, the direct quote from the student response, and coded based on several factors. The coding factors included whether a comment was especially insightful, whether it reflected affinity or aversion toward math, and any comments directly or indirectly reflecting student perspective of locus of control. This then allowed for a comparison of before and after quantitative results to be compared with qualitative results to triangulate and confirm consistency and patterns emergent from both sets of data.

Threats to Validity. As is the case in all quasi-experimental studies where random sampling and random assignment are not possible, it is possible that the treatment classes could be unique from the controls. Analysis of data demonstrated no significant differences between the Intermediate Algebra classes or between the Geometry classes, so this is unlikely, though it remains a possibility. As both these groups were assigned to their particular set of classes under consistent criteria (Geometry students randomly and Intermediate Algebra students by department faculty evaluation), it is believed that the individual classes were not statistically different, though still possible that Geometry and Intermediate Algebra were unique from one another given their different assignment criteria. Additionally, because the students were intentionally *not* randomly assigned to the Intermediate Algebra classes, it was expected that their results would not be generalizable outside of this unique sub-population. Approximately 8 students were unable to obtain parental permission, and 2 students from the treatment classes failed to complete the posttest, thereby further potentially affecting random selection.

To account for this, analysis was made to compare the treatment Geometry class to the treatment Intermediate Algebra class to assess those places where the Intermediate Algebra students were unique. This analysis found no significant differences between the two groups, and when the groups were combined for collective analysis on the larger sample size, only those items which had proved significant in each group individually were found to be significant for both groups.

Because the researcher is also the students' teacher, there is clear potential for the researcher's own enthusiasm for the hypotheses to affect student responses as well as analysis such that the researcher's vested interest in the results could affect the outcome. Therefore, no comments were made other than an introduction of the study before the pretest, and both the pretest and posttest were completed semi-anonymously, with coded initials simply to confirm receipt and to guarantee correct before-after comparisons. The ability to triangulate between quantitative and qualitative questions also helped to counteract responses which would be intended to impress rather than reflect beliefs. Even with this counter-measure, it does remain possible that students would answer what they believe the researcher wanted them to say rather than what they genuinely experience. Additionally, because a substantial amount of the survey relies on students' self-perception both now and in the past, the data could potentially be skewed under any of the following conditions: 1) if students were not sufficiently self-aware, 2) if students intentionally provided false data, or 3) if students could not accurately recall their previous state. While the first and third scenarios are unintentional errors, the second was mitigated by analysis demonstrating significant correlation before and after between all 12 pretest and posttest questions, confirming consistency in responses, and thus extremely unlikely to have been equally fabricated.

A known threat to validity in this study is in the failure to consider multiple variables and the interaction between them. Due to the timeframe of the study and the access offered to the researcher as a student teacher, the additional task of consistently applying multiple variables and interactions is beyond the scope of this research, though it is understood to have been a valuable inclusion.

Finally, as the data collection did not measure posttest results for the control groups, any changes between pre- and post- test scores found in the treatment group cannot be validly attributed to the treatment itself with certainty. Though unlikely that any alternate external treatment was the cause of any statistically significant changes found in the treatment groups' pretest and posttest results, it remains possible, thus failure to document the absence of change in the control groups' results substantially weakens potential claims to be made for the treatment groups. However, as the data will show, only one significant difference between the treatment group's pre- and post- test scores was noted, which, when combined with pretest statistical similarity between the control and treatment groups does allow for the reasonable assumption that the treatment is largely ineffective in improving mathematical self-concept. Additionally, qualitative data will be used to triangulate the interpretation of the one observed statistical difference, increasing validity. Because the methodology does not allow for the isolation of this variable, any causation attributed to the treatment must be made with caution. Thus, while the nature of the observed change will be discussed in full, the causes of the change are not conclusively determined by this study.

Data

Quantitative

Likert Scale Data. Quantitative data was collected via 5 point Likert scale for each of 12 questions. The responses highlight student understanding and self-concept within the mathematics setting, particularly perspectives on whether intelligence (within mathematics specifically) is a fixed given amount or varies with other skills and habits. Questions were within 4 general categories: the fixed nature of intelligence (questions 1, 5, and 8), external versus internal locus of control (questions 3, 6, 9, 11), comparing math to other subjects (questions 2 and 10), and feelings and attitudes toward math itself (questions 4, 7 and 12). Table 1.1 provides summary data of each of these, including mean scores and standard deviations before and after the treatment, as well as the pretest-posttest correlations and significance of both correlations and any changes noted.

Table 1.1 Comparison of Pretest and Posttest Mean, SD, Correlations and Significance

#	Question	Mean		Standard Deviation		Correla-tions	Significance	
		Before	After	Before	After		Correlations	Change
	The fixed nature of intelligence:							
1	I do well in my math classes because I'm just naturally good at math.	3.06	3.03	1.29	0.95	6.72	0.000	0.86
5	I think either you are born with a math-brain or you aren't.	3.06	2.51	1.03	1.07	0.32	0.060	0.013
8	I don't do well in my math classes because I'm just not good at math.	2.32	2.09	1.01	0.97	0.72	0.000	0.073
	External versus internal locus of control:							
3	I would do better in math if I worked harder.	3.71	3.77	1.20	0.65	0.33	0.053	0.773
6	I work hard at math because my parents expect me to.	3.03	2.89	1.15	1.05	0.54	0.001	0.431
9	I just can't get myself to do all the homework required for math classes.	3.34	3.31	1.23	1.15	0.61	0.000	0.869
11	I only do well in math if I have really good teachers.	3.83	3.60	1.07	1.19	0.41	0.016	0.283
	Comparing math to other subjects:							
2	My other classes aren't as difficult as math.	3.34	3.69	1.26	0.99	0.26	0.134	0.148
10	I don't think math is harder than any of my other subjects.	2.71	2.91	1.15	1.12	0.62	0.000	0.242
	Feelings and attitudes toward math itself:							
4	When I look at a math test, my brain just freezes.	2.82	2.88	1.34	1.41	0.87	0.000	0.624
7	Math requires memorizing lots of steps; I just can't remember all the steps.	3.26	3.03	1.20	1.15	0.68	0.000	0.16
12	Answers to math questions are either right or wrong; if you can't get the right answer, you're wasting your time.	2.74	2.47	1.16	1.08	0.56	0.001	0.152

Grade Level Estimates. An additional quantitative measure of student self-assessment was taken of affinity or aversion. Below is the number of students at each grade level who first recall experiencing the thought "I hate math!" or "I really like math!" These responses are reflected in Figure 1.1:

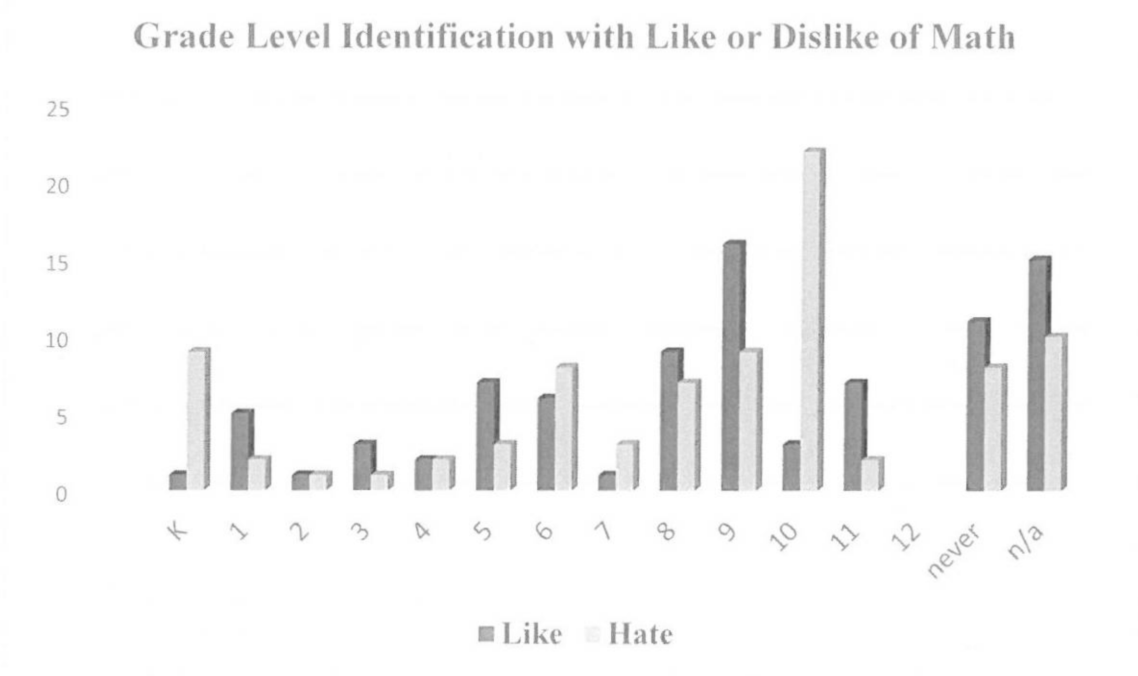

Figure 1.1. Grade level identification with like/dislike of math bar graph. This figure illustrates the grade levels at which students reported their first or most significant experience liking or disliking mathematics.

The differences between Intermediate Algebra and Geometry students ("like" was approaching significance; "hate" had a significant alpha of .049) demonstrated about one year between the average grade levels. While the overall average of all classes was 6.97 and 6.85 (equivalent to the end of 6th grade) for "like" and "hate" respectively, the Intermediate Algebra classes showed a consistency in their averages at 7.28 and 7.29 (mid-7th grade) respectively, while Geometry reflected experiencing those feelings nearly a year sooner, whether strong affinity or strong aversion: 6.68 and 6.43 (mid-6th grade) respectively.

Self-Concept. Additional quantitative data was collected of student self-concept. Student responses to the question asking them to answer one of the following: "I think of myself as 'good at math,'" "I think of myself as 'bad at math,'" or "I think of myself as 'average at math.'" are reflected below in Figure 1.2:

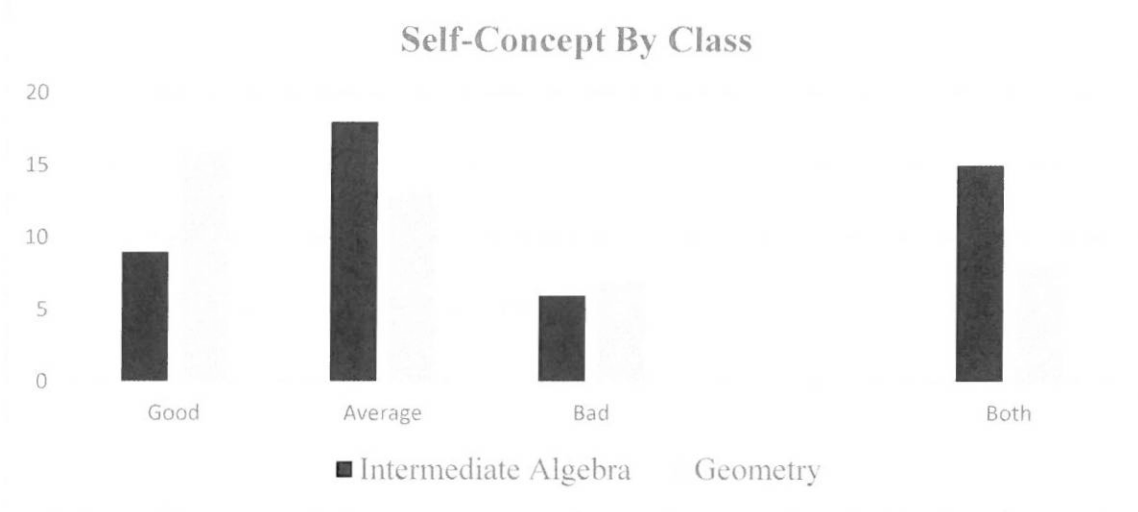

Figure 1.2. Intermediate Algebra and Geometry student self-concept evaluation bar graph. This figure illustrates how students from both classes self-identified as "good," "average," or "bad" at math.

Qualitative

Qualitative data was collected via open-ended questions prompting personal input. Questions on the pretest included comparing basic feelings about math versus other subjects. "Is it more interesting/totally boring? Is it harder/easier? Do you remember when (what grade) you first started to feel like this?" It also asked students to respond to one or more of the following phrases: "I think of myself as 'good at math' because," "I think of myself as 'bad at math' because," and "I think of myself as 'average at math' because" with the objective of gaining insight into overall self-concept. The posttest retained the self-concept question to compare before and after perspectives, and added the following questions, "What is one thing you learned from the packet about math ability that you didn't know previously?" and "What is one thing you learned from our research discussions that you wish you had known earlier?" to assess specific items which individual students might have considered significant or which, had they known earlier in their academic careers, might have impacted their current status.

Self-Concept. The question asking students to choose the self-concept that each felt described him- or herself best: "good," "bad," or "average" at math, also asked them to describe why they view themselves in this way. Excerpted pertinent quotes have been grouped by class and question, and reflect the breadth of comments from all 5 classes. The first table below, Table 2.1, reflects those students whose responses before and after were most different or specifically reflected an alteration in thinking from the pretest to the posttest.

Table 2.1 Altered Thinking

Intermediate Algebra Comments		
Student S	Before	"I can memorize systems well but sometimes fail when applying them to actual problems."
	After	"I dislike doing math but generally feel able to figure things out."
Student T	Before	"I really like math... I always do my best to get the math homework done on time."
	After	"I study more, I get more good at the math." [ESL]
Student U	Before	"I never have and never will like math. I understand it, yes, but I will NEVER like it."
	After	"I sometimes enjoy it."
Student V	Before	"Sometimes I understand math, and other times I don't understand."
	After	"I can use skills from different math units to help me solve a problem."
Geometry Comments		
Student W	Before	"I don't usually try. But when I do, I understand everything."
	After	"I don't try to the best of my ability."
Student X	Before	"I can use math outside of school in real life, not just hypothetical situations."
	After	"I can use my math 'know-how' to solve problems in real life."
Student Y	Before	"I understand & can easily use math in multiple ways."
	After	"I am persistent in math & continuously work at problems."
Student Z	Before	"I practiced myself back home and I even know many ways to solve an equation." [ESL]
	After	"I learned math in different levels and in different languages."

Table 2.2 below highlights comments that were made which suggested deeper, more critical thinking in evaluating reasons behind responses to any of the qualitative questions.

Table 2.2 Insightful Responses

Intermediate Algebra Comments	
Student M	"I am generally apathetic to math. I understand its importance, and I do feel proud when I accomplish a difficult concept, but just because I concede its importance does not mean I adore math."
Student N	Good because: "I like challenges." Bad because: "I give up easily on what I don't understand."
Student O	"Math is interesting when I understand the problem and know how to do it. It is really frustrating to not know how to do something and I lose interest in wanting to do it."
Geometry Comments	
Student P	"Math is a very important subject. Math is interesting, however it tends to be harder. I realized this in 7th grade."
Student Q	"I feel a sort of resentment for it because you must pay attention more than other classes, although it is easy."
Student R	"Every time I don't understand something and get frustrated I say I hate math but I know I don't; it's just difficult for me."

These perceptions potentially offer greater insight into the "why" behind student thinking. Table 2.3 then presents student-worded reasoning for self-concept in support of why they self-identified as "good at math," "bad at math," or "average at math," again grouped by class. Here we quickly gain a snapshot into the unique perspectives of students with different levels of confidence in their mathematical ability, and the reasons they offer for their confidence, or lack thereof.

Table 2.3 Self-Concept by Class and Category

Intermediate Algebra Comments	
Good	"I take my time to understand how things work, and the work is usually easy."
	"I actually try."
	"I always want to learn more!"
	"I actually pay attention and try."
	"Once I understand it I'm really good at it."
Bad	"I don't try to the best of my ability."
	"I can't get myself to memorize steps for math, but I am still determined to improve."
	"I don't have a good brain to remember every things." [ESL]
	"It takes a while for it to click; there are a lot of rules to remember."
Average	"I can memorize systems well but sometimes fail when applying them to actual problems."
	"I dislike doing math but generally feel able to figure things out."
	"Sometimes I understand math, and other times I don't understand."
	"I can use skills from different math units to help me solve a problem."
Geometry Comments	
Good	"I am able to think of many scenarios I could use it in and I am good at memorizing."
	"I can use math outside of school in real life, not just hypothetical situations."
	"I understand & can easily use math in multiple ways."
	"I practiced myself back home and I even know many ways to solve an equation." [ESL]
Bad	Because "it takes me longer to understand than everyone else. I can't keep up with the pace."
Average	"I don't usually try. But when I do, I understand everything."
	"I can get the stuff down and the homework done but when it comes to tests I suck."
	"I learned math in different levels and in different languages."

Locus of Control. The following comments on the next two pages were made by students when answering the question regarding when they noted that they liked or hated math in explanation of what it was that made them feel that way at the time. Their thinking reflects positively (Table 2.4) or negatively (Table 2.5) on multiple factors, revealing insight into student perspective of locus of control. These responses will be further grouped and explored more extensively in the Data Analysis.

Table 2.4 Locus of Control Reflected in Why Student Thought "I really like math!"

Intermediate Algebra Comments

6th grade because "I had a teacher that I understood what she was teaching and felt smart."

9th grade because "I was good at it and my mom praised me on good math grades."

8th grade because the teacher "took the time to teach me and I got good at it and then I liked it."

3rd grade because they had "a really good teacher and I loved to learn because she made learning fun and easy."

Middle School because "I had the best math teacher. He helped us work hard and wanted us to succeed. Motivation is what made me start to like math."

1st grade because "I was starting to know how to add and subtract and to count money in Mexico."

9th grade because it "was the best year. I would get A+'s on all my tests."

9th grade because "I realized the real world application of math and found it useful."

"This year because of the hands-on learning."

"5th Grade! Best Math Teacher Ever! It was elementary where we only have one class with all subjects, but my teacher was all about math."

"I've always liked math ever since I was little."

"I really like math... I always do my best to get the math homework done on time."

Geometry Comments

2nd grade because "my teacher taught us Sudoku and other math games."

6th and 9th "were my favorite grades." "Doing well has me enjoying math."

5th grade because "I thought that it was easy so I knew that I would like it."

PARENTAL 1st grade "when Dad would teach me my times tables while he walked me home from daycare."

"Every year at points when I actually understand the unit."

7th grade because "I had 100% all year."

"My 5th grade teacher was really good and also my 9th grade teacher."

"When my teacher said I was really good even though I talk a lot; he says algebra comes easy to me."

"9th grade, I think: I was determining orbital velocity of a satellite at 140,000m for a project."

"5th grade/6th grade because it was easy for me."

"When I was little I really liked math because I was one of the best."

"I was in grade 3. I understood before others and helped other classmates."

"I really began to like math in 8th grade because the teacher I had made it very interesting & motivated me."

"9th grade when I actually knew how to do it right and get the right answers, but it only lasted for like a quarter."

"I think that whenever I find math easy or not as challenging."

"I started to like math when I was in grade 9 when I started doing good."

Table 2.5 Locus of Control Reflected in Why Student Thought "I hate math!"

Intermediate Algebra Comments

"I miss a lot of school, meaning I don't come to class."

"I never have and never will like math. I understand it, yes, but I will NEVER like it."

8th grade because "it was the only class I had a bad grade in."

10th grade because "I didn't understand and she was a bad teacher and I didn't like her."

7th grade because they had "a horrible math teacher. She made me feel stupid and never really taught us."

"I've said this every time we have a test or quiz: mostly I'm just not good at math."

10th grade because "I didn't like the teacher. She wasn't patient and moved on to new subject whether or not we fully understood the last one."

(Never good!) "Mostly kindergarten and 0-6th grade. Now I don't care."

4th grade: "My math work was very sub-par because I believed math wasn't as important as I was told."

In 5th grade "when everyone else was faster at grasping the concept of fractions."

"All the time. It's long and confusing and just pisses me off. *Every* grade."

Geometry Comments

"I have never thought of liking math because I suck."

1st grade because "my teacher was mean and strict/hard."

Usually likes it, but "when I don't get it, it becomes hard to enjoy."

8th grade (last year) because "I had a difficult time at got a B."

"I have always disliked math through all grades."

"Every year if I'm really confused."

Middle School: "almost everyday since middle school. Not my subject."

"All the time. Ever since I was little."

"8th grade. My teacher was really scary."

"9th grade because my teacher wasn't much help."

"This year and last year because sometimes it's really frustrating even though I'm generally good at it."

"In the 6th grade I didn't like math because it was easy & I disliked the way my teacher taught."

"When math is a struggle/challenge for me."

"When I was young I hated math, because I was having problems."

Posttest Learning. Excerpted pertinent quotes have been grouped by class for comments in response to the questions "What is one thing you learned from the packet about math ability?" (Table 2.6), and "What is one thing you learned from our research discussions that you wish you had known earlier?" (Table 2.7) which were included in the posttest for the treatment classes. Their responses have again been grouped by class for potential analysis of any themes which might differ between the struggling Intermediate Algebra and grade-level Geometry students.

Table 2.6 Something New Learned from the Packet about Math Ability

Intermediate Algebra Comments
If you try and challenge yourself you will understand it.
You have to continue to practice to even stay where you are intellectually.
You can develop skills.
That apparently brain size correlates to intelligence.
Your brain grows & you never stop learning.
You can become good at math.
That you're not just born knowing it or how good you're going to be at something.
That everyone has it; you just have to work at it.
Your brain grows when you challenge yourself in something you weren't really good at.
Geometry Comments
That students with goals have better grades than student without goals.
Everyone can be good at math.
If I practice, I will be better at it.
Your brain continues to develop.
One can grow their mind at will by practicing and honing abilities.
I was unaware it doesn't matter what kind of brain you have.
Those who learn will actually prosper more financially than those who just perform.
I didn't know that you could make yourself good at math.
I learned that continuously working at math can physically make your brain grow.
That doing math will grow your brain and you'll get smarter.
The brain grows as you learn.
I learned that students with goals have better grades.
That the reason people aren't good at math is because previous math teachers were not good at it.

Note that the above is more likely to reflect factual knowledge and learning from the presented content, while the following is more likely to reflect personal experience: something of which the student personally wished they had previously been aware.

Table 2.7 Something New Student Wished They Had Known Earlier

Intermediate Algebra Comments
If you practice harder problems tests will be easier.
Hard work determines skill.
Your math teachers affect your math skills in a way.
To study more to make my brain grow and expand.
People aren't born with certain math abilities.

Geometry Comments
That you can exercise your brain.
That if the teacher was scared, that reflects on students.
I wish I had known more about learning and practicing.
How learning affects the brain.
People that say they aren't smart aren't willing to [work to] achieve [good] grades.
That persistence is key if you don't get something.
Simply doing [something as a] performance may in fact hinder you instead of help you.
That saying you "can't" is not valid or a good thing, but trying harder will help more.
Math isn't about how 'smart' you are.
Practicing is like exercising.
Better study skills [would have helped].
When people learn and practice new ways of doing algebra or statistics, it can grow their brains.
If you ask more questions you will learn more and get smarter.
Ask questions.

Data Analysis

Quantitative data was statistically analyzed to identify any trends within the subject population for origins or severity of poor self-concept and high anxiety, as well as comparison of any changes between pretest and posttest for treatment groups. Inquiry utilized statistical analysis, seeking to disprove the null hypothesis that there is no pattern to the data, thereby demonstrating the trend. Qualitative data was entered verbatim by question, allowing for axial coding of similar responses to ascertain any potential deeper, more significant trends in student self-concept and anxiety experience. Quantitative and qualitative results were then compared to note any similarities and differences in order to confirm accuracy of analysis through triangulation.

Quantitative

Likert Scale Data. Of the twelve Likert scale questions for which quantitative data was collected on the treatment classes from the pretest and posttest, ultimately only one question proved to demonstrate a significant change with an alpha of .013: question 5, "I think either you are born with a math-brain or you aren't." While this appears to be a positive sign in the midst of a lack of any other significant findings, it is actually even more interesting to compare this finding to questions 1 ("I do well in my math classes because I'm just naturally good at math") and 8 ("I don't do well in my math classes because I'm just not good at math") which were also in the same category of questions: the fixed nature of intelligence. Neither question 1 nor question 8 proved to be significant (alphas of .860 and .073 respectively), though all three questions were developed to measure the same concept.

What becomes apparent, and will be later corroborated by qualitative analysis, is that both questions 1 and 8 are personal evaluations: "*I* do well…" or "*I* don't do well…" while question 5 measures the concept much more generally: "*you* are born with… or *you* aren't." Thus, while it is true and significant that the students now more fully understand that intelligence is incrementally malleable through the positive incremental cognitive messages methods discussed and studied in the packet, they remain unable to connect it to their own experience or unwilling to believe that it also applies to them personally. Without this personal connection, little effect on self-concept or math anxiety can be expected, thus in order to see positive changes in these arenas, future research must more effectively encourage students to connect the information to their own experience.

Questions regarding locus of control (questions 3, 6, 9, 11), comparing math to other subjects (questions 2 and 10), and feelings and attitudes toward math itself (questions 4, 7 and 12) showed no significant change, though all twelve questions did demonstrate extremely significant correlation from pretest to posttest, indicating that the students were consistent in their reading of and response to the questions.

Grade Level Estimates. An important objective of this study was in understanding at what grade level students first recall experiencing the thought "I hate math!" or "I really like math!" It was also important to compare the struggling Intermediate Algebra students to the grade-level Geometry students in order to see if there was a point at which the two groups might have diverged on their separate paths.

As was reflected above in the data, there was approximately a one year difference for both strong affinity and strong aversion between Intermediate Algebra and Geometry students for "like" (approaching significance) and "hate" (significant alpha of .049) between the average grade levels, with Intermediate Algebra students experiencing both later. Figure 3.1 below helps to separate the two so that their trending is more apparent.

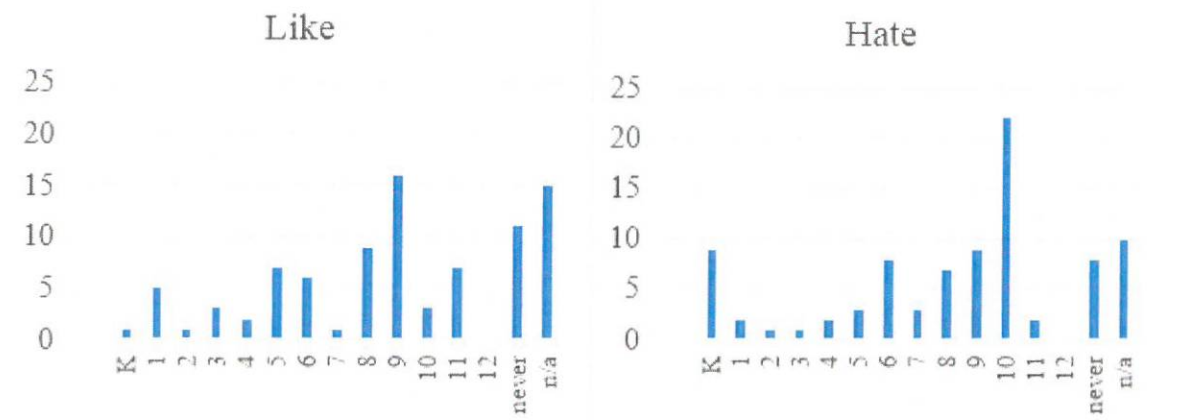

Figure 3.1. Grade level identification isolated by like/dislike of math bar graph. This figure isolates the grade levels at which students reported their first or most significant experience liking mathematics from disliking mathematics.

Several interesting facts become apparent in this view, namely that strong negative feelings of aversion are attributed to a much younger age than strong feelings of affinity toward mathematics: only one student claimed to have "always" liked math, while nine claimed to have "always" hated it. There is also a notable difference in the peaks of both curves, as 10th grade (usually Geometry) reflects the greatest aversion with very few preferences, while affinity peaks in 9th grade where there are still quite a few negative feelings. Another interesting feature is noting that 7 students, all from Intermediate Algebra, claim to have liked math for the first time in 11th grade, indicating that the intervention class in which they are now participating is meeting their needs and drawing their interest in a way not previously experienced, inviting further inquiry.

Self-Concept. The final area of quantitative data collected was of student self-concept, as they identified with one of the following: "I think of myself as 'good at math,'" "I think of myself as 'bad at math,'" or "I think of myself as 'average at math.'" Below, Figure 3.2 provides a breakdown of the variances between the struggling

Intermediate Algebra students and their grade-level Geometry counterparts who self-identified as "good," "bad," or "average" at math.

Figure 3.2. Student self-concept identification isolated by class pie chart. This figure isolates student self-concept percentages as identified by Intermediate Algebra and Geometry students separated by class type.

Here several interesting insights surface. Clearly visible here is the expectation that a greater percentage of successful students (36%) would feel "good" about themselves than would the struggling students (19%). What was surprising, however, was that there was no statistical difference between the percentages that identified as "average" (30% versus 37%) or "bad" (16% versus 13%) at math. The research hypothesis had anticipated a much poorer self-concept within the Intermediate Algebra students, as they had been placed in the class directly as a result of poor performance, thus it was actually a significant finding that this assumption did not hold true. This apparent contradiction will be considered more fully in suggestions for future research. The remaining difference in results was because of students in both classes who selected more than one choice: future research would benefit from clearer instructions to only choose one.

Qualitative

Qualitative data was collected via open-ended questions prompting personal input. Questions on the pretest included comparing basic feelings about math versus other subjects. "Is it more interesting/totally boring? Is it harder/easier? Do you remember when (what grade) you first started to feel like this?" It also asked students to respond to one or more of the following phrases: "I think of myself as 'good at math' because," "I think of myself as 'bad at math' because," and "I think of myself as 'average at math' because" with the objective of gaining insight into overall self-concept. The posttest retained the self-concept question to compare before and after perspectives, and added the following questions, "What is one thing you learned from the packet about math ability that you didn't know previously?" and "What is one thing you learned from our research discussions that you wish you had known earlier?" to assess specific items which individual students might have considered significant or which, had they known earlier in their academic careers, might have impacted their current status.

Self-Concept. As the data presented earlier in Table 2.1 is observed, it does demonstrate that for at least a few students, there was an impact on self-concept produced by the treatment. By comparing comments from these students whose responses before and after reflected an alteration in thinking, the potential for positive cognitive messages regarding incremental nature of intelligence is both confirmed and challenged. The following addresses insight offered by several of the students in Table 2.1, first focusing on the Intermediate Algebra students.

Both Student S's, "I can memorize systems well but sometimes fail when applying them to actual problems," and Student V's, "Sometimes I understand math, and other times I don't understand" comments in the pretest, reflecting their understanding of Boaler's (2008) indicted "ladder" of mathematical thinking, yet their posttest comments of "I… generally feel able to figure things out" and "I can use skills from different math units to help me solve a problem" reflect a powerful change in understanding toward seeing mathematics as a body of tools available for persistent problem-solving. Student U's before and after comments are dramatic: "I will NEVER like it" becomes "I sometimes enjoy it." Though likely that other factors were also at play in such a dramatic transformation, it is clear that something has altered for Student U.

Interestingly, however, the comments made before and after by the Geometry students reflect much more nuanced impact, and in fact demonstrate that for at least these 4 students, they had previously understood the importance of perseverance and utilizing mathematics as a body of tools. Student W admits beforehand that "I don't usually try, but when I do, I understand everything," while noting afterward that "I don't try to the best of my ability" showing his new deeper understanding of the importance of perseverance. Similarly, Student Y's comments reflect the same idea, with new vocabulary for describing her meaning: "I can easily use math in multiple ways" becomes "I am persistent in math and continuously work at problems."

Thus, the hypothesis that the treatment would have greater significance for struggling students than for grade-level students seems corroborated by the substantial changes that were noted in 4 of the 48 Intermediate Algebra students' perspectives, while only very minute changes were noted within the 44 Geometry students.

As the data summarized in Table 2.2 is evaluated, several more insightful comments surface. Intermediate Algebra students M and O both offer insight into the connection between the excitement experienced with success and the frustration experienced with failure: "I do feel proud when I accomplish a difficult concept" and "Math is interesting when I understand the problem and know how to do it. It is really frustrating to not know how to do something and I lose interest in wanting to do it." Both of these comments reflect how affinity is based on whether the problem is easy or challenging, yet an understanding of the feeling of pride achieved with persistence. Student N presents this idea more bluntly, describing himself as simultaneously good and bad at math: 'good' because "I like challenges;" 'bad' because "I give up easily on what I don't understand." Student M offers additional insight as she describes the importance of mathematics (where other struggling students more readily offer the familiar adage "when am I going to use this anyway?"), yet genuinely feels no interest or affinity toward it: "Just because I concede its importance does not mean I adore math."

Geometry's Student R concurs with this thinking as she notes, "Every time I don't understand something and get frustrated I say 'I hate math' but I know I don't; it's just difficult for me." Students P and Q also reflect on how math is more difficult than other subjects, which affects their overall feeling toward it. Student P notes that while it is very important and interesting, math "tends to be harder," and Student Q adds emotion to the thinking, stating, "I feel a sort of resentment for it because you must pay attention more than other classes." Clearly affinity and aversion are again very linked to daily successes or failures for students from both classes.

Understanding the reasoning behind self-concept continues on a more focused level as Table 2.3 is evaluated. Here differences between struggling and grade-level students are often apparent in their verbiage. Of the 5 most specific comments made by

Intermediate Algebra students viewing themselves as "good" at math, 3 specifically note that self-concept is based on their work ethic: "I take my time to understand," "I actually try," and "I actually pay attention and try." Of these 3, the final two also reveal an assessment of their classmates, passively implying that their peers do not pay attention or try. Understanding that effort results in success is key in student ownership of internal locus of control, but it is also interesting to note that the focus retains an external comparison—it is not just about doing one's best, but about doing better than one's classmates. The other two students note either a passion for learning, "I always want to learn more!" or a confidence in his or her ability to retain learning once it has been mastered: "Once I understand it I'm really good at it."

Interestingly, the commentary by all four Geometry students focuses not on effort or a comparison to classmates, but on understanding how to utilize math flexibly: "I am able to think of many scenarios I could use it in," "I can use math outside of school in real life, not just hypothetical situations," "I understand and can easily use math in multiple ways," and "I even know many ways to solve an equation." This is a powerful difference in perspective, particularly noting the similarity in responses between the Intermediate Algebra students and between the Geometry students. It reflects not only on the way in which even the more successful struggling students still see math as something that requires hard, perhaps tedious, work, while the successful students see it as an enjoyable, flexible tool which they apply at will even when not required to do so.

In observing Intermediate Algebra students who report self-concept as "bad at math," there is again a focus on Boaler's (2008) "ladder" due to a belief that math is dependent on memorization. Three of the four students point to this reasoning as they describe why they see themselves in this light: "I can't get myself to memorize steps," "I don't have a good brain to remember," and "there are a lot of rules to remember." The consistency in these comments confirms Boaler's (2008) research and objective that teachers would intentionally work to combat this line of thinking which is not present in those with a positive self-concept. Clearly, this confirms the importance of overtly addressing this topic with this student population in the future.

In looking for patterns in those students with "average" self-concept presented in Table 2.3, no theme emerges. Each student, within both Intermediate Algebra and Geometry, seems to focus on a balance of something they do well and something they do poorly, resulting in an overall "average" performance, yet none of these foci are duplicated, thus no further conclusions are drawn.

Locus of Control. One particular arena of insight that rose somewhat unexpectedly out of the qualitative data summarized in Tables 2.4 and 2.5 was that of student understanding of locus of control. Two particular themes were clear as each student backed up their reason for a particular moment in their student career at which they recall thinking "I really like Math!" or "I hate Math!" First, that affinity and aversion are dependent on the teacher (rather than self), second, that affinity *follows* success, while difficulty or struggle with math are the sources of aversion.

Of these two, the broadest is evident in both the positive and negative for both Intermediate Algebra and Geometry: that a good teacher causes one to like math, and a bad teacher can ruin math forever. This line of thinking is apparent in numerous positive quotes such as "[he] took the time to teach me and I got good at it and then I liked it," and "5th grade—Best Math Teacher Ever!" from Intermediate Algebra students to "I really began to like math in 8th grade because the teacher I had made it very interesting" from a Geometry student. Similarly, negative quotes reflect on the teacher as well: "she was a bad teacher and I didn't like her," or "I didn't like the teacher. She wasn't patient and moved on to new subjects whether or not we fully understood the last one" from Intermediate Algebra students, while a Geometry student traced his dislike of mathematics back to the first grade when "my teacher was mean and strict/hard" and another noted the same in 8th grade because "my teacher was really scary."

The second theme that emerged was far stronger within the Geometry classes than the Intermediate Algebra classes. While only 4 quotes out of 23 in Intermediate Algebra reflected the thinking that students liked math after succeeding or disliked it after struggle, 15 of the 30—*half*—quotes from Geometry indicated in some way that affinity follows success. While it is to be expected that fewer of the struggling students would have experienced success to attribute positive thinking, they would be expected to have had plenty of opportunities to attribute the negative thinking to failure, but this did not prove to be the case. On the other hand, the grade-level students clearly were fixed on this thinking. Consider the following reasoning presented for affinity: "doing well has me enjoying math," "because I had 100% all year," "because I was one of the best," or "I started to like math when I was in grade 9 when I started doing good." Each of these is as overt as it could be in communicating the perspective that something one does well is something one can like. Equally clear are the following reasons presented to explain aversion: "I have never thought of liking math because I suck," "when I don't get it, it becomes hard to enjoy," and "when I was young I hated math because I was having problems." All of these reflect the thinking that if it is difficult, it isn't likable.

Posttest Learning. Tables 2.6 and 2.7 present quotes from student comments to new questions included on the treatment classes' posttest as to what they had learned from the treatment lessons and the packet. More specifically, it asks for anything they learned which they wished they had known earlier in their student careers. Here again, the understanding of the broader concept that one has the ability to develop one's intelligence through persistence and challenge is reflected in 19 of the 22 Table 2.6 responses, yet at the same time, only *one* of the 19 statements reflects conviction or belief that this is a personally applicable concept: "If I practice, I will be better at it."

Table 2.7 is worded to encourage more personal application, asking students to identify something they wished they had known earlier. The same phenomenon holds true, as only 3 of the 19 comments here reflect a personal connection: "[I wish I had known] to study more to make my brain grow and expand," "I wish I had known more about learning and practicing," and "[I wish I had known] better study skills," while the other 16 comments hold the learned concepts at arms' length: "Math isn't about how 'smart' you are," "If you ask more questions you will learn more and get smarter," "Practicing is like exercising," or "People aren't born with certain math abilities." Again, the students demonstrate that they believe, understand, and have internalized the research; again, they do not believe it is true of their own experience.

Implications

Further Inquiry

More research is needed to understand the non-intuitive results that statistically equivalent percentages of the grade-level and struggling students report average or poor self-concept. The findings discussed earlier clearly suggest future inquiry into whether grade-level students consider themselves poorer students than they actually are or whether struggling students consider themselves better than they actually are. Additional inquiry is also recommended into the possible effect on self-concept that the intervention class itself offers to struggling students in addressing learning styles and needs previously unmet in the traditional classroom, an idea supported by the substantial number of students who noted the intervention class was the first year they had noted affinity toward math. This would likely entail a medium-term longitudinal study, evaluating students at the end of the grade-level Algebra 1 course when they have most recently been recommended for the Intermediate Algebra class, and then again at the end of the Intermediate Algebra course after the intervention has occurred. In fact, these findings would not only prove interesting, but could potentially affect district policy on the controversial topic of tracking within mathematics.

Should a similar study be repeated, both qualitative and quantitative questions of specific locus of control would be a valuable addition, as would clearer instructions for selecting only one self-concept. The inclusion of a posttest for control groups as well as treatment groups is critical for any study to ensure that any significant changes can be validly attributed to the treatment. Although the current study only found one significant difference in pre- and post- test scores, should future studies have greater success, this inclusion will be essential for demonstrating causality.

Perhaps the most crucial critique is in the need for the treatment itself to be developed. While the packet provided a suitable foundation for presenting the research in student-friendly terminology, the 10 days of instruction and discussion were both insufficient to address all potential locus of control misunderstandings, and clearly insufficient for encouraging students to internalize their understanding and see their own self-concept impacted. Additional trials should work to include time and space for overt self-analysis by the students while more directly having daily topics address the locus of control perspectives. And finally, utilizing the treatment with younger students would allow for evaluating the impact before self-concept is fully ingrained, as most of the Intermediate Algebra students in this study were in their final year of math requirements, and thus not as likely to care about the instruction. Therefore, a middle school trial would be an interesting and potentially more effective intervention, as it would address locus of control at the time students would be most situated to apply the understanding.

Recommendations

What this does mean for students right now is that any treatment in addressing self-concept must also include an element of self-evaluation in order for students to note any personally applicable impact on how they view themselves within the mathematics classroom. Second, though it was assumed, the data does confirm that affinity and aversion are closely linked to success or failure. This points to the value of addressing the importance of persistence over the importance of getting ‘the right answer’ so that students can experience the high of success regardless of the ease of completion.

Clearly the bulk of observations made as a result of this study are supportive of Boaler’s (2008) research. Though this study does present data indicating that tracking of lower abilities actually has a greater positive impact on self-concept of struggling students in contrast to her research on tracking, all other points did confirm the critical importance of addressing—and seeking to transform—student perspectives of math from that of a body of tools from which to pull rather than a ladder of steps to memorize

(Boaler, 2008). All of these are important additions to Im's (2012) positive incremental cognitive messages exposure: students must not only understand that one's intelligence is malleable, but also understand and apply the tools available for growing, developing and strengthening one's intelligence.

Finally, this study demonstrates both qualitatively and quantitatively that student experience of strong affinity or aversion often stretches back to their first experiences in the classroom, but is most often cemented in middle school or the first two years of high school. Furthermore, this perspective is intimately tied with the student's positive or negative experience of the teacher. Because of this, it is critical 1) that middle schools formally address these concerns and seek to understand student affinity or aversion before it is set in stone, and 2) that teachers take the time to purposefully address locus of control topics with students, to help students understand the control they do have, and the reality that the teacher does not define their success and need not define their affinity.

Conclusions

In summary, several key points were noted in qualitative and quantitative analysis of student mathematical self-concept. First, distinct qualitative impact of positive cognitive incremental messages was overall very slight on individuals within the general student population, yet significant changes did occur for students within the struggling student population. Second, regardless of subgroupings, the only statistically significant quantitative change demonstrated was in students' increased perception that intelligence is a malleable construct and that individuals have control over it. Ironically, this finding was juxtaposed with the finding that student perception of their own intelligence remained unchanged as a fixed construct. This apparent contradiction is perhaps the most significant finding of the study: that while students may understand these concepts in the abstract, identifying means by which to connect the research and data to their own personal experience is the key to deeply impacting student self-concept.

Finally, qualitative inquiry into timeframes at which students identified liking or hating math reflected more on student perspective of locus of control: either a teacher was to be credited with or blamed for the student's experience, or being successful was a pre-requisite for affinity. Quantitative inquiry noted that negative experience is often ingrained very early on, but for most students their permanent affinity or aversion is established between 8^{th} and 10^{th} grade.

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Appendices

Appendix A: Survey Pretest

Survey: Pretest

Initials: ____ Gender: _____ Grade: _____ Period: _____

1. Describe your basic feelings about math versus other subjects. Is it more interesting/totally boring? Is it harder/easier? Do you remember when (what grade) you first started to feel like this? ____

   ____

   ____

2. Please answer one of the following:

   I think of myself as "good at math" because ____

   ____

   I think of myself as "bad at math" because ____

   ____

   I think of myself as average at math because ____

   ____

3. Do you ever remember a specific time when you thought to yourself, "I really like math!"? About what grade you were in? Do you remember what happened that made you think it? ____

   ____

   ____

4. Do you ever remember a specific time when you thought to yourself, "I really hate math!"? About what grade you were in? Do you remember why you thought it?

   ____

   ____

MATHEMATICAL SELF-CONCEPT

1. *I do well in my math classes because I'm just naturally good at math.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

2. *My other classes aren't as difficult as math.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

3. *I would do better in math if I worked harder.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

4. *When I look at a math test, my brain just freezes.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

5. *I think either you are born with a math-brain or you aren't.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

6. *I work hard at math because my parents expect me to.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

7. *Math requires memorizing lots of steps, and I just can't remember all the steps.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

8. *I don't do well in my math classes because I'm just not good at math.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

9. *I just can't get myself to do all the homework required for math classes.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

MATHEMATICAL SELF-CONCEPT

10. I don't think math is harder than any of my other subjects.

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

11. I only do well in math if I have really good teachers.

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

12. Answers to math questions are either right or wrong, and if you can't get the right answer, you're wasting your time.

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

Appendix B: Survey Posttest

Survey: Posttest

Initials: ____ Gender: _____ Grade: _____ Period: _____

1. Please answer one of the following:

   I think of myself as "good at math" because ______________________________

   ____

   I think of myself as "bad at math" because ______________________________

   ____

   I think of myself as average at math because ______________________________

   ____

2. What is one thing you learned from the packet about math ability that you didn't know previously? ____

   ____

3. What is one thing you learned from our research discussions that you wish you had known earlier? ____

   ____

1. I do well in my math classes because I'm just naturally good at math.

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

2. My other classes aren't as difficult as math.

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

3. I would do better in math if I worked harder.

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

MATHEMATICAL SELF-CONCEPT

4. *When I look at a math test, my brain just freezes.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

5. *I think either you are born with a math-brain or you aren't.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

6. *I work hard at math because my parents expect me to.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

7. *Math requires memorizing lots of steps, and I just can't remember all the steps.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

8. *I don't do well in my math classes because I'm just not good at math.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

9. *I could get smarter at math if I had clearer goals and study skills.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

10. *I just can't get myself to do all the homework required for math classes.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

11. *I don't think math is harder than any of my other subjects.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

12. *I only do well in math if I have really good teachers.*

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

13. Answers to math questions are either right or wrong, and if you can't get the right answer, you're wasting your time.

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

14. I can grow my intelligence by working on problems that are challenging.

Strongly Disagree	Disagree	Don't know/ Neutral	Agree	Strongly Agree
□	□	□	□	□

Appendix C: Cognitive Incremental Messages Packet

Name ______________________

Day 1:
Research shows you have the ability to change your total intelligence by exercising your brain. Overall intelligence, including math ability, can be incrementally increased through persistence and effort. If you think you don't have the brains for something, just like any other muscle, you can build intelligence with exercise (Im, p. 44-44, 99).

Day 2:
Reading—YOU CAN GROW YOUR BRAIN: New Research Shows the Brain Can Be Developed Like a Muscle

But most people don't know that when they practice and learn new things, parts of their brain change and get larger, a lot like the muscles do. This is true even for adults. You can improve your abilities a lot, as long as you practice and use good strategies. Inside the outside layer of the brain—called the cortex—are billions of tiny nerve cells, called neurons. The nerve cells have branches connecting them to other cells in a complicated network. Communication between these brain cells is what allows us to think and solve problems. When you learn new things, these tiny connections in the brain actually multiply and get stronger. The more you challenge your mind to learn, the more your brain cells grow.

Day 3:
Students with goals have better grades than students without goals. By setting clear expectations for yourself, you will have a reason for trying and a goal to work toward, which will help to keep you focused, and perhaps most importantly, makes learning more enjoyable (Blackwell et al., 2007; Dweck, 1999; Kennett & Keefer, 2006, Ladd, p. 137-139).

Day 4:
Students who have had two teachers who get anxious about math are nearly twice as likely to believe they aren't good math as students who have had only teachers who are confident about math. In fact, one of the biggest predictors of low self-confidence in math in a student is the number of teachers that student has had who are math-anxious.

Day 5:
Reading—YOU CAN GROW YOUR BRAIN: Can Adults Grow Their Brains?

Scientists have recently shown that adults can grow the parts of their brains that control their abilities—like the ability to do math or even to juggle. In one study, scientists found that people who learned how to juggle actually grew the parts of their brains that control juggling skills—the visual and motor areas. Their brains had changed, so they actually had more ability. These people said before the study that they couldn't juggle—just like some people say they're "not good at math." But when they learned good strategies for practicing and kept trying, they actually learned and grew their brains. This can happen because learning causes permanent changes in the brain. The jugglers' brain cells get larger and grow new connections between them. These new, stronger connections make the juggler's brain stronger and smarter, just like a weightlifter's toned muscles.

Day 6:
Students who ask the most questions are usually the highest-achieving. Thinking critically about what the teacher is teaching and making sure you understand well enough to ask questions, not just take notes, is the best study skill out there.

Day 7:
Most math books break everything you're learning down into steps, so students think it is a series of steps like a ladder that you have to do one at a time. Instead, try thinking about math as a set of skills that you need to pull from to solve bigger questions. Once you're in the real world, you won't be using one math skill at a time—you'll need to decide which ones are needed for each new challenge (Boaler, p. 151).

At least one study followed students who started high school as high-performers and were taught math skills as steps to memorize and low-performers but were taught math skills as problem solving tools. Once in the workforce, the "low-performing" students actually did better than their parents financially, and the "high-performers" made less money than their parents. Don't write yourself off just because you don't test well in math—you might be math-smart in the way that actually makes money (Boaler, p. 81)!

Day 8:
Reading—YOU CAN GROW YOUR BRAIN: A Formula For Growing Your "Math Brain":

Scientists have also found that learning to juggle is a lot like getting better at math. When people learn and practice new ways of doing algebra or statistics, it can grow their brains— even if they haven't done well in math in the past. Strengthening the "math" part of your brains usually happens when you try hard on challenging math problems. But it's not just about effort. You also need to learn skills that let you use your brain in a smarter way. If you use a bad strategy, you may not learn—even if you try hard. If a weight lifter watched other people exercise all day long, he wouldn't get any stronger. And if someone tried to learn how to juggle by just reading a book about juggling, they wouldn't learn. You actually have to practice the right way—and usually that means the hard way—to get better at something. In fact, scientists have found that the brain grows more when you learn something new, and less when you practice things you already know. People often learn those good strategies from others, like teachers or students who do well.

Day 9:
Students who understand that learning requires persistence also don't blame their failures on a lack of ability—they are willing to change their learning strategies (study more, ask more questions, etc.) and ultimately succeed (Blackwell et al., 2007).

Day 10:
Reading—ATTACHED ARTICLE: "Motivation in an Academic Setting: An Essay"

Answer the questions at the end.

YOU CAN GROW YOUR BRAIN
DAY 2—New Research Shows the Brain Can Be Developed Like a Muscle

Many people think of the brain as a mystery. We don't often think about what intelligence is or how it works. And when you do think about what intelligence is, you might think that a person is born either smart, average, or dumb—either a "math person" or not—and stays that way for life. But new research shows that the brain is more like a muscle— it changes and gets stronger when you use it. Scientists have been able to show just how the brain grows and gets stronger when you learn.

Everyone knows that when you lift weights, your muscles get bigger and you get stronger. A person who can't lift 20 pounds when they start exercising can get strong enough to lift 100 pounds after working out for a long time. That's because muscles become larger and stronger with exercise. And when you stop exercising, the muscles shrink and you get weaker. That's why people say "Use it or lose it!"

But most people don't know that when they practice and learn new things, parts of their brain change and get larger, a lot like the muscles do. This is true even for adults. So it's not true that some people are stuck being "not smart" or "not math people." You can improve your abilities a lot, as long as you practice and use good strategies.

Inside the outside layer of the brain—called the cortex—are billions of tiny nerve cells, called neurons. The nerve cells have branches connecting them to other cells in a complicated network. Communication between these brain cells is what allows us to think and solve problems. When you learn new things, these tiny connections in the brain actually multiply and get stronger. The more you challenge your mind to learn, the more your brain cells grow.

Then, things that you once found very hard or even impossible to do—like speaking a foreign language or doing algebra—become easier. The result is a stronger, smarter brain.

How Do We Know That The Brain Can Grow Stronger?

Scientists started thinking the human brain could develop and change when they studied adult animals' brains. They found that animals who lived in a challenging environment, with other animals and toys to play with, were different from animals who lived alone in bare cages. While the animals who lived alone just ate and slept all the time, the ones who lived with different toys and other animals were always active. They spent a lot of time figuring out how to use the toys and how to get along with other animals.

These animals had more connections between the nerve cells in their brains. The connections were bigger and stronger, too. In fact, their whole brains were about 10% heavier than the brains of the animals who lived alone without toys. The adult animals who were exercising their brains by playing with toys and each other were also "smarter" –they were better at solving problems and learning new things.

DAY 5—Can Adults Grow Their Brains?

Scientists have recently shown that adults can grow the parts of their brains that control their abilities—like the ability to do math or even to juggle.

In one study, scientists found a group of adults who were not jugglers. They taught half how to practice juggling in the right way. These people practiced for a long time and got much better at juggling. The other half didn't practice, and didn't get better. Next, the scientists used a brain scanner to compare the brains of the two groups of people. They found that the people who learned how to juggle actually grew the parts of their brains that control juggling skills—the visual and motor areas. Their brains had changed, so they actually had more ability. This was surprising because these people said before the study that they couldn't juggle—just like some people say they're "not good at math." But when they learned good strategies for practicing and kept trying, they actually learned and grew their brains.

This can happen because learning causes permanent changes in the brain. The jugglers' brain cells get larger and grow new connections between them. These new, stronger connections make the juggler's brain stronger and smarter, just like a weightlifter's toned muscles.

DAY 8—A Formula For Growing Your "Math Brain": Effort + Good Strategies + Help From Others

Scientists have also found that learning to juggle is a lot like getting better at math. When people learn and practice new ways of doing algebra or statistics, it can grow their brains— even if they haven't done well in math in the past. Strengthening the "math" part of your brains usually happens when you try hard on challenging math problems. But it's not just about effort. You also need to learn skills that let you use your brain in a smarter way.

If you use a bad strategy, you may not learn—even if you try hard. A few people study for math by doing the same set of easy problems and skipping the hard ones, or just re-reading the textbook, because it feels easier. Yet when it comes time to do the test, they don't do well because they didn't work on problems that stretched their brains and taught them new things. When this happens, they may even say "I'm just not smart at math."

But the truth is that everyone can become smarter at math if they practice in the right way. If a weight lifter watched other people exercise all day long, he wouldn't get any stronger. And if someone tried to learn how to juggle by just reading a book about juggling, they wouldn't learn. You actually have to practice the right way—and usually that means the hard way—to get better at something. In fact, scientists have found that the brain grows more when you learn something new, and less when you practice things you already know.

This means that it's not just how much time and effort you put in to studying math, but whether, when you study, you learn something new and hard. To do that, you usually need to use the right strategies. People often learn those good strategies from others, like teachers or students who do well. Luckily, strategies are easy to learn if you get help.

The Truth About "Smart" and "Dumb"

People aren't "smart" or "dumb" at math. At first, no one can read or solve equations. But with practice, they can learn to do it. And the more a person learns, the easier it gets to learn new things—because their brain "muscles" have gotten stronger. This is true even for adults who have struggled for a long time to learn something. Dr. Wittenberg, a scientist from Wake Forest University, said "We used to think adults can't form new brain connections, but now we know that isn't true… The adult brain is like a muscle, and we need to exercise it." People who don't know this can miss out on the chance to grow a stronger brain. They may think they can't do it, or that it's too hard. It does take work to learn, just like becoming stronger physically or becoming a better juggler does. Sometimes it even hurts! But when you feel yourself get better and stronger, you realize that all the work is worth it!

References:

A similar version of this article was written by Lisa Blackwell and can be downloaded from: www.brainology.us/websitemedia/youcangrowyourintelligence.pdf

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DAY 10—Motivation in an Academic Setting: An Essay

Motivating students to work and study hard on a daily basis can be a challenge. Bribing students with rewards, cheering them on with "pep talks" or heaping praise on them can be just a short term quick fix. One way that researchers try to help is to develop the strategies teachers might use to boost motivation. They believe that if students could be inspired to control their own **motivation**, then progress could be made to solve the problem. In that way, students by themselves would, unprompted, put forth effort, keep on through difficulties, and complete the tasks from which they will ultimately benefit.

One group of students, when asked why they willingly completed assignments, reported that they wanted to make every effort to learn and improve themselves. This group was described as having **learning goals**. A second but different group, when presented with assignments, tended to favor **performance goals**. They were more concerned about showing their abilities and outdoing others. Realistically, we all hold multiple goals in schools.

People who prefer learning goals engage in **self-regulation**. Self-regulation occurs when people control their mental resources like willpower, skills, and knowledge. They use them to plan carefully. They exert extra effort. For example, José, a junior, found his first geometry course to be far more difficult than he had imagined so he decided to take careful notes, focus on understanding how proofs worked together, and assess his progress as he studied. In fact, he reported that "I spent more time on that class than all of my other classes combined, which ended up being worth it because it brought up my whole GPA."

Second, people who prefer learning goals engage in **deep processing**. Deep processing occurs when people seek understanding and search for fuller meaning. When engaged in deep processing, people think about the material, relate it to what they already know, and concentrate on it. In contrast, surface processing occurs when people try to memorize rather than understand the information. For example, Kristen, a sophomore in LA 10, had a teacher who focused the class on Shakespeare, wanting them to learn the basic plot and characters from ten of Shakespeare's plays. Lina memorized everything the teacher wrote down because she wanted an A on the unit test, but Kristen was determined to learn more than just the superficial plot and characters pieces. She invested study time in interpreting the symbolism and searching for hidden themes. So, in addition to learning the famous lines and stories, Kristen focused on developing deeper understanding of Shakespeare's plays.

Third, learning goals are linked to **persistence**. Persistence refers to the tendency of people to continue working even when the academic task is difficult. Alex's ultimate vocational goal was to become an athletic trainer, and his college required 3 years of high school math. Alex received a D his second quarter of Algebra 1 as the content grew progressively more difficult. In preparing for the following semester, Alex was determined that he would learn the foundational concepts of Algebra 1 so he could be prepared for Geometry and Algebra 2. It was a struggle, but gradually Alex gained analytical skills in identifying mathematical strategies that enabled him to succeed better each quarter as he moved toward his goal. By the time he finished Algebra 2, he had a B+ in the course and decided to take Math Analysis to prepare himself for the math he would take in his college program.

Fourth, people with learning goals enjoy learning purely **for the sake of learning**. For example, Mike took a web design class in high school. He became intrigued with the subject and enrolled in increasingly difficult programming courses once he got to college. These courses became electives because they couldn't be applied to his major, but he enjoyed every minute, and had no regrets. He still fantasizes about inviting the inventors of those programming languages to an imaginary dinner.

Based on your reading of the essay, please write the letter of the BEST answer on the line provided:

______1. José engaged in self-regulation. One result from that choice was that he:
a) earned a high grade in the course
b) felt the knowledge "really stuck" with him
c) could self-teach the material and miss classes

______2. Kristen engaged in deep processing. One result from that choice was that she:
a) spent a lot of time studying for tests
b) participated in study groups that discussed issues
c) really enjoyed and experienced her Shakespeare class

______3. Alex persisted in one of his classes. One result from that choice was that he:
a) learned a lot about algebra
b) received an "A" on the class project
c) gained a strong foundation for his pre-college requirements

______4. Mike's experience shows us this important lesson:
a) impressing our teachers is more important than grades
b) learning for mastery allows us to enjoy our learning more
c) earning good grades is the highest priority in learning

______5. According to the essay, why did Lina do better in the Shakespeare class than Kristin?
a) The teacher's learning style worked better for Lina
b) Lina prioritized good grades
c) Kristin wasn't as good at studying

______6. Which sentence best summarizes how you approach learning?

a) I haven't ever really set learning or performance goals because I don't think they work
b) I haven't ever really set learning or performance goals, but I can see how they could help
c) When I set goals, they are usually performance goals, because grades matter the most or because it is important to me that my teachers and parents know how hard I have worked
4) When I set goals, they are usually learning goals, because I think it is more important that to remember things in the long run or because I like learning just for the sake of learning

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Ladd, Judith Arlene. (2009). The influence of actively open-minded thinking, incremental theory of intelligence, and persuasive messages on mastery goal orientations. University of Florida, ProQuest, UMI Dissertations Publishing. 3385952, p. 137-139, 149.