12-2019

Implementation and Effects of University College Algebra Growth Mindset Structured Assessments in Large Lectures

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IMPLEMENTATION AND EFFECTS OF UNIVERSITY COLLEGE ALGEBRA GROWTH MINDSET STRUCTURED ASSESSMENTS IN LARGE LECTURES

by

Hannah Mae Lewis

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Mathematical Sciences

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UTAH STATE UNIVERSITY
Logan, Utah

2019

ABSTRACT

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by

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Recent scientific evidence shows the incredible potential of the brain to grow and change. Students with a growth mindset view errors and obstacles as opportunities for growth. These students welcome challenges and the opportunity to learn from their mistakes. Although some university instructors are incorporating growth mindset into their lectures, attitudes, and exams in small classes, the traditional exam method used in large lecture undergraduate mathematics classrooms is a fixed mindset model.

The purpose of this study was to understand the relationship between (1) large lecture college algebra undergraduate growth mindset structured assessments and (2) students' achievement, drop/fail/withdraw rates, mindsets, and anxiety. No statistically significant difference in mean final exam scores was found, however, withdrawal and fail rates were lower for the class participating in the growth mindset structured assessments than the control classes. Lower levels of math test anxiety and higher levels of growth mindset were demonstrated in the class participating in the growth mindset structured assessments.

(193 pages)

PUBLIC ABSTRACT

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Recent scientific evidence shows the incredible potential of the brain to grow and change. Students with a growth mindset view errors and obstacles as opportunities for growth. These students welcome challenges and the opportunity to learn from their mistakes. Although some university instructors are incorporating growth mindset into their lectures, attitudes, and exams in small classes, the traditional exam method used in large lecture undergraduate mathematics classrooms follows a fixed mindset model. The growth mindset structured assessments developed for this study incorporate a testing center portion (matching, short answer, fill in the blank and free response) with structured rework opportunities, a written portion with peer reviews, and a group portion.

The purpose of this study was to understand the relationship between (1) large lecture college algebra undergraduate growth mindset structured assessments and (2) students' achievement, drop/fail/withdraw rates, mindsets, and anxiety. This relationship is determined using the final exam scores, the withdraw and fail rates, and the responses from a Likert scale survey and a Qualtrics free response survey. No statistically significant difference in mean final exam scores was found, however, withdrawal and fail rates were lower for the class participating in the growth mindset structured assessments than the control classes. Lower levels of math test anxiety and higher levels of growth mindset were demonstrated in the class participating in the growth mindset structured assessments.

DEDICATION

To Judy, I miss you. You saw me and believed in me. I wish you were here to see this finished.

To Oma. You are my inspiration and a reminder that higher education is important and worth persuing.

ACKNOWLEDGMENTS

Throughout my doctoral journey at Utah State University, I have had the rare honor of working with phenomenal faculty, staff, and colleagues in both the Mathematics and Statistics and Teacher Education and Leadership departments. I want to thank Dr. Kady Schneiter who inspired me to believe that I was actually capable of getting a doctorate degree and provided me invaluable help and support along the way. My heartfelt thanks goes out to the members of my dissertation committee for their insightful feedback, sincere encouragement, and their devotion to my success. I cannot express enough gratitude to Sheri Christopherson and Chris Dayley in the University testing center for their patience, understanding, and sacrifice. Sheri and Chris, you made this journey possible, so much easier, and fun. An additional big thank you to Randall Haws for making the tutoring center a wonderful place to encourage a growth mindset.

Finally, I am so grateful to my incredibly supportive family. Dow, as always, we challenge and enjoy trials in life facing forward together. You have been my rock and my inspiration through it all. Now our family is moving on to a new amazing chapter. I could never have completed this journey without the unending support from my parents. Mom, you are indeed splendid. Dad, I and the kids could never have made it though this without your constant support. Our talks helped me to ground my thinking and kept me focused on what is most important in life, family, and my research. John Patrick and Becca Judy, you honed my patience and perseverance. Without you, I might have considered failure as a sign to quit instead of as an incredible opportunity to learn.

Hannah Mae Lewis

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CHAPTER 1

Introduction

Many students begin their college experience enrolled in a large lecture class. These classes can be overwhelming and uncomfortable to students that are used to comparatively small high school classes. Without the proper support, students that have a negative experience in their freshman year are more likely to drop out of college (Martin, 2017). Math test anxiety is one of these common negative experiences. This anxiety occurs frequently among college students. Betz found that higher levels of math anxiety were related to lower mathematics achievement test scores and higher levels of test anxiety (1978). Additionally, research has shown a correlation between students' belief that intelligence is fixed and low achievement in mathematics at all academic levels. This correlation is stronger for younger students, females, and minorities (Zhang, Kuusisto, & Tirri, 2017).

Fortunately, recent scientific evidence shows that the brain has potential to grow and change. Teaching about students brain plasticity can promote a belief that intelligence is not fixed and that hard work can increase intelligence (Carol S. Dweck, 2016). Equally important are the observations of the positive impact that having this kind of mindset, a growth mindset, has upon students' achievement. Students with a growth mindset view errors and obstacles as opportunities for growth. These students welcome challenges and the opportunity to learn from their mistakes (Carol S Dweck, 2006).

Some teachers and instructors at all educational levels are fostering growth mindset through their lectures and attitudes by teaching that mistakes are opportunities to learn or by telling stories about people who worked hard to achieve their goals (Zhang et al., 2017). However, the traditional exam method used in undergraduate mathematics classrooms is structured to foster a fixed mindset. In these exams if a student makes a mistake, their score is reduced and they have no structured opportunity to learn from those mistakes. In large lecture courses where grading is very time consuming, it is especially difficult to avoid this

type of scoring. The first step in creating well developed university classroom assessment practices is to ensure that grades are a meaningful representation of student understanding. This can be achieved by creating an environment in the classroom that encourages a growth mindset, including in the assessments.

Purpose of the Study

Traditional college large lecture mathematics exams are structured to be scored quickly and efficiently. This typically results in exams with a high number of multiple choice, true and false, and short answer questions. Teachers that embrace the need for a growth mindset culture could, understandably, be frustrated by this traditional assessment structure. They teach students that mistakes are opportunities to learn and that their brains grow when they make mistakes and learn from them, but are forced to mark down grades every time a student makes a mistake. Alternatively, growth mindset structured exams are built to encourage hard work and learning from and correcting errors. The purpose of this study was to understand the relationship between (1) large lecture college algebra undergraduate growth mindset structured assessments and (2) students' achievement, fail/withdraw rates (DFW), mindsets, and anxiety, by answering the following questions.

Research Questions

Assessments intended to encourage a growth mindset have been used at many different levels of incorporation from allowing students to rework the original exam question for partial credit all the way to incorporating group projects, papers, and structured reworks with formative growth mindset feedback. For teachers that are willing to take the extra time to give formative feedback, correct rework questions, monitor group projects, and/or read papers this can be an amazing learning experience for the students. However, not all teachers are willing or able to take the time to do this much feedback and grading. Even more rare is a teacher that can do this for a large lecture style class in a university setting.

This issue is addressed in this dissertation as follows. A historical context of assessments followed by the conceptual framework for this study is included in the literature review contained in Chapter 2. Next, the methodology used in this study is discussed and justified

in Chapter 3. The effect that these assessments have on the students mindset, anxiety, and the withdraw, and fail (DFW) rates and achievement are examined in Chapter 4. A discussion of the usability of the growth mindset structured assessments developed for this research, including instructor time commitments for incorporating growth mindset structured assessments is included in Chapter 5. This leads us to the following research questions shown in *Tables 1.1-1.3*:

Table 1.1

Quantitative Research Questions

Research Question	Instrument/Data Source	Data Analysis
Does incorporating growth mindset structured assessments in large lecture college algebra courses affect final exam scores?	The final exam	ANOVA Descriptive Statistics (mean, standard error)
Does incorporating growth mindset structured assessments in a large lecture college algebra course affect DFW rates?	Math Department DFW rate collection system ("Utah State University", 2018)	χ^2 test for homogeneity of proportions Descriptive Statistics (proportions)

Note. DFW=fail withdraw rates, final exam as created by Utah State University Mathematics and Statistics department faculty.

Table 1.2

Qualitative Research Questions

Research Question	Instrument/Data Source	Data Analysis
What is the effect on math anxiety of incorporating growth mindset structured assessments in large lecture college algebra courses?	Qualtrics Survey (Lewis, Tait, & Schneiter, 2018)	Thematic axial coding

Table 1.3

Mixed Methods Research Questions

Research Question	Instrument/Data Source	Data Analysis
How does incorporating growth mindset structured assessments in a large lecture college algebra course affect student's mindset?	**Qualitative** Qualtrics Survey (Lewis, Tait, & Schneiter, 2018)	Thematic axial coding
	Quantitative Dweck's Growth Mindset Likert Scale Survey (Carol S Dweck, 2006)	Descriptive Statistics (mean, range, sd)

*Note.*DFW=fail withdraw rates, sd=standard deviation.

Significance of the Study

Changing from the traditional methods of exams to assessments that assess for learning with a growth mindset framework is a challenge for college/university instructors, but it is important. The growth mindset structured assessments in this study incorporates the following standards:

- The type of assessment will fit the learning level that the learning objective was taught at and the learning level for the learning objective that is being assessed.
- Diagnostic and encouraging feedback will be provided on all formative assessments, and scoring will be removed from assessments until reworks are complete.
- Multiple forms of assessment will be used including, group work, papers, long and short free response questions, and presentations.
- Scaffolding will be used to facilitate productive struggle in exam corrections, papers, and group work.

Definitions of Key Terms and Acronyms

The level of *cognitive demand* is the level of thinking, reasoning, or processes that are elicited by a specific task (Web, 1997). *Cognitive load* is determined by the level of working memory used to complete a task (Sweller, van Merrienboer, & Paas, 1998). A *learning objective* is defined as a statement that specifies what students will do or be able to do if

the lesson is successful. These *objectives' learning levels* are determined by the manner in which students will mentally interact with the objective's mathematical content after the student has achieved the objective. The assessment question and the corresponding rubric are defined as a *mini-experiment*. These assessments are considered to have learning level relevance to the degree that its mini-experiments require students to operate at the learning levels that were specified by the learning objectives (Cangelosi, 2003).

An *assessment* (or measurement) is a sequence of mini-experiments conducted for the purpose of collecting information that is used for either formative or summative evaluations. *Formative assessments* are assessments that are used by teachers to make judgements that influence how they continue to teach. *Summative assessments* are assessments that are used to make judgements of students achievement for the purpose of reporting student success (Cangelosi, 1999). This research will determine if implementing these changes in a university setting will increase student performance, attitudes, and mindset about mathematics. Using detailed rubrics, professional development, and technology, these opportunities to learn with growth mindset assessments can extend to students in large lecture sections.

Formative assessments are an important process that we participate in as teachers to help our students achieve the learning objectives that we want them to achieve. Students can ignore our teaching but, if they want to move forward with their education, they have to participate in the assessments teachers have designed to determine their achievement of learning objectives. If we can assess with the basis of a growth mindset in large lectures, we can increase the growth mindset and the achievement of significantly more students every academic semester.

Summary

Changing from the traditional methods of exams to assessments that assess for learning with a growth mindset framework is a challenge for college/university instructors teaching large lecture sections, but it is important. This change will ideally happen in the following ways:

- Assess students at the same learning level that the learning objective is taught.
- Provide students the opportunity to communicate about mathematics through group work and essays.
- Provide diagnostic, encouraging, and wise feedback on all formative assessments.
- Provide rubrics for every assessment that inform students of their current achievement of the learning objectives.

My hypothesis is that implementing these suggestions using technology, detailed rubrics, and specialty leaders (trained recitation leaders and graders) will reasonably allow teachers to assess students with growth mindset assessments a in a large lecture environment without lowering student expectations.

CHAPTER 2

Review of the Literature

The way that teachers assess students plays an important role in the mindsets students develop. A mindset is a self-perception that people hold. Those who have a fixed mindset believe traits like intelligence and talent are unchanging. They spend time documenting their intelligence instead of trying to learn and grow. Those with a growth mindset believe that intelligence and talents can be developed through hard work and dedication. Growth mindset has been shown to have a positive impact on student achievement (C. Dweck, 2007).

There are a number of techniques that teachers can use to foster growth mindset in their students. First, let students know what growth mindset is and teach them that their brains can grow. Second, praise them for their efforts and not for intelligence (C. Dweck, 2007). Third, tell students stories of people that achieved great things with hard work and a growth mindset (Aronson, Fried, & Good, 2002). Finally, teach students that mistakes help our brains to grow (Moser, 2011). This last strategy creates an atmosphere in the classroom that leads students to look at mistakes (theirs or others) without shame, but instead as opportunities to improve. Like the other techniques mentioned, openness to mistakes can be fostered through changes to classroom instruction. Importantly, it can also usefully be addressed when assessing the students' achievement of the course objectives.

This chapter contains three main sections. The first section gives a historical context of (1) growth mindset and assessments, (2) a review of the current literature concerning growth mindset practices in mathematics teaching, and (3) assessment practices in K-12 and college mathematics courses.

The second section of this chapter develops and outlines a conceptual framework that explains how the structure of growth mindset assessments is developed in growth mindset theory. This structure includes standards-based grading, wise feedback practices, scaffolded

group projects, and structured papers. Finally, the extension of these concepts and application to large lecture sections will be discussed.

History of Assessments and Grading

In the 1960's and 1970's assessments were starting to be used more often than they had been previously. This was a result of many large scale federal education programs that were launched at the time. The launch of these programs could only continue if the program directors were able to show that the programs had positive change. It was decided that the positive change would be ascertained by standardized assessments evaluated largely using quantitative methods (Banta & Associates, 2002).

In the fall of 1985, the First National Conference on Assessment in Higher Education published a report entitled *Involvement in Learning.* This report had three main recommendations that were strongly informed by the current research for teachers and other assessors. To promote higher levels of student achievement, they should: first, have high expectations established for students; second, involve students in active learning environments; finally, provide students with prompt and useful feedback (Banta & Associates, 2002).

This report motivated the higher education community to fill the gaps caused by three major challenges: the definition of assessments, the instruments used for assessment, and the proper methods used to implement these instruments.

Definitions

Since the term *assessment* meant different things to different people, there was an immediate communication problem. There was no clear differentiation between group assessment, formative assessment, and summative assessment definitions. The distinction between these different types of assessments had not been established. All three were just labeled as assessments (Banta & Associates, 2002).

In 1992, the American Association for Higher Education published a terminological consensus that centered on the use of multiple types of methods for program improvement (Banta & Associates, 2002). This article gave nine principles of good practice for assessing student learning. These principles included, "assessment works best when the programs it

seeks to improve have clear, explicitly stated purposes", and "assessment works best when it is ongoing not episodic". These principles were used, in part, to develop better assessment practices in the coming years (pp. 264-279).

Instruments

Instruments are the tools used to determine student achievement, gather evidence of student learning, and/or evaluate learning programs. Almost all of the instruments available in the early 1980's were designed with other goals than to gather evidence of student learning. Tests such as the American College Test (ACT), the Graduate Record Examinations (GRE), and licensure examinations were designed to test student proficiency and not gather evidence of student learning or evaluate teaching programs (Banta & Associates, 2002).

From 1986 to 1989, the major testing organizations filled this gap with group level exams designed to evaluate programs. These were exams such as the Collegiate Assessment of Academic Proficiency (CAAP), the Educational Testing Service (ETS), and the Major Field Achievement Tests (MFAT). Although these became readily available and most institutions felt like that had little choice but to use them, there were growing doubts about the wisdom of this assessment approach. These doubts stimulated work on faculty-created assessments in the years to come (Banta & Associates, 2002).

Implementation

Throughout the late 1970's and into the late 1980's many universities developed systems of program assessments. They helped to define a "standard" approach to implementing campus-level program assessments. This standard led states to institute assessment mandates that were enforced by accrediting bodies. This and other stimuli led to a steady and upward trend of institution reported involvement with assessment. In 1987 55% of higher education institutions reported that they had established an assessment program and by 1993 this rose to 98%. The American Council on Education reported these numbers as a result of their annual *Campus Trends* survey. This survey also showed that these numbers were on an upward trajectory (Banta & Associates, 2002, p. 12).

Current assessment practices still need improvement. With modern technology, teachers have access to psychometric tools that can be used to improve the assessments they create. These tools require training to use and interpret. As a result they are not widely used at a classroom level. However, these tools are being used to analyze and improve assessments that are used on a large scale. These improvements are intended to make assessments more valid and reliable. There is still a lot of work to do to close the gap between students' assessment scores and their true knowledge of the material.

History of Growth Mindset Intervention

Dweck's research in 2016 on growth and fixed mindsets suggests that students who have adopted a fixed mindset may learn more slowly or less than they are actually capable of doing. They also shy away from challenges because poor performance might either confirm they can not learn, or indicate that they are less intelligent than they think. This research also suggests that students who fail, as we all do, react to the failure differently based on their mindset. When students with fixed mindsets fail at something, their tendency is to tell themselves they can not or will not be able to do it, or they make excuses to rationalize the failure.

In a growth mindset people believe that intelligence and talents can be developed through hard work and dedication (Carol S. Dweck, 2016). Students who embrace a growth mindset may learn more, learn it more quickly, and view failures and challenges as opportunities to increase their learning and growth. As a result, mindset can be a positive predictor of achievement at all academic levels.

Growth mindset has a positive impact on primary school student achievement (C. Dweck, 2007). Blackwell, Trzesniewski, and Dweck conducted two studies published in 2007. In the first study, they found that having a growth mindset predicted an upward trajectory in grades over the two years of junior high school, while a fixed mindset predicted a flat trajectory. The researchers then conducted a second study with a growth mindset intervention (study skills class for the control). They found that the growth mindset intervention group had an upward trajectory in their grades, while the control group displayed

a downward trajectory (Blackwell, Trzesniewski, & Dweck, 2007). These findings show that not only is growth mindset correlated with increased achievement, but mindset can be changed, resulting in increased achievement.

Dweck designed an intervention that helps change mindsets called *Brainology.* Brainology lets students know what growth mindset is and teaches them that their brains, like their muscles, become stronger with effort and practice. The program praises for efforts and not for intelligence while giving study techniques that reinforce the idea that mistakes are opportunities to learn. Brainology also helps students develop self regulation strategies to reinforce their own internal growth mindset thoughts and self feedback.

In 2012, Donohoe and colleagues looked at the impact of an online intervention (Brainology) on the mindset and resiliency of secondary school pupils. They found this particular program only had short term positive impacts on the growth mindset of the students (Donohoe, Topping, & Hannah, 2012). Two years later Elwick implemented a neuroscience workshop that taught about brain elasticity in Year-7 secondary students. Before the intervention, all three groups (the intervention group, the active control, and the passive control) had similar beliefs about the nature of intelligence. The intervention group had an increase in growth mindset statements from their baseline results at the final two assessment points. This indicates that there was a statistically significant increase in their growth mindsets over the course of the study (Elwick, 2014). The researchers did not show a significant impact on grades as a result of the intervention, but they determined this was likely because the study was time restricted. Both of the studies done by Donehoe and Elwick were done on secondary (high school) students. Previously, researchers completed studies on junior high students that showed an increase in achievement when tracked over a longer time period. These studies and others were compiled by Zhang et. al. In 2017, these researchers completed a meta-analysis analyzing how teachers' and students' mindsets and learning have been studied. They found that as students get older, it takes more effort to change their mindset and for that mindset to have an impact on their achievement. However, their mindsets can change and impact their achievement in a positive way.

The correlation between mindset and achievement has been shown to translate to university students by Maure and Marimon in 2014. They looked at the attitudes and achievement of 1076 college students from Panama and Mexico. Their results showed academic achievement correlates positively with attitude with a correlation coefficient of $r = .725$ (Mexico) and $r = .829$ (Panama) and $p < .01$ (Maure & Marimon, 2014). The findings also indicate the mindsets that university students hold is a good predictor of their achievement.

At Utah State University, Bagley (2015) found that mindset was a good predictor of student outcomes in developmental math courses, especially in college pre algebra (Math 1010) in which students with a growth mindset performed much higher than students with a fixed mindset. This was confirmed in overall percentage of points earned as well as scores on exams and pass rates in math courses at the developmental (900) and freshman (1000) level. It was found that math-related anxiety had one of the largest and most statistically significant effects on students' percent of points earned and on pass rates. In particular, the analysis showed that math anxiety during homework and learning math had a higher predicted effect upon student success than math test anxiety (Bagley, 2015).

Teacher's choice in method of assessing student achievement has an important role in the mindsets that these students develop. In fact, providing wise feedback as a method of assessment encourages students to have a growth mindset (Yeager et al., 2013). In 2017, Boaler offered a method of assessment that can change the relationship students have with their learning from anxiety to growth. Currently most assessments do not focus on mathematical problem solving, creativity, and persistence. Instead they test what is easy to assess, calculations with a single correct answer (Boaler & Confer, 2017).

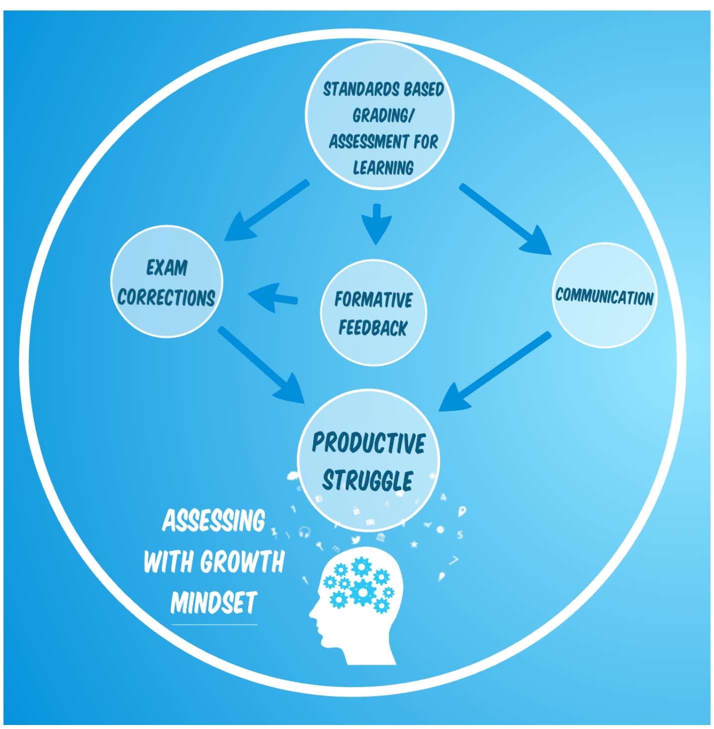
Standards-Based Grading/Assessment for Learning

To create a growth mindset environment in the classroom, students need to be provided with opportunities to achieve the learning goals that have been communicated to them. These opportunities can be group projects, quizzes, testing center exams, papers, projects, presentations, etc. Teachers must be able to assess what has been learned and use those assessments to make valid decisions about what to do next in their classrooms with formative

assessments. Students must be able to correctly interpret the teacher's learning goals, and use the opportunities to achieve those learning goals. Then students should be able to accurately reflect on an assessment of their achievement.

Figure 2.1 is a visual description of the conceptual framework this research followed. This conceptual framework starts with assessing based on predetermined weighted standards or objectives. standards-based grading is a philosophy which involves measuring students' proficiency and progress on well-defined weighted course objectives or standards. These standards or objectives are specific learning goals that focus on what students should know and be able to do. Another way of viewing standards-based grading is called assessment for learning. This is the process of seeking and interpreting evidence for use by learners and their teachers to decide where the learners are in their learning, where they need to go, and how best to get there. Because the starting point to building assessments based on weighted objectives is writing those weighted objectives for the lesson plans, this circle is at the top of the framework shown in *Figure 2.1*.

Fig. 2.1. Conceptual Framework



Objectives should be developed with an appropriate learning level in mind. Clarification of the subject content and the learning level is necessary in order to design assessment questions and rubrics that are relevant to the objectives (Cangelosi, 1999). The objectives' learning levels are determined by the manner in which students will mentally interact with the objective's mathematical content after the student has achieved the objective. These learning levels are outlined and defined by Cangelosi in two different domains. The cognitive domain includes constructing a concept, discovering a relationship, simple knowledge, comprehension and communication, algorithmic skill, application, and creative thinking. The affective domain includes appreciation and willingness to try.

Assessments should fit the purpose, or the learning objectives that were laid out by the teacher. Teachers need to consider not only which learning objective they are assessing, but also the learning level they want that objective to be assessed at (Brown, 2004) when constructing the objectives for a course. The learning levels and teaching style should be reflected in the learning levels and style of the assessment. Brown states: "Assessment methods and approaches need to be focused on *evidence of achievement* rather that the ability to regurgitate information" (Brown, 2004, p. 82). A true test of student learning will show evidence of the knowledge or application of knowledge at the exact level of that student's true ability. This starts with assessing based on predetermined weighted standards or objectives at the chosen learning level.

In 2017, MacCrindle studied the effect that implementing standards-based grading has on the teachers' mindset and attitude. The school in which the research occurred served 435 students with 22 certified teachers in grades 1-5. His data showed 80% of teachers participating began the change initiative with evidence of a growth mindset. In the post-survey, 94% of teachers participating showed evidence of possessing a growth mindset at the end of the research time period. This comparative analysis of the mindset statements from the teachers signifies an increase in growth mindset as a result of implementing standards-based grading (MacCrindle, 2017). In 2016, Hawe studied the impact of implementing assessment for learning (similar to standards-based grading) with undergraduate students.

In their students' interviews, even though they were not specifically looking for growth mindset shifts, these shifts from a fixed to a growth mindset were found in the researchers qualitative analysis. The students stopped focusing on their grades and started focusing on their learning (Hawe & Dixon, 2016).

In 2013, Auten published her dissertation exploring how community college educators create classroom environments that foster a growth mindset. They found that many instructors with a growth mindset purposefully tried to promote a growth mindset in the classroom. They emphasized to students that success comes from hard work, lots of practice, a willingness to seek help, and that time is required to master any skill. Some of these instructors taught students directly about fixed and growth mindsets. They described mistakes, failures, challenges, and frustrations as opportunities to learn instead of experiences to be avoided (Auten, 2013). When teachers have a growth mindset, they tend to foster a growth mindset in their students. Further, research has also shown that the teacher's mindset plays a significant role in determining his or her expectation of students, teaching practices, and relationships with students (Brooks & Goldstein, 2008).

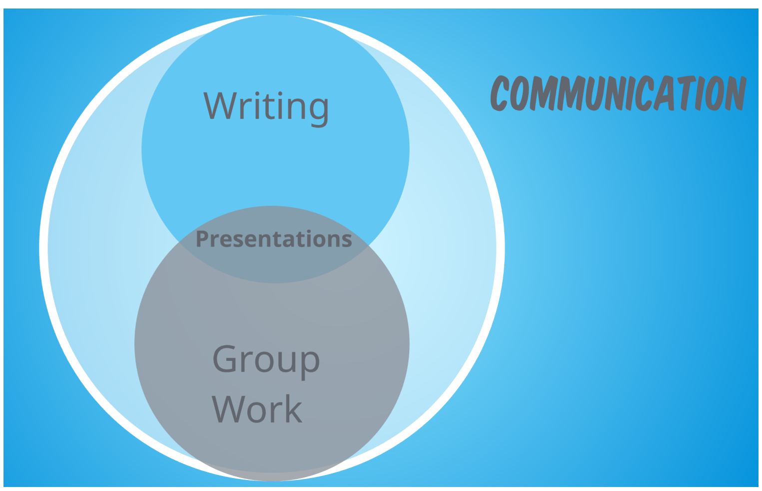
Teachers and students both have more of a growth mindset when standards-based grading is implemented than when traditional difficulty level and percentage based grading practices are used. Teachers that have a growth mindset influence their students' mindsets to be more growth oriented. Having a focus on growth mindset leads students to look at their mistakes as opportunities to learn and then achieving more in their academic pursuits. Improving assessments with defining the objectives students should achieve and then assessing those objectives at appropriate learning levels is the first step.

Communicating About Mathematics

One of the learning levels that is underutilized in mathematics classrooms and assessments is the *comprehension and communication* learning level. However, math teachers do want their students to be able to comprehend and communicate about the subject contents of the lesson. That means the assessments of the objectives at the comprehension and communication learning level also need to be assessed at this learning level.

To assess students at the comprehension and communication level or at the discover a relationship level, students need to communicate in some form. Having students write papers enables the instructor to assess whether students can comprehend and communicate the mathematical concepts presented to them. This can also be facilitated through group projects. If scaffolded well, group projects can facilitate useful discussion about the relationships and ideas discussed in the course. These two methods can come together by asking students to present their group projects. In this way students have to discuss with their groups, write a presentation, and then formally communicate their findings to the class. This relationship is shown below in *Figure 2.2*.

Fig. 2.2. Relationship Communicating About Mathematics



Writing and Papers.

Many studies have been done on the effects that writing papers in mathematics classes has on academic achievement. In 2004, a meta analysis on these types of studies found that 36 of 48 study outcomes (75%) were positive. This suggests a fairly consistent positive achievement effect attributed to writing-to-learn interventions. The mean effect of writing to learn interventions found on content achievement was small but significantly greater

than no effect (Bangert-Drowns, Hurley, & Wilkinson, 2004). Writing about mathematics increases achievement of learning objectives, but also positively effects the growth mindset and attitudes that students have about mathematics.

In 2012, Johnston looked at the relationship between homework journals and students' attitudes towards writing in mathematics, and students' achievement in mathematics. The participants were 119 university students enrolled in a sophomore (2000) level mathematics course. Of these participants, 60 were in the study and 59 were in the control group. The experimental group participated in homework journaling for the entire semester. Their interview responses showed a positive mindset shift for individual students. To be able to show this shift in a more quantitative way, they recommend that writing in mathematics courses should be studied in lower level university mathematics courses (Johnston, 2012). In a similar study by VanDyke et al., college students were asked to write eight papers for a mathematics college course were compared with students that did not have the writing component. In one of the classes in the study, students had a significant difference in improvement in a visual skills assessment. Additionally, Van Dyke et al. found at a 10% significance level that there were fewer negative attitudes at the end of the course about one's ability to do mathematics with a $p = 0.0848$ (2013). Writing about mathematics for the purpose of comprehending and communicating specific learning objectives can increase the achievement and attitudes of students.

Group Work

Another way students can communicate about mathematics in a structured way is group projects that have appropriate scaffolding. In a study done in 2010, Students that participated in small groups that integrated technology, cooperative activity designs, and broader educational practices lead to a positive impact on students' mathematics learning (Roschelle et al., 2010). Their analysis of observational data confirmed that these students participated socially in questioning, explaining, and discussing disagreements, whereas students in the individual condition did not.

Six years later, Fung and Lui looked at how learning is affected by scaffolded group work

in high school science classrooms. Their results showed a statistically significant increase in post test scores compared to pre test scores (2016). When Sorensen used group quizzes in a developmental college mathematics course, he found a 10% increase in pass and success rates compared to classes without the group quizzes. Additionally, average final exam scores had an 8% increase over the other classes. Endurance of the students in the classes with the group quizzes was nearly 10% greater than those without the group quizzes (2012).

These studies show that small groups, when scaffolded appropriately, facilitate communication about mathematical topics. Additionally, these small groups have a positive impact on achievement and endurance. Endurance is directly correlated with growth mindset (Carol S. Dweck, 2016). When incorporated in lower level university mathematics classes, students that communicate about mathematical topics in small groups improve their attitudes and mindset about mathematics. For the objectives that have learning levels of comprehension and communication or discovering relationships, students should write and work in groups on scaffolded projects to assess their achievement of these objectives. Doing this can increase growth mindset and achievement of the objectives.

Formative Assessments and Constructive Feedback

For standards-based grading to be effective and truly assess for learning, students should use the assessments formatively to learn from their mistakes. This is achieved through constructive feedback provided by the teachers, instructors, and graders. The constructive feedback is used by students with a growth mindset, when given the opportunity, to learn from their mistakes.

In the article, "Inside the Black Box: Raising Standards Through Classroom Assessment", Black and Wiliam synthesized the results of 250 sources on formative assessments. They determined that innovations that included strengthening the practice of formative assessment produced significant and substantial learning gains. The students analyzed range from 5 year olds to university undergrads, over several countries and many different subjects. The typical effect sizes of the formative assessment experiments were between 0.4 and 0.7. These effect sizes are larger than are what is typically found in educational interventions.

The investigators concluded that students need a culture of success backed by the belief that all pupils have the ability to achieve. “Feedback to any pupil should be about the particular qualities of his or her work, with advice on what he or she can do to improve, and should avoid comparisons with other pupils” (Black & Wiliam, 2010, p. 84). When the culture of the classroom focuses on grades and class ranking, students look for ways to improve those grades and class ranking instead of working to improve their learning. Self-assessment is an essential component of formative assessment. When students are trying to learn, the feedback about their effort includes three elements: recognizing the desired goal, evidence about their present position, and having understanding about how to close the gap between the two. They concluded that the feedback on tests, homework, and quizzes should give students guidance on how to improve and that students also need to be given help and an opportunity to work on their improvement.

Based on the analysis done in their previous article, Black and Wiliam decided to run their own study. They enhanced formative assessments to provide feedback that allows students to self assess and make changes with 19 teachers. End of year exams or national end of year tests were the output measures for the classes in the study. For each project, the teacher identified a class that was found to be a good comparison class for control. The standard effect size, which is found by taking the difference between the scores of the experimental and control groups and then dividing by the standard deviation, was found to be an average of .3 standard deviations (Black, Harrison, Lee, Marshall, & Wiliam, 2004).

Their research gave them some insight as to the amount and the nature of feedback for students. “When giving students feedback on both oral and written work, it is the nature, rather than the amount, of commentary that is critical. Research experiments have established that, while student learning can be advanced by feedback through comments, the giving of numerical scores or grades has a negative effect, in that students ignore comments when marks are also given”(Black et al., 2004, p. 13). They found that the fears about how students would react to not having scores was unjustified. Instead, because the feedback and comments helped students to focus on what needed to be done to improve, there was

less frustration than before the change. Ruth Butler found that achievement increases when teachers stop grading and give diagnostic comments instead. She further found that both high achieving (top 25% GPA) and low achieving students (bottom 25% GPA) suffered deficits in their performance when they received numerical grades, compared with students who only received diagnostic comments (Butler, 1988).

Students can only achieve a learning objective if they understand what that objective is and they can determine what they need to do to achieve that learning objective. This means that self-assessment is essential to learning. This self-assessment does not happen when students are distracted by scores and grades. If they just have the feedback to focus on, the self-assessment is a natural byproduct of the teachers' constructive feedback. Another finding reported by Black et al. in this meta analysis of research studies is that students that are trained to prepare for tests by making and then answering their own questions outperform comparable groups who prepared in more conventional ways(2004).

In a comprehensive review of research studies, Black and the other researchers found that feedback improved students' performance in 60% of the studies. However, in the cases where the feedback was not found to be helpful, the feedback was a judgement or grade without any indication of how to improve. Feedback that focuses on what the student needs to do to improve can encourage students to believe that they can improve (Black et al., 2004, p. 18). It was found through their analysis that examinations must become a positive part of the learning process. Students need to be actively involved in the testing process. Through this involvement, students see that the test is a benefit to their learning and growth instead of feeling like victims of the testing process.

In 2013 Yeager et al. found that wise feedback increased students' likelihood of submitting a revision of an essay and improved the quality of their final drafts. This shows that providing wise feedback to students motivates them to correct and learn from their mistakes. In the same paper, the researchers discussed a study undertaken in a low-income public high school. They used attributional retraining to teach students to attribute critical feedback in school to their teachers' high standards and belief in their potential. They

found a significant improvement in African American students' grades, which reduced the achievement gap. This shows that constructive and wise feedback can help students develop a growth mindset and can lead to higher achievement (Yeager et al., 2013).

So how do we effectively embed formative assessments and wise feedback into mathematics classrooms? In a pilot program to try embedded feedback in formative assessments on elementary school students, researchers trained teachers in formative assessments and feedback. They then implemented an embedded feedback assessment protocol in science classrooms (C. Ayala et al., 2008). They found that even though the teachers were trained in the protocol, they used the formative assessment summatively which distorts the purpose of the assessment tools. Also, the teachers did not provide feedback to students quickly, in fact, it often took as long as several weeks to get the feedback to the students. The researchers made modifications such as reducing the time used for assessing and increased training, but were only partially successful. As a result, their theoretical predictions that embedding formative assessments into a science curriculum would result in increased achievement of objectives and motivation were not realized (Yin et al., 2008). The results of the study were not statistically significant. However, the teachers varied considerably in the extent to which they used the formative assessments as they were intended. These researchers learned that "simply embedding assessments in curriculum will not impact students' learning and motivation, unless teachers use the information from embedded assessment to modify their teaching" (Yin et al., 2008, p. 354). Using formative assessment in teaching requires pedagogical content knowledge as well as a conducive class structure.

Ayala et al. studied middle school physical science teachers looking at the embedded assessment content, task types, and length (2008). They found that collaboration of assessment specialists with curriculum developers is vital. Further, embedded assessments need to be linked to overall goals and objectives of the curriculum and not just the material recently covered (C. C. Ayala et al., 2008).

In 2013 ten certified secondary school mathematics teachers from Michigan voluntarily participated in a three-day workshop. They analyzed responses from teachers that were

correcting students' errors. In analyzing the teacher feedback and the student responses, they found that causes of student errors could be broken into three distinct categories: vocabulary misconceptions, computational errors, and erroneous belief misconceptions. A vocabulary misconception is based on mistaken terminology or language; a computational error is based on calculation mistakes; and erroneous belief misconceptions are inaccuracies in mathematical thinking. Their recommendation was to correct the misconception rather than the error (Holmes, Miedema, Nieuwkoop, & Haugen, 2013). Giving feedback that corrects the student's misconceptions rather than focusing on their computational errors turns feedback into wise feedback and will increase student understanding of mathematical problems.

This wise feedback has also been directly linked to student achievement. In 2011 Anderson and Palm looked at the impact of formative assessment in Swedish classrooms. They put twenty two teachers through a comprehensive professional development program. Then, two tests of student achievement were used to study the effect of the formative assessment practice implemented by the teachers in the intervention group, in comparison to the practice of the teachers in a control group. A pretest and a posttest were administered to the students in the classes of both the teachers in the intervention group and the control group. The results of the classes in the intervention group and the control group were compared. They found the classes that were taught by the teachers who had participated in the professional development program significantly enhanced their mathematics achievement over one year of formative classroom practice compared to the control group (Andersson & Palm, 2017). When teachers understand how to provide students with wise feedback that corrects misconceptions, students will take the opportunity to learn from their mistakes and improve their mathematical abilities. Constructive, wise feedback on exams then should also lead to an opportunity to grow and learn. This means that for wise feedback to to be effective, students need the opportunity to rework their exam problems and provide additional evidence that they have taken the opportunity to learn from their mistakes and achieve the learning objectives.

Exam Corrections

To truly asses student's achievement of the objectives, teachers should facilitate opportunities for students to show what they have learned. One way that teachers can foster the idea that mistakes are an opportunity to learn is by allowing students an additional opportunity after exams to show their understanding of the learning objectives. This can be done in a couple of different ways as shown in this section. Some teachers in the literature had students rework the original missed exam problems while describing their mistakes. Some also assigned additional work to show learning.

In 2013, a protocol for this was implemented in Calculus II classrooms at Worcester State University (Libertini, Krul, & Turner, 2016). The students were asked to provide a correct solution for any incorrect exam problem including an explanation of the error. They also needed to provide a similar problem example from the class notes, suggested book problems, assigned readings, or quizzes. These exam reworks were graded separately from the initial exam and were worth between 10% to 15% of the course grade. These researchers found that for students that struggle with basic background algebra material, writing about their errors allowed them to identify the skills they needed review to achieve the learning objectives of the course. Writing also allowed them to recognize the underlying concepts and understand them at a comprehension and communication level. For the students that had an incorrect conceptual understanding, writing forced them to face those misconceptions directly and replace them with correct concepts. This self formative feedback moves students off the path of misconception and onto the path of correct conceptual understanding. Students that struggle with multiple minor errors such as arithmetic or sign errors were made aware of this trend through writing (Libertini et al., 2016). Although there were some other course changes that happened during the introduction of the exam rework assignment, the authors were able to make some useful comparisons. They found that the final exam average was 7% higher than the sections where the rework assignment was not used. Also, the number of students who passed the course was 19% higher in the section that did use the rework assignment. The next semester, all sections were required

to use the rework assignment on all four of their exams. They compared these sections with the same instructors from the previous semester where the rework assignment was not used. There was a 12% decrease in DFW (drop, fail, and withdraw) rates and a 20% increase on scores for conceptual questions on the final exam.

In 2003, Nolan found that high school science students' perceptions of their teachers focus on learning predicted higher achievement and motivation than the students' perceptions of their teacher's focus on performance and covering content (Nolen, 2003). This focus on learning can be communicated through the feedback that is given to students on all assessments. Many different studies have shown that this critical feedback can be structured in ways that encourage students to progress and provide the information needed for the student to build strategies to improve work and achieve the learning objectives. Teachers should be careful that their feedback is not constructed in an attempt to spare the student's feelings. This can prevent students from having the opportunity to learn from their mistakes and improve their work (Nolen, 2011).

Gradeless Assessments

Unfortunately, even when the teacher's feedback on assessments is encouraging and clear, it may not have the desired effect on student participation and achievement of learning objectives. Students need to also be given the opportunity to act on the feedback. The value of feedback to students is reduced significantly by a punitive grading system (Nolen, 2011).

The research done by Butler in 1987 and Thorkildsen et al. in 1994 on fifth and sixth grade and children from 7-22 years of age respectively found that providing specific information about achievement of learning objectives in an encouraging way leads to increased motivation and persistence. Students also felt that this feedback was more fair and effective than traditional grades, extrinsic rewards, and praise (Butler, 1987; Thorkildsen, Nolen, & Fournier, 1994). This kind of research is why teachers are encouraged to give constructive feedback without grades (Black et al., 2004). The nature and culture of school and university systems in mathematics is not conducive giving feedback to students without

scores. Teachers should consider collecting enough information about students' achievement of learning objectives and skill levels to make reliable and valid decisions about final grades for the course.

More recently, in a paper published in 2013, Butera et al. looked at the relationship between a no grade condition and a engineered high grade condition both compared with the standard grading methods. They wanted to see how these different conditions affected task interest and continuing motivation for the task. Eighty nine seventh to ninth grade students in Switzerland participated in the study. Their results support Bulter's assertions (Butler, 1987) that grade quality influences motivation and task interest. They showed that, compared with the standard grading conditions, both the no grade and the high grade conditions enhanced task interest and motivation for the task (Butera, Pulfrey, & Darnon, 2013).

So how do we implement gradeless learning without introducing other problems? McMorran et al. looked at this question for a study published in 2017. They interviewed 7000 undergraduate students in Singapore that were involved in the study on gradeless learning. Some respondents said that gradeless learning would give them room to make mistakes, allow them to venture into learning and encourage them to wrestle with the concepts, all without having a negative effect on their GPA. However, they found that relieving stress among one group of students increases the stress for others (McMorran, Ragupathi, & Luo, 2017).

Brilleslyper et al. looked at implementing a point free approach in classes with no more than 30 students. They found that a points-free course design can have multiple benefits. First, it creates a system in which the assessments are closely aligned to the course objectives. This increased student learning and development by focusing the attention squarely on development with respect to the learning objectives rather than focusing on points and grades. Student comments supported this. They said, "It focuses the class more on learning and understanding," and, "The only goal is the one that matters most. Learning" (Brilleslyper et al., 2012, p. 424). Another result is the final grades better

reflected student achievement of the course objectives and their final grades were more meaningful to the student. Because the students got wise detailed feedback using clear grade descriptions that are tied directly to the course objectives, their final grade had more meaning and was tied to their learning. One student said that a benefit to this points-free design was, "At the end of the course, the student gains insight on their progress as a whole" (Brilleslyper et al., 2012, p. 424).

Since giving artificially inflated grades poses some ethical issues and personal consequences at a university level, the best way to apply these principals is to give wise feedback without grades or scores until the exam corrections have been completed. This allows students to have room to make mistakes, venture into learning, and engage in productive struggle while still conforming to the grade requirements of the university and lower the stress of grade worried students at major milestones throughout the course.

Productive Struggle

Through appropriate scaffolding, rubrics for the exam corrections and communication assessments lead to productive struggle for the students that approach these assessments with a growth mindset. In the case of exam corrections, students rework their original problem, describe their mistake, and then get an additional prompt that tests the same objective, but at a higher cognitive/difficulty level. Students that struggle with this process have the tools to guide them through the learning process given in the rubric to facilitate a productive struggle.

In group projects or papers, students are presented with prompts that lead them through a problem step by step. Because the prompts have leading questions to guide them through the process of the problem, students can productively struggle through the questions instead of getting overwhelmed and giving up. This is supported by Granberg's study results published in 2016. They looked at what kind of activities and problems lead to a productive struggle. The study showed all students made mistakes because of their incorrect prior knowledge and as a result, erroneously constructed new knowledge. The students that succeeded in a productive struggle were the ones that got the appropriate scaffolding

to reconstruct useful prior knowledge and use this to construct correct new knowledge, and solve the problem (Granberg, 2016).

In 2015, Warshauer published an article describing his study analyzing productive struggle in middle school mathematics classrooms. Through the patterns found from coding the videos of 39 classroom sessions, they saw some patterns emerge. One of the patterns suggested that the level of cognitive demand seemed to influence how the teachers responded to students' struggles. A second pattern suggested that teachers responded to different kinds of struggle in different ways. In the third pattern, the teachers were better able to assess students' struggles when the students wrote down their responses (Warshauer, 2015). Appropriate scaffolding that prompts the student to describe their thought processes can give teachers opportunities to provide wise feedback that fixes the misconceptions.

Zeybek confirmed these patterns in his study on productive struggle in middle school geometry classrooms. He stated, "In order for any struggle to be productive, these struggles with mathematics must be documented. Productive struggle is supported by a developmental progression in thinking and learning. This developmental progression can and should be nurtured in order for meaningful learning to occur in math classrooms" (Zeybek, 2016, p. 396).

Extending to Large Lectures

A goal of this research is to show that the growth mindset assessment structure laid out above can be extended to large lectures. Paunesku et al. implemented a large scale growth mindset intervention. They had success at changing mindsets and improving success of their students (Paunesku et al., 2015). Many other articles, however, recommended against introducing growth mindset interventions on a large scale, especially with assessments. The main concern was the time constraint for instructors. Quality feedback, creating and facilitating exam corrections, managing groups, and reading papers take time. I propose the following solutions to make the structure of the a large lecture class properly facilitate growth mindset assessments.

Classroom Structure

Supplemental practice session. In 2015 Miller and Schraeder implemented a supplemental practice (SP) session. The SP was based on active learning in a group work environment. They found that the experimental group's achievement was statistically significantly higher, especially when prior knowledge was figured into the data (Miller & Schraeder, 2015). This was particularly successful because the group work was taking place in a smaller classroom setting. This shows that the group portions of the assessments will be most effective when incorporated in the recitation sections and not attempted in the large lecture.

Inquiry based lecture style. In 2018, Schraeder implemented an inquiry based lecture style in a high enrollment class. They were trying to find a relationship between this type of lecture style and achievement as well as mindset. Schraeder determined that for large lecture sections, the teaching style is inconsequential (2018). However, in this dissertation he described the techniques they used to handle high enrollment classes. They recommended at least one recitation leader for every 50 students minimum. This can be taken one step further to ask that these recitation leaders run the logistics of the groups projects and help check for achievement of objectives during the exam retakes.

Interventions. Paunesku et al. implemented a large scale growth mindset intervention. They built two 45 minute interventions two weeks apart. They found that the prestudy GPA was positively associated with the baseline scores for growth mindset after controlling for school, race, and gender. The two online interventions raised achievement in a large and diverse group of underperforming students over one semester. These effects were found across a sample of similar schools and with interventions that could be scaled to virtually unlimited numbers of students at low marginal cost (Paunesku et al., 2015). Many other studies, however, recommended against introducing growth mindset interventions on a large scale, especially with assessments. The main concern is the time constraint. Quality feedback takes time, doing exam corrections takes time, and reading papers takes time. I suggest the following solutions to make growth mindset assessments available to students in large lectures.

Assessments in a Large Lecture Setting

Detailed rubrics. Quality feedback is necessary for students to know when they have done well, to help them understand what is good about their work, and to know how to build on those positive aspects in the future. Formative feedback for errors needs to be detailed, comprehensive, meaningful to the individual, fair, challenging and supportive (Brown, 2004). This is a difficult task for busy teachers and instructors who may have hundreds of students. Fortunately, a detailed rubric can greatly reduce the impact on teachers in the issues described above.

For teachers to support student learning, students can be provided with opportunities to achieve the learning goals that have been communicated to them. The teachers should be able to assess what has been learned and to use those assessments to make valid decisions about what to do next in their classrooms. Students need to be able to correctly interpret the teacher's learning goals, and use the opportunities to achieve those learning goals. Then students need to accurately reflect on an assessment and their achievement of the objectives.

Many things must go right for the process described to work. In 2011, Nolan examined the link between teachers' assessment practices and students' motivation and engagement in the context of the social systems that they are placed in (Nolen, 2011). Formative assessment documents like rubrics and tests and the feedback on these documents should be used to not only communicate values, learning goals, and objectives, but to show students how well they have achieved those learning goals and objectives. These documents communicate to students precisely what the gap is between their current and desired performance.

Rubrics for individual written exam (may be taken in a testing center) that are detailed and have prewritten quality feedback responses based on typical errors will reduce the time involved in handwriting wise feedback. Over time, this prewritten feedback can be improved in quality and become more specific for common and uncommon mistakes. These rubrics also should be detailed and scaffolded with the appropriate prompts for exam rework problems.

Professional development. The communication between the lead instructor and the TA/recitation leaders is critical to a course running smoothly. Weekly meetings with the instructor and TA/recitation leaders is necessary to teach and discuss growth mindset classroom and grading strategies. Since the mindset of the instructor (and recitation leader) affects the mindset of their students (Brooks & Goldstein, 2008), these meeting should include growth mindset training. These meetings continue all semester and also include active learning, and a focus on content knowledge. This pattern of professional development is based on the elements determined to be effective for teacher change (Garet, Porter, Desimone, Birman, & Yoon, 2001).

Technology. Technology can be used in multiple ways to give feedback quickly and efficiently to students. *My Math Lab* is a computer application that can instantaneously tell students if the answers they provide are correct or incorrect and can give helpful videos and links to learn the material they are struggling with. For students to use this technology appropriately, the instructor needs to show them all of the tools they have access to and warn them about common notational errors that cause frustration.

Canvas, a widely used learning platform, has capabilities that allow for students to be assigned to give feedback on each others' papers with a detailed rubric designed by the instructor. If each student reads three papers and the rubrics are comparable, then that rubric and feedback can be forwarded to the student. Papers with wide ranges of feedback and rubrics can be read by the recitation leaders and the course instructor. This reduces the instructor grading time commitment on papers significantly.

A study at an Australian university found that, although feedback needs to be timely, students do not differentiate between timely feedback and extremely timely feedback. Additionally, this study found that a replacement of manually generated feedback with automatically generated feedback improved students' perception of the constructiveness of the provided feedback (Bayerlein, 2014). This means that university and college instructors can use automatic feedback with tools such as MyMathLab, Canvas, LaTeX, or applets without being concerned about the impact on student perceptions. Additionally, instruc-

tors only need to provide extremely timely feedback vs. timely feedback if they have sound pedagogical justification for the extra effort.

Conclusion

In this chapter we have reviewed the historical context of assessments and growth mindset. A conceptual framework was developed explaining how the structure of growth mindset assessments was developed in growth mindset theory. The extension of these concepts and application to large lecture sections was discussed. This literature shows that the growth mindset assessment structure involving a written portion, group portion, and testing center portion with reworks may enhance the growth mindset of the students participating. We have also shown how these changes can be implemented in a large lecture setting without creating an undue strain on the instructors or recitation leaders and without negatively impacting the growth mindset or achievement of the participating students.

CHAPTER 3

Methods

The purpose of this study was to understand the relationship between (1) large lecture college algebra undergraduate growth mindset structured assessments and (2) students' achievement, fail/withdraw rates (DFW), mindsets, and anxiety. This chapter states and describes the research questions in detail. The research design is then described and justified. A pilot study and pilot project were completed in preparation for his study. The pilot study used to determine the relevance, reliability, and validity is reported. The pilot project used to refine the administration of the growth mindset structured assessments for large lecture classes is detailed. The procedures, participants, and setting are given. Next, the data sources and instruments used for this study are described in detail. Then, the phases in which these sources were used to collect and organize the collected data is given. Finally, the basic process for analyzing the data collected is described.

Research Questions

Assessments designed to increase a growth mindset have been used at many different levels of incorporation from allowing students to rework the original exam question for partial credit to incorporating group projects, papers, and structured reworks with formative growth mindset feedback. When teachers take the extra time to give formative feedback, correct rework questions, monitor group projects, and/or read papers, this can create an amazing learning experience for the students. However, not all teachers are willing or able to take the time to do this much feedback and grading. It is even more difficult for a large lecture style class in a university setting.

For an assessment to be useable, instructors need to be able to provide or facilitate quality feedback to many students in a reasonable time frame. This research is focused on minimizing the instructor time commitments for incorporating growth mindset structured assessments including group projects, papers, and structured reworks with formative

feedback. This time minimization is achieved in the following ways: using technology to streamline formative feedback in LaTeX, using Canvas to encourage students give formative feedback to each other on papers, and to grade group projects using speed grader in Canvas. The researcher documented the grading time commitments comparable for growth mindset assessments versus traditional exam grading for two graders familiar with both types of exams. This helped determined the usability of these growth mindset structured assessments. The usability of these assessments are discussed in chapter 5.

After three growth mindset structured assessments were administered to the experimental class, the effect that these assessments had on the students' mindset, anxiety, DFW rates, and achievement were examined using the common final exam scores and surveys.

Table 3.1

Quantitative Research Questions

Research Question	Instrument/Data Source	Data Analysis
Does incorporating growth mindset structured assessments in large lecture college algebra courses affect final exam scores?	The final exam	ANOVA Descriptive Statistics (mean, standard error)
Does incorporating growth mindset structured assessments in a large lecture college algebra course affect DFW rates?	Math Department DFW rate collection system ("Utah State University", 2018)	χ^2 test for homogeneity of proportions Descriptive Statistics (proportions)

Note. DFW=fail withdraw rates, final exam as created by Utah State University Mathematics and Statistics department faculty.

Does incorporating growth mindset structured assessments in large lecture college algebra courses affect final exam scores? This question, shown in *Table 3.1*, addresses whether the incorporation of the growth mindset structured assessments encouraged students to take charge of their own learning in a measurable way. Because the common final exam had a different test structure than the assessments that the experimental group participated in (which are mostly free response), practice traditional exams were accessible to all students. Multiple choice exams were reviewed in both the experimental and control recitation sections.

Does incorporating growth mindset structured assessments in a large lecture college algebra course affect fail/withdraw (DFW) rates? By asking this second question in *Table 3.1*, the researcher was trying to determine if the incorporation of the growth mindset assessment structure had an effect on successful completion of the course. This analysis was combined with the final exam score data in the discussion chapter. The researcher included in this discussion an analysis that first compared the DFW rates in all large lecture precalculus classes taught in the spring 2019 semester and secondly examined the effect these rates may have had on the average final exam score differences.

Table 3.2

Qualitative Research Questions

Research Question	Instrument/Data Source	Data Analysis
What is the effect on math anxiety of incorporating growth mindset assessments in a large lecture college algebra course?	Qualtrics Survey (Lewis, Tait, & Schneiter, 2018)	Thematic axial coding

Researchers compiled phrases based on themes associated with fixed/growth mindset and more/less anxiety and used them to code the responses given by students in a pilot study Qualtrics survey. This pilot study was conducted during the summer 2018 semester. It is described in detail later in this chapter. Using this coding template, researchers found that out of 21 responses, 7 were coded with math anxiety before the implementation of the growth mindset structured assessments and 2 were coded as not being anxious about math. After the implementation, there were 0 out of 21 responses coded with math anxiety and 10 out of 21 coded with a reduction in math anxiety. Because of these promising results the researchers were encouraged to formally ask the question given in *Table 3.2*: What is the effect on math anxiety of incorporating growth mindset assessments in a large lecture college algebra course? This question's objective was to determine if the reduction of math related anxiety in students was a direct result of student participation in growth mindset structured assessments.

The researchers improved the Qualtrics survey that was used in the pilot study using

Table 3.3

Mixed Methods Research Questions

Research Question	Instrument/Data Source	Data Analysis
How does incorporating growth	**Qualtitative**	Thematic
mindset structured assessments	Qualtrics Survey	axial coding
in a large lecture college algebra	(Lewis, Tait, & Schneiter, 2018)	
course affect students' mindsets?	**Quantitative**	ANOVA
	Dweck's Growth Mindset	Descriptive Statistics
	Likert Scale Survey	(mean, range, sd)

Note. DFW=fail withdraw rates, sd=standard deviation.

the student responses that gave the most applicable results. This improved version of the Qualtrics survey and Dweck's growth mindset Likert scale survey were used to determine the if the incorporation of assessments structured to foster a growth mindset actually did improve the mindset of the students participating. In the discussion chapter, these two types of analysis are combined with examples of student responses to give the mixed methods results with respect to the question in *Table 3.3*: How does incorporating growth mindset structured assessments in a large lecture college algebra course affect students' mindsets?

Growth Mindset Assessment Structure

Each growth mindset structured exam had three parts. There was a portion of each assessment administered in the testing center, a written portion, and a group portion. The written portion and group portion were completed outside of class.

Testing Center Portion

The testing center portion of the exam was not given a time limit, but typically took students between one to three hours to complete in a three to five day window. The majority of this portion of the exam was used to assess the objectives associated with the algorithmic skill, construct a concept, and simple knowledge learning levels. There were sixteen mini-experiments (prompts and corresponding rubrics) for each of the three midterm portions of the exam taken in the testing center.

For each mini-experiment in the testing center portion, students had the opportunity to participate in reworks for missed problems. In this case, students were asked to rework their original problem, describe their mistake, and then complete an additional mini-experiment

that assessed the same objective, but at a higher cognitive level.

Written Portion

The written portion of the exam had a rough draft due a couple of days before the final draft was submitted on Canvas. The rough draft was reviewed by peers during time reserved for open questions in recitation. After the final draft was turned in, three formal peer reviews were completed on Canvas. Comprehension and communication and discover a relation were the main learning levels of the objectives assessed by the written portion of the assessments. A few times it was appropriate to assess objectives in this portion with the application learning level. The number of mini-experiments given in this portion of the exam were four, three, and five respectively.

Group Portion

Students were assigned groups within their recitation classes. They were encouraged to sit in their groups in large lecture as well as in recitation. Some recitation time usually used for open questions was used for students to work on the group portion of the assessments.

For each of the group portions of the exams there were four different due date. These were used to keep students accountable to their groups. First, they needed to make assignments. Each prompt was assigned to two to three people in each group and each member of the group completed three to four prompts independently. Second, they needed to complete assigned problems. Next, they needed to comment on the completed prompts of their group members. After adjusting their work based on comments and completing the rest of the prompts based on the group work the student turned in a final draft of the group work portion of the exam. There were five miniexperiments on the first two group work portions of the assessments and and one miniexperiment on the last one. The objectives assessed using the group work portion of the assessments was primarily used for the application and discovering a relation learning levels.

Research Design

This was a convergent parallel mixed methods design which utilizes quasi-experimental grouping methods. There was an experimental group and two comparison groups. This

was quasi-experimental because the participants were not chosen randomly and were not randomly divided into the three different groups. A mixed methods approach was chosen, since both qualitative and quantitative methods were used in a single study (Creswell & Clark, 2007). Quantitative measures were used to determine if there were differences in achievement and mindset. Qualitative measures were used to give a more comprehensive picture of the mindset and attitude changes in the students that participated in the study.

The students in both control classes participated only in a pre-post Likert scale growth mindset survey (quantitative). The intervention class participated in a pre-post Likert scale mindset survey (quantitative) and an open-ended survey (qualitative) included to inform the effectiveness that growth mindset structured exams may have had with students' mindset and anxiety. The students all participated in the same common final exam. These scores were compared (quantitative) to discover the effectiveness of growth mindset structured assessments on overall achievement. Thus, convergent qualitative and quantitative themes informed a main finding in this study. The qualitative and quantitative data are integrated in the results and discussion chapters.

Procedures

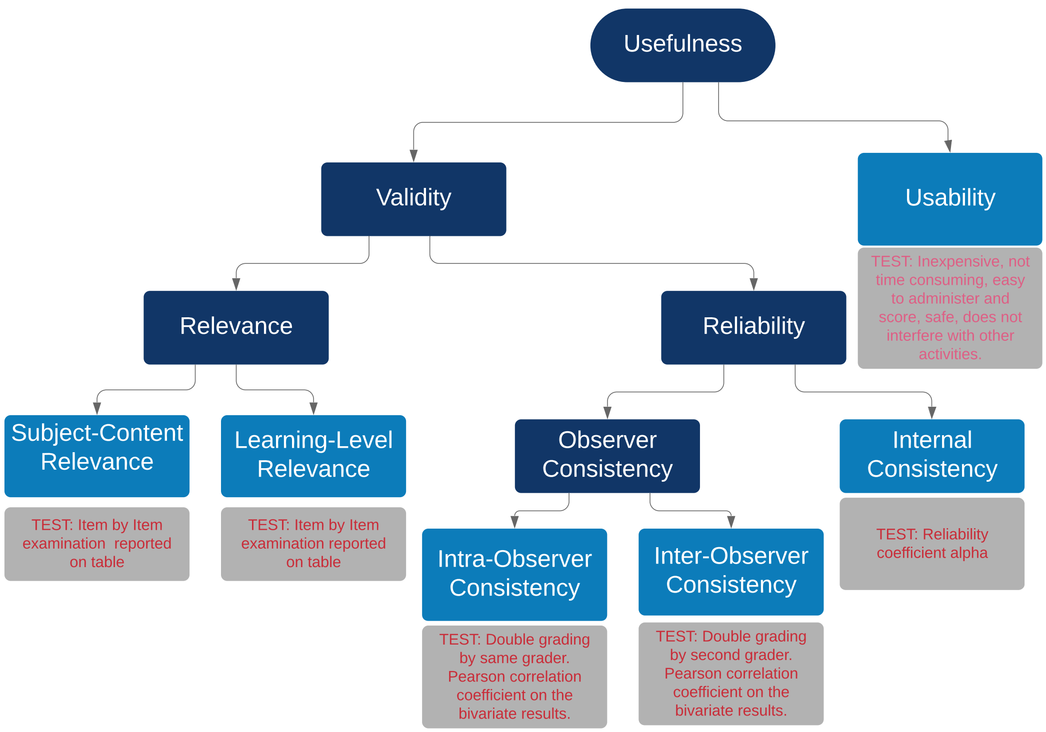
The participants were students registered in three different sections of college algebra in the spring semester of 2019. The student researcher was instructor of record for two of the sections, the experimental section and the first control class. A veteran college instructor was in charge of teaching the second control section and writing the traditional exams administered to both control classes. The students in the experimental class were given the option to take the traditional exams and a default of the growth mindset assessments.The students in the experimental section that opted out of participating in the growth mindset structured assessments took the same exams as the first control class. The first control section was given the same traditional assessments questions as the second control section.

Relevance, Reliability, and Validity

Pilot Study Analyzing Assessments

The researchers conducted a pilot study during the summer of 2018 with the purpose of determining the usefulness of the growth mindset assessments that were developed for this research. This usefulness was determined by both the validity and the usability (Cangelosi, 1999).

Fig. 3.1. Usefulness of Growth Mindset Structured Assessments



An assessment is found to be useable if it is inexpensive, not time consuming, easy to administer and score, is safe, and does not interfere with other important activities (Cangelosi, 1999). The usability of this growth mindset structured assessment was determined by analyzing the experience of the instructors that administered the assessments. The us-

ability of the assessment should be balanced with the validity. To determine the validity of an assessment both the relevance and reliability need to be found.

The relevance of an assessment is found by having someone other than the researcher complete a table showing the subject content relevance and the learning level relevance. An item-by-item examination of the exams showed they were relevant to the objectives previously set forth. To prevent bias, the instructor that wrote the exam did not complete these relevance tables. To see a full list of the stated learning objectives, see Appendix A. The researcher found that the assessments are relevant to the stated objectives as shown in the relevance tables in Appendix B.

Reliability is determined by both internal consistency and observer consistency. The assessments demonstrated internal consistency based on internal consistency tables and the reliability coefficient α. The standard error of measure was also calculated. These values are shown in the *Table 3.4* below.

Table 3.4

Reliability Coefficient α and Standard Error Measure (SEM)

Exam 1	Exam 2	Exam 3
$\alpha = .88$	$\alpha = .82$	$\alpha = .75$
SEM= 3.55	SEM= 4.12	SEM= 4.55

An item by item analysis was also calculated to determine if any questions could be changed to improve the efficiency and effectives of the exams. A few items on the first and third exams were identified and altered based on this analysis. This item by item analysis also showed a good range of difficulty for each exam.

To determine observer consistency, a random sample of 30 exams were collected from consenting students. One grader scored the assessments two times, a week apart, to determine intra-observer consistency. A second grader scored the same exams once. These scores were compared to the first scoring by the first grader to determine inter-observer consistency. These scoring tables were compared for differences. Intra-observer consistency was found to be within reasonable limits. Inter-observer consistency analysis found some

clarification was needed in a few of the rubric items for the assessments. These changes were made and implemented on the assessments.

The researcher and assistant student researcher developed a protocol of thematic axial coding for the Qualtrics survey questions during this pilot study. These researchers double coded 15% of the student survey responses. The researchers determined the coding protocol to be valid based on the double coding. The protocol that the researchers developed for training the second coder is in the Appendix C.

Pilot Project Refining for Large Lectures

During the Fall 2018 semester researchers conducted a pilot project with the purpose of refining the process of administering and grading the assessments for a large lecture section. There were 262 enrolled in the participating class section. Three recitation leaders and a grader were assigned to the class. Recitations have a smaller subset of students from the large lecture section; in this case about 30-35 students enrolled in each. In recitation, students enrolled have the opportunity to ask questions, get clarification on the lecture/notes, learn how to solve difficult homework problems, work on group projects, and check off exam retake problems. The results from this project resulted in minor adjustments to a few exam questions to speed up grading. These adjustments did not alter the cognitive load (Sweller et al., 1998), the cognitive demand (Web, 1997), or the learning level relevance (Cangelosi, 1999) of the exam items.

Participants and Setting

There were 335 students total asked to participate in the study. In the experimental section 92 of 107 students consented to participate. In the first control class 76 of 133 and in the second control class 23 of 102 consented to participate in the study. Of these 23, 20 and 3 respectively took both the pre and post Likert scale surveys. The participants in this study were students from a university in the western United States. The majority of the students were freshman and sophomores. About 40% were female and 60% male. The majority of students were white. These demographics are generally consistent with the university undergraduate population demographics. This study assumes the population to

be any potential set of Utah State University students placed in this setting.

The study involved three different classes. The instructor of record for the experimental class and the first control class was the researcher. These classes had the same instruction and the same notes and were held for 75 minutes twice a week. This first control class controlled for the different kinds of assessments. The experimental class was asked to participate in growth mindset structured assessments until the final exam. They were given the option take either the growth mindset structured exams, or the traditional exams. In either case, they were asked to participate in the study. The second control class controlled for instructor teaching type. This class was held for 50 minutes three times a week. This second control class participated in the same traditional unit exams as the first control class. These exams were traditional exams created by Utah State University Mathematics and Statistics Department course coordinator. This course coordinator was the instructor for the second control class. All three classes took the same common final exam created by Utah State University Mathematics and Statistics Department faculty. The class separations are given in *Table 3.5* below.

Table 3.5

Class Separations

	Experimental Class	Control Class 1*	Control Class 2**
Instructor	Researcher	Researcher	Seasoned Instructor
Type of assessments	Growth Mindset	Traditional	Traditional
Number of student participants	92	76	23

Note. *Controlling for exam type. **Controlling for instructor.

Data Sources and Instruments

There were five sources of data for this study. Because all three participating sections took the same common final exam, this exam was a source of data to compare those three sections. The fail and withdraw (DFW) rates were a data source that was used to compare changes across all four large lecture sections taught in the spring 2019 semester. The results of the pre and post growth mindset Likert surveys for all three participating sections was

analyzed for changes. A post course Qualtrics survey was given to the experimental class and qualitatively analyzed. Video data for similar lessons for each class were be compared and summarized.

Final Exam

All three sections took the same common final exam with scores represented as points. They were a combination of twenty multiple choice and four free response questions. These exams were all graded at the same time, with the same rubric, and with the same team of graders consisting of the recitation leaders, the instructors of record and the graders assigned to the course.

Because of the low study participation in the second control class, aggregate average final exam score and descriptive statistics for this section were collected from the university. The experimental section and control class 1 had high enough participation to be samples that are representative of the population. We are treating these classes as a sample of of any Utah State University student placed under these assessment and class conditions.The aggregate data from control class 2 was compared with the data collected from the experimental class and control class 1 using ANOVA. This statistical method was used to test for a significant difference in the mean final exam scores between the experimental section and the two control sections. The exam scores were also analyzed to determine nuances in the descriptive statistics such as standard error, range, and variance.

DFW Rates

The fail, withdraw (DFW) rates for each class were collected by the Mathematics and Statistics department. The proportion of student fails and withdraws from each course were compared and analyzed. Because the drop deadline occurred before the first growth mindset structured assessment was administered, the drop rates were not be collected by the researcher or analyzed.

Growth Mindset Likert Survey

Participants in all three sections were asked to take a growth mindset Likert scale survey at the beginning of the course and again at the end of the course. This mindset

assessment is a diagnostic tool drawn from research-validated measures used to assess their mindsets. This Likert scale survey was developed, used, and recommended by Carol Dweck (2006). The survey consisted of 16 statements regarding the respondents beliefs about change in talent and intelligence. The full survey is given in Appendix I.

Qualtrics Survey

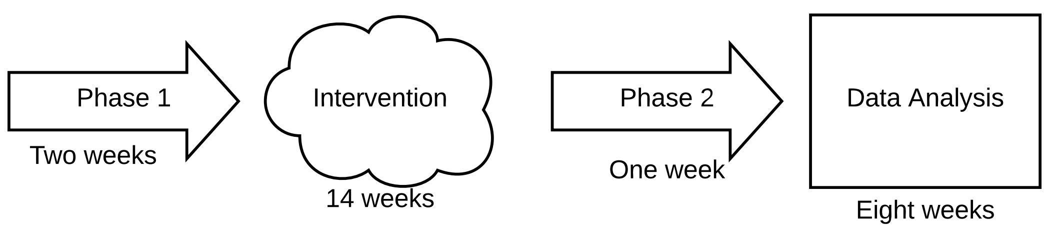
Participants in the experimental section were asked to participate in a Qualtrics survey within three weeks after the course was completed. This survey was 21 open ended questions. These questions asked about likes and dislikes of the different portions of the growth mindset structured assessments. These questions were developed for the pilot study and refined based on the usefulness of the results of that study. A complete list of survey questions is included in Appendix J and the protocol for the thematic axial coding is given in Appendix C.

Video Data

A sampling of lessons were filmed for similar lessons in all three sections. These were summarized and compared to determine if any of the results were a result of the instructional styles.

Data Collection and Organization Procedures

This study had two phases with an intervention in the middle and a data analysis occurring after the second phase.



Phase One

Participants in all three sections were given the growth mindset Likert scale survey developed and used by Carol Dweck (Carol S Dweck, 2006). This survey was administered before the first exam, but after the first week of class.

Intervention

Participants in the experimental section of college algebra had the option to either take growth mindset assessments throughout the semester or take the traditional assessments. Both control sections took the same traditional exams. These exams were constructed in the traditional method used in previous semesters. The experimental section and the first control section were taught using the same method, and using the same notes. The only difference between the experimental section and the first control class was the three unit assessments.

Phase Two

At the end of the semester, students in all three sections took the same common final exam. This exam was constructed in the traditional method used in previous semesters. All three sections retook the growth mindset Likert scale survey by Dweck again. Participants in the experimental section additionally took part in a Qualtrics survey about their experience with the growth mindset assessments.

Data Analysis

Quantitative Analysis

A one way analysis of variance (ANOVA) was used to statistically analyze the quantitative data from the mean final exam scores. Of the 107 students registered in the experimental class, 92 consented to participate. The mean final exam scores of these 92 students was collected. The mean final exam score of the consenting 76 out of total 133 total registered students in the first control class was also collected. Because only 23 out of the 102 registered students in the second control class consented to participate, consent was requested from and given by the Institutional Review Board to collect the aggregate mean final exam score for the 95 students that took the final exam in the second control class. The three mean final exam scores were compared using a significance level of $\alpha = .05$. This means that an F value higher than 3.031 would result in a rejection of the null hypothesis that the mean final exam scores were the same. An F value less than 3.031 would result in a failure to reject the null hypothesis. Descriptive statistics such as mean, and standard

error were also compared for similarities and differences. For the DFW rates, proportions of student fail and withdraws were compared.

Qualitative Analysis

The thematic axial codes developed in the pilot study were used to inform the deductive coding which the researcher used for the qualitative analysis in this study. The researcher inductively coded the Qualtrics survey results using thematic axial coding to develop emergent themes for the comments. These are: growth mindset, neutral mindset, fixed mindset, less anxiety, more anxiety, positive attitude, neutral attitude, negative attitude, and irrelevant.Twenty students from the experimental class consented to participate in the post course Qualtrics survey. Responses were coded as having “less anxiety” if they contained phrases similar to “confident”, “not worried” “ not anxious”, or “comfortable”. The responses were coded as having “more anxiety” if they contained phrases similar to “not confident”, “afraid”, “anxious”, or “nervous”. Responses were coded as “growth mindset” if they contained phrases such as “learn from mistakes” or “worked hard to improve”. A code of fixed mindset was given to a response containing phrases similar to “ not smart” or “can not do math”. For a response to be coded with a positive attitude, responses included phrases such as, “like”, “happy with” or “enjoy”. For a response to be coded with a negative attitude, responses included phrases such as, “hate”, “dislike” or “annoying”. The protocol for the thematic axial coding is included as Appendix C.

Mixed Methods Analysis

The researcher looked for convergent themes between the quantitative and qualitative results of the post course Qualtrics survey, the Likert scale survey, and the student email communications. The Qualtrics survey was only given to the experimental section, however, email communications and the Likert scale survey were analyzed for more than one section. The researcher looked to determine if the quantitative results of the growth mindset Likert scale survey were consistent with the quantities of growth vs fixed mindset responses in email communications and the post course Qualtrics survey.

To analyze and compare instructor time commitment and student mindset, the email

correspondence between students and the instructor was coded for relevant themes in the experimental class and the first control class. Each email chain (initial email with replies) was only counted once. Questions about location and time of office hours, where to find resources on Canvas, questions about class announcements, due dates, syllabus questions, and how to navigate other student resources were coded as logistical email chains. Email chains regarding improvement in study techniques, or suggestions about general improvement in the class without mentioning grades were coded as feedback email chains. Email chains with students asking for specific help with a homework or or math question were coded as math help email chains. Email chains regarding grade questions, grade disappointment, or asking for grade improvement were coded as grade question email chains.

CHAPTER 4

Results

The purpose of this study was to understand the relationship between growth mindset structured assessments given in a large lecture section of college algebra and student achievement, fail/withdraw rates, mindset, and anxiety. This study was informed using Dweck's (2006/2007/2017) work with growth mindset and fixed mindset. The assessments were built with a structure that provided students with feedback in multiple settings and opportunities to learn from mistakes. The hypothesis for this study was that students participating in growth mindset assessments would perform better on a traditional final exam, be more likely to pass the course, and be less likely to withdraw from the course than students who did not participate. We also hypothesized that the students participating in growth mindset structured exams would feel less anxiety about mathematics and have a growth mindset.

Research Question One

To address the first research question, "Does incorporating growth mindset structured assessments in large lecture college algebra courses affect final exam scores?" we conducted a one way analysis of variance (ANOVA) to determine whether the differences between the means on the final exams of the three groups (experimental, control for exam, control for instructor) were statistically significant at a significance level of $\alpha = .05$.

The ANOVA calculations resulted in an $F = 2.270$ with F critical value of 3.031 and $p = .1053$. Thus, we fail to reject the null hypothesis. We do not have enough evidence to conclude that the mean final exam scores are not all the same. The results are summarized in Table 4.1 below.

Figure 4.1 gives the final exam course means for all three sections with the 95% confidence intervals shown graphically. Although the differences in the final exam scores are not statistically significant, the experimental class did have a lower mean score than both of the

Table 4.1

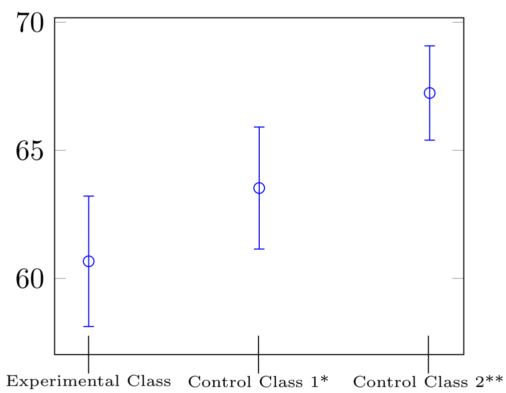
ANOVA

	N	Mean	Standard Error
Experimental Class	92	60.6667	2.3819
Control Class 1*	76	63.5263	2.5459
Control Class 2**	95	67.2368	1.8411

Note. *Controlling for exam type. **Controlling for instructor.

control classes. This may be because the second control class was taught by the instructor that was in charge of writing all of the traditional assessments including the common final exam. The first control class was given the traditional assessments written by the instructor of the second control class for all midterms as well as the final. So students may not understand less, they just have less practice with the exam type.

Fig. 4.1. ANOVA Results for Final Exam Means



Note. *Controlling for exam type. **Controlling for instructor.

Even when teaching the same material, different teachers emphasize different aspects of the topics taught. These emphasized topics typically show up on the exams. Additionally, the traditional exams were a series of true/false and multiple choice questions followed by a few free response questions. This format is significantly different from the growth mindset structured exams given to the experimental section which were mostly free response questions. The format difference could have been an influencing factor in the experimental class having a lower final exam score mean than the class controlling for exam type. Familiarity

with the exam, given the instructor writing the exam was teaching the second control class, could have been an influencing factor in this class having a higher final exam score mean.

The traditional assessments were not validated for relevance to objectives, internal consistency, or reliability as the growth mindset structured assessments were. These traditional exams did not discourage guessing due to negative marking, and are therefore considered to be a less reliable measure of understanding than the same question with negative markings given for incorrect responses. The exam question is even more reliable if the same question is given in a free response format (Burton, 2004). Because the reliability and relevance of the traditional assessments is not known, students may perform better on the exam as a result of factors other than understanding of the material. From this analysis we cannot conclude that incorporating growth mindset structured assessments significantly changes scores on the traditionally structured final exam for college algebra courses at Utah State University.

Research Question Two

Secondly we asked, "Does incorporating growth mindset structured assessments in large lecture college algebra courses affect DFW (Fail, Withdraw) rates?" We focused on the fail and withdraw rates because the drop deadline for the course occurred before the first growth mindset structured exam was administered. Consequently, the drop rates did not need to be collected and no analysis was completed on them. The proportions given in *Table 4.2* are the actual proportions for the courses. First we give the results of the χ^2 test for homogeneity of proportions followed by an analysis of these numbers using the proportions and other descriptive statistics. The number of student withdrawals and fails were combined as shown in the *Table 4.2*.

For a test of the hypothesis that the proportions of fail and withdraws were the same for all three sections, we obtained with a significance level of $\alpha = .05$, the critical value of χ^2 is 5.911 with two degrees of freedom. The test statistic is 5.836. This difference is considered to be not quite statistically significant. So there is marginal evidence of a difference between the combined withdraw/fail rates for the three participating large lecture college algebra

Table 4.2

Withdraw and Fail Summary Table

Number of :	Withdraw (W)	Fail (F)	$W + F$	Total Students in Class
Experimental Class (EC)	0 ***	15	15	99
Control Class 1* (CC1)	5	36	41	133
Control Class 2** (CC2)	3	21	24	102

Note. *Controlling for exam type. **Controlling for instructor. ***One student removed as a data point. Justification given later in this section.

classes.

Table 4.3 gives the proportions of student withdraws and fails for all four large lecture college algebra courses that occurred during the spring 2019 semester. For the purposes of this study, a student is considered to have a fail for the class if they received a grade of 'D' or 'F'. This table shows the experimental class had lower withdraw and fail rates than both control sections.

Table 4.3

Proportions Withdraw and Fail Summary Table

Proportion of :	Withdraw	Fail
Experimental Class (EC)	.0100	.1500
Control Class 1* (CC1)	.0376	.2707
Control Class 2** (CC2)	.0294	.2059

Note. *Controlling for exam type. **Controlling for instructor.

One student withdrew from the experimental section. This student took the testing center portion of the first exam, but did not participate in any of the growth mindset activities for this exam. The student withdrew from the course before the second exam was available. The growth mindset portions of the exam included opportunities for students to show understanding by reworking the original exam prompt and answering an additional prompt (testing the same concept but at a higher cognitive level), peer reviews for a written portion, and a group assignment. Because this student did not participate in the growth mindset activities, it is appropriate to include additional analysis with their data point removed. These results are given in the *Table 4.4*.

Table 4.4

Proportions Withdraw and Fail Summary Table Revised

Proportion of :	Withdraw	Fail
Experimental Class (EC)	0	.1500
Control Class 1* (CC1)	.0376	.2707
Control Class 2** (CC2)	.0294	.2059

Note. *Controlling for exam type. **Controlling for instructor.

Research Question Three

To address the third research question, "What is the effect on math anxiety of incorporating growth mindset structured assessments in large lecture college algebra courses?" the researcher completed thematic axial coding on the post course Qualtrics survey given to the experimental section. Twenty students participated in this survey. Because of the length of the survey, it was expected that the response rate would be low. However, the proportion of positive to negative responses is consistent with the University evaluations for the course, so we feel confident this is a representative sample. A response was coded as less anxiety for phrases similar to "confident", "not worried", or "comfortable" being contained in the comment. If "not confident", "afraid", or "nervous" was a part of the response, it was coded as having more anxiety. The proportion of responses that coded as showing either less anxiety or more anxiety are given in *Tables 4.5* though *4.8*.

Table 4.5

Qualtrics Growth Mindset Post Course Survey Pre and Post Course General Feelings Anxiety Responses

	Less Anxiety	More Anxiety
How did you feel about math before this class?	0	0.15
Do you feel differently about math now? Explain.	0	0

The survey questions shown in *Table 4.5* compare the proportions of the student responses to the survey showing anxiety about math before and after participating in the growth mindset structured assessments. This shows a reduction in anxiety responses from

15% to 0% for these prompts.

Table 4.6

Qualtrics Growth Mindset Post Course Survey Group Work Questions Anxiety Responses

	Less Anxiety	More Anxiety
What did you like about group work in class? What did you not like?	0.2	0
How did group work affect your feelings and attitudes toward the class and math in general?	0.15	0.05
What did you like about writing papers for this class? What did you not like?	0	0.05

The survey questions in *Table 4.6* compare the proportions of student responses to the survey showing either more anxiety or less anxiety as a result of the group work portion of the assessments. The responses show lower anxiety responses for two of the questions for 20% and 15% of the students respectively.

Table 4.7

Qualtrics Growth Mindset Post Course Survey Rework Questions Anxiety Responses

	Less Anxiety	More Anxiety
What did you learn from the exam rework process?	0.55	0
How did knowing you would have the opportunity to rework in-class exam questions affect your study habits?	0.35	0
How did knowing you would have the opportunity to rework in-class exam affect your feelings and attitudes?	0.63	0

The survey questions in *Table 4.7* compare the proportions of student responses to the survey showing either more anxiety or less anxiety as a result of the rework opportunities available as a portion of the assessments. In a range of 35% to 63% the students responses

coded as showing less anxiety as a result of the rework opportunities. None of the student responses coded showing higher levels of anxiety as a result of the rework opportunities.

The survey questions in *Table 4.8* compare the proportions of student responses to the survey showing either more anxiety or less anxiety as result of the general test structure. Students' responses coded showing lower anxiety as a result of the general growth mindset test structure for 20% and 37% of the responses given.

Table 4.8

Qualtrics Growth Mindset Post Course Survey Test Structure Questions Anxiety Responses

	Less Anxiety	More Anxiety
How is the test structure different than a typical math class? How is it the same?	0.2	0
How do you think this test structure affected your attitude toward mathematics?	0.37	0

Research Question Four

To answer the fourth research question,"How does incorporating growth mindset structured assessments in a large lecture precalculus course affect student's mindset?" the researcher used both quantitative and qualitative analyses. The researcher quantitatively analyzed the growth mindset Likert scale survey and qualitatively analyzed with thematic axial coding of the post course Qualtrics survey given to the experimental section.

A response was coded as growth mindset if phrases such as "learn from mistakes" or "worked hard to improve" were present in the comment. A code of fixed mindset was given to a response for phrases such as " not smart" or "can not do math" being present. For a response to be coded with a positive attitude, responses included phrases such as, "like", "happy with" or "enjoy". For a response to be coded with a negative attitude, responses included phrases such as, "hate", "dislike" or "annoying". The protocol for the thematic axial coding is included as Appendix C.

The Likert scale survey was administered to the three sections pre and post course.

The seven possible responses were ranked from 1 to 7 with a 7 for the response showing the most growth mindset and a 1 for showing the most fixed mindset.

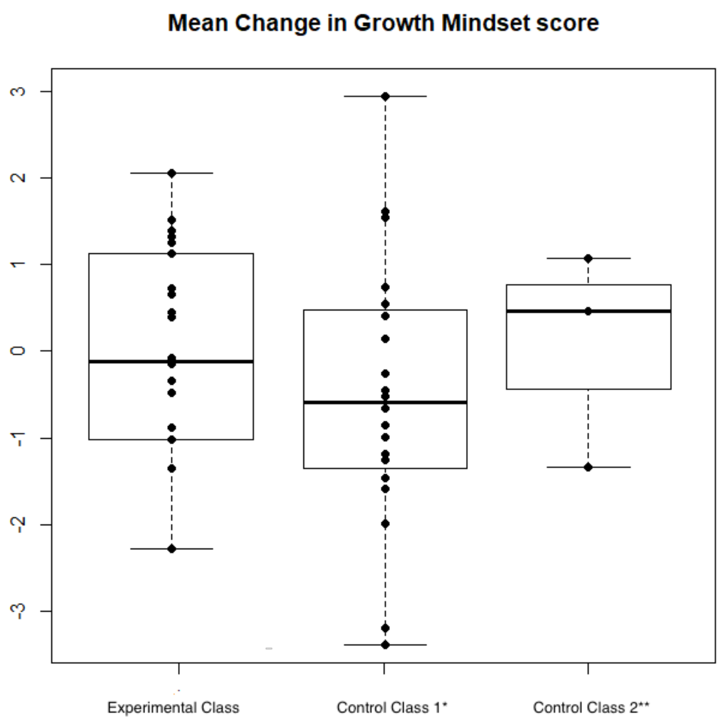
Of the students that consented to participate in this research in, twenty three students participated in both the pre and post growth mindset Likert scale survey for the experimental section. Twenty participated in the class controlling for exams and three participated in the class controlling for instructor. Of the three students that did participate, one showed a slight decrease in growth mindset responses, and two showed a slight increase in growth mindset responses. The average original mindsets for all the students that participated was a 5.37 out of 7 in the experimental section, 5.39 out of 7 in class controlling for exam type, and 5.68 out of 7 in the class controlling for instructor. Because the pre-study mindsets were already so high, the participating students did not have much room to improve their mindset scores.

A boxplot for the mean change in growth mindset scores is given in *Figure 4.2.* This boxplot shows a slightly higher median positive change in mindset for the experimental section compared to the control class 1. This boxplot also shows that the range of change in mindset scores was less in the experimental section than in the control section 1. While it looks like the range for control class 2 is large, only three of these students participated in the both the pre and post Likert scale surveys.

The post course Qualtrics survey for the experimental section had 20 respondents to the survey questions. The first two questions compared feelings and attitudes about mathematics before and after participating in the experimental section of college algebra. Question one asked, “How did you feel about math before this class?” and Question two asked,“Do you feel differently about math now? Explain”.

The survey questions in *Table 4.9* compare the proportions of student responses to the survey showing growth mindset, fixed mindset, positive attitude, and/or negative attitude responses. This table shows the comparison between the proportion of responses that coded in one of those four categories of student responses before and after participating in the growth mindset structured assessments. There was an increase in growth mindset responses

Fig. 4.2. Boxplot of Mean Change in Growth Mindset Score



Note. *Controlling for exam type. **Controlling for instructor.

of 21% and a decrease in fixed mindset responses of 10%. Positive attitude responses increased by 13% and negative attitude responses decreased by 22%.

Table 4.9

Qualtrics Growth Mindset Post Course Survey Pre and Post Course General Feelings Questions Mindset and Attitude Responses

	Growth	Fixed	Positive Attitude	Negative Attitude
How did you feel about math before this class?	0.1	0.1	0.25	0.3
Do you feel differently about math now? Explain.	0.31	0	0.38	0.08

The survey questions in *Table 4.10* compare the proportions of student responses to the survey that coded as a growth/fixed mindset or positive/negative attitude as a result of the group work portion of the assessments. These responses coded with 10% growth mindset responses and 0% fixed mindset responses. For the first question in *Table 4.10*, 40% more of the students had responses that coded with a positive attitude than a negative attitude. For the second question in *Table 4.10* 10% more of the student responses coded with a positive attitude than with a negative attitude.

Table 4.10

Qualtrics Growth Mindset Post Course Survey Group Work Questions Mindset and Attitude Responses

	Growth	Fixed	Positive Attitude	Negative Attitude
What did you like about group work in class? What did you not like?	0.1	0	.55	.15
How did group work affect your feelings and attitudes toward the class and math in general?	0	0	0.35	0.25

The survey questions in *Table 4.11* show the proportions of student responses to the survey that coded as growth/fixed mindset and positive/negative attitude as a result of the rework opportunities available as part of the assessments. None of these questions resulted in responses that could be coded as fixed mindset feedback. The student responses to the first two rework questions coded with 50% and 55% growth mindset responses. Two other things of note in Table 4.10 is that 45% of the responses coded with a positive attitude to the first survey question about the rework opportunities and 30% of the responses coded with a negative attitude to the third survey question about the rework opportunities.

Table 4.11

Qualtrics Growth Mindset Post Course Survey Rework Questions Mindset and Attitude Responses

	Growth	Fixed	Positive Attitude	Negative Attitude
What did you like about the exam re-work opportunities? What did you not like?	0.5	0	0.45	0.05
What did you learn from the exam re-work process?	0.55	0	0	0.05
How did knowing you would have the opportunity to rework in-class exam questions affect your study habits?	0	0	.05	0.3
How did knowing you would have the opportunity to rework in-class exam affect your feelings and attitudes?	0.05	0	0.16	0.05

The survey questions in *Table 4.12* give the proportions of student responses to the survey that coded as growth/fixed mindset and positive/negative attitude as a result of the general growth mindset test structure. Student responses coded as growth mindset for 11% to 35% for these three questions. None of them coded as fixed mindset responses. Between

17% and 60% coded with positive attitude responses and between 0% and 11% coded with negative attitude responses.

Table 4.12

Qualtrics Growth Mindset Post Course Survey Test Structure Questions Mindset and Attitude Reponses

	Growth	Fixed	Positive Attitude	Negative Attitude
How do you think this test structure affected your attitude toward mathematics?	0.11	0	0.26	0.11
How is the test structure different than a typical math class? How is it the same?	0.35	0	0.6	0.05
Which part of this test structure did you learn the most from and why?	0.28	0	0.17	0

Summary Results to Research Questions

This chapter provided the results for the data analysis for the methods described in chapter three. Analyses indicate no statistically significant difference in the traditional final exam scores for the students that participated in the growth mindset structured assessments compared to the students that participated in traditional assessments. The fail and withdraw rates for the experimental large lecture section were lower than the other three large lecture sections of college algebra taught in the spring 2019 semester. Students showed less anxiety and higher growth mindset responses as a result of participating the growth mindset structured assessments in a large lecture setting.

CHAPTER 5

Discussion

This chapter begins with a discussion of the different class structures for the three classes participating in the study. This is followed by a review of the usability of the growth mindset structured assessments compared to the traditional exams. Finally, for each of the four research questions, the results are summarized and there are discussions about the meaning of the results, how they relate to prior research literature, the implications of this research, and how these results should be used.

Class Structures

The structure of instruction in the experimental class and the class controlling for exam type (control class 1) was the same. As the researcher, I taught both of these sections. These classes were both taught in a large lecture hall with a live instructor that met twice a week for 75 minutes over a 15 week semester. An analysis of the classroom video recordings collected for this research showed technology such as applets, supplemental short videos, and desmos.com were used at least once a week. The examples and notes for the entire class were printed in a packet and available for the students to purchase from the bookstore, print out as needed, or use as an online pdf. The online pdf had hyperlinks to all technology resources used in lecture. Think, pair and share activities, and group discussions were built into the notes. The concept of growth mindset was introduced on the first day of class for both of these sections and many group activities were structured to build the belief that mistakes are opportunities to learn.

The type of instruction used in the class controlling for instructor (control class 2) was a live lecture style in a large lecture hall. This class met three times a week for 50 minutes over a 15 week semester. The analysis of the three classroom video recordings collected showed the only reference material used was the book required for the class. A document camera was used to display open notes that were given as handouts at the beginning of class every

day. The instructor introduced examples by showing the format the final answer should take. Most final answers for examples were included in the open notes handed out. All examples used in class were similar to test questions for future exams. These observations were confirmed by the recitation leader for the class as a good representation of typical classroom structure.

All three large lecture sections participating in the study had recitation sections that met twice a week. In the experimental section and the control class 1, these recitations were used for group activities and supplemental instruction. In the recitation sections for control class 2, the recitation sections were used to do group worksheets and take quizzes. There were two quizzes each week. The first was a group quiz and the second was individual.

Usability

The usability of an assessment is determined by expense, time commitment, ease of administration and scoring, safeness, and amount of interference with other activities. Although a lot of these criteria are subjective in nature, as the researcher, I have tried to keep my notes on the usability of these assessments as objective as possible. These exams were not perfect, and as I move forward with my teaching I will continue to improve these exams to make them more usable while trying not to lose their current high level of validity.

Expense

The expense for both exams was minimal and similar. No materials other than paper, pencils, and calculators were used in the administration of the exams. Instructors, recitation leaders, and graders were already employed by the university and required no extra expense. All technology and computer applications were either free or already owned by the university. Therefore, for both the growth mindset structured assessments and the traditional assessments, the expense was minimal.

Time Commitment

Student time commitment. There was an increased student time commitment above traditional instructor expectations outside of class for the group work portion and the written portion of the growth mindset structured assessments. However, students com-

mented that the papers and group work helped them study for the testing center portion of the exam, so some of the student time commitment was shifted from traditional cramming right before an exam to scaffolded group work and writing. Students also commented that the increased time commitment earlier in the semester allowed them to spend less time nearer to the end of the semester preparing for the college algebra final exam.

Instructor time commitment. As an instructor, using growth mindset instructional principles takes more time. Three different parts to each exam along with the opportunity to check off reworks during office hours, meant there were more questions from students about logistics during the course. These questions were answered in class, with announcements and over email. Because of this there was an increased instructor email load. The experimental section had 107 students registered and there were 101 email chains regarding logistics of the course and exams during the semester. Questions were about things like, location of office hours for reworks, where to find resources and materials on Canvas, and how to navigate other student resources. Control class 1 had 133 students registered and 52 email chains regarding the logistics of the course during the semester. These were more traditional logistical course questions such as where to find specific files on Canvas or where/when office hours are.

Developing growth mindset structured assessments does not take any more time than developing a multiple choice exam. In fact, basing exam questions on predetermined learning objectives with specific learning levels is a more direct approach to building assessments.

One of the challenges of using growth mindset structure is the increased amount of time it takes to create and provide quality constructive feedback. Technology tools, such as LaTeX, Canvas, and My Math Lab can help minimize this obstacle. For example, a list of common quality feedback responses was commented out (hidden) and compiled in a LaTeX document. This tex document was copied for every student. Then, during grading, the applicable feedback was uncommented (revealed).

Students took advantage of rework opportunities during regular office hours. Students taking the traditional exams spent more time utilizing office hours before the exam and

students in the growth mindset section tended to use more office hours after the exam.

My Math Lab has built in feedback for homework. The growth mindset feature that allows unlimited tries is included in this program. Having all homework assignments in this program allowed the instructor to spend more time giving feedback on assessments instead of grading and giving feedback on homework.

The peer review feature in Canvas allowed students to use a detailed rubric to give feedback to each other. The instructor then spent less time providing feedback on the written portion of the growth mindset structured assessments than would have been required without the peer reviews. Another benefit to using peer reviews was the student interest in reviewing each others work because looking at other students' papers helped them discover and improve on their own written work. Student comments about the paper and peer review process included, "I learned how to think about math as a concept, rather than using rote memorization" and "I learned that I learn things even more better when I have to explain them in words, especially with math". They also enjoyed sharing math puns and funny math stories with their peers. This added levity to what some view as a difficult or heavy subject.

Instructors who intend to implement growth mindset structured assessments can combine the written portion and group portion of these assessments. This will ease administration, and reduce the time commitment for students in managing course related administrative tasks.

Ease of Administration

The testing center portion of the growth mindset structured assessments took the same amount of effort as administering a traditional assessment. The written portions and group portions of the assessments were posted on Canvas and took minimal effort to administer. The administration of the rework portion of the exams was simplified by requiring the students to complete the reworks before coming to office hours. They were required to rework the original problem describing their mistakes and complete an additional more difficult problem before meeting with the instructor or recitation leader. To assure the student

understood the learning objective being assessed, they were asked a brief predetermined question verbally. These questions are included in Appendices D, F, and H.

Ease of Scoring

The amount of time it took to score the exams was tracked by two graders that were familiar with grading both the growth mindset structured and traditional types of exams. The testing center portion of the midterm growth mindset assessments took an average of seven minutes to grade per exam. The traditional midterm exams took an average of four minutes per exam to grade.

The written portion of the exams were each scored with a rubric by three peers. Although the instructor/recitation leader reviewed every paper, the process was streamlined because of the peer reviews. The graders only reviewed in detail the written portion of the exams which did not get peer reviewed by at least three peers or had inconsistent peer reviews. The final scoring took an average of one minute per paper turned in.

In the group portion of the assessments the students worked together to solve three to five learning level appropriate prompts. However, they were required to turn in individual work and scored based on their submission. It took about five minutes per group to give individual scores. This was an average of about one minute per student submission.

Safeness and Amount of Interference with Other Activities

This study to administer growth mindset structured assessments to students was reviewed and approved by the Institutional Review Board at Utah State University. It was determined to be safe and a minimal risk study. Measures were taken to minimize any risk to student safety and interference of their other activities.

Research Question One

The first research question asked, "Does incorporating growth mindset structured assessments in large lecture college algebra courses affect final exam scores?" The results of the analysis for this question found that there was not a statistically significant difference in mean final exam scores. We do not have enough evidence to conclude that the mean final exam scores are not all the same. Even though there was a difference in the final

exam scores between the samples of the three classes this was not a statistically significant difference.

These results are similar to research done by Elwick in 2014. Although there was a positive impact on the mindsets of the students that took part in the study, they did not see a significant impact on grades. They concluded that achievement needed to be tracked over a longer time period to see a positive impact of the intervention. This conclusion can also be said for this study. In addition to a longitudinal study, a breadth study analyzing overall GPA's is recommended.

All of the midterm exams in the experimental section were learning objective based and learning level appropriate. However, the traditional exams and the final exam were not. The comprehensive final exam consisted of 20 multiple choice/ true false questions followed by 5 free response questions of which students picked 4 to complete. The traditional midterm exams were shorter, but the same structure. Each multiple choice question was worth 6 points and no partial credit was given with the exception of one question on which half credit was given for an acceptable, but not the most correct answer. The dramatic differences in exam structure could account for the difference in mean final exam scores for the three classes. This exams are all included in Appendices D, F, and H. Further research on the relevance, reliability and usability of the traditional assessments is recommended.

The structure of the traditional final exam may have affected conclusions referred to in this research question. Grading of the traditionally structured exams highlighted issues resulting in misrepresentation of student understanding. For example, correct work shown for multiple choice questions with minor errors would result in an incorrect choice and no points given. Students showed understanding of the concepts and receive no credit for that understanding. True/False questions that show student understanding are difficult to develop. For example, two groups of students informed me of a pattern they noticed with the wording of the True/False type questions. If the question had the words “must” or “always”, then the answer was false. If these words did not show up, then the answer was typically true. Students that recognized this pattern did not need to show understanding

of the material to get these True/False questions correct.

Students taking the growth mindset structured assessments had the opportunity to rework the original exam questions describing their mistakes and then complete additional more difficult problems for exam credit if they attempted the original prompts. They were required to do this work outside of class. The student was then required to check off these reworks by verbally answering a question to the instructor or recitation leader. If the student demonstrated understanding of the concept, full points were given back for the original prompt. If the student attempted all of the questions on the testing center portion of the exam and worked hard to complete all of the rework opportunities needed, they could get a final score of 100% on the testing center portion of the midterm exams.

Consequently, when students were turning in the final exam, a couple of the students remarked that because of the growth mindset structure of the midterms, they did not have as much anxiety walking in to the final exam. A few students also remarked that they were not as worried about their grade on the final exam in this class and as a result were able to focus their final exam studying to be more heavily weighted to other classes they were more worried about passing. As a result of these comments, further research should be done to determine if incorporating growth mindset structured assessments has an impact on overall GPA an on overall anxiety levels.

Research Question Two

The second research question is,"Does incorporating growth mindset structured assessments in large lecture college algebra courses affect DFW (Fail and Withdraw) rates?" The proportion of student withdraw and fail rates were lower for the experimental section than the other two participating large lecture sections for college algebra taught in the spring 2019 semester. Only one student chose to withdraw from the experimental class. This student was only registered for the class until shortly after the first exam was administered and did not participate in any of the growth mindset activities available as part of that exam. With this student's data disregarded, the percent of withdrawals for the experimental section was 0%. The withdraw rate for the control class 1 and control class 2 were 3.7%

and 2.9% respectively. A student was counted in the fail rate if they received a 'D' or an 'F' for the course. The experimental section had a fail rate of 15% and the large lecture college algebra control sections had fail rates of 27.1% and 20.6%. The test for homogeneity of proportions using the chi-square distribution via contingency tables resulted in marginal evidence of a difference between the combined withdraw/fail rates for the three participating large lecture college algebra classes.

In 2017, Martin found that students that have a negative experience in their freshman year are more likely to drop out and give up on the dreams that led them to enrolling in college. Incorporating these growth mindset assessments gave a significant percentage of students the positive experience of creating their own success through hard work and avoided the negative experiences that come from early failure without the opportunity to recover. A study in 2016 also found a decrease in DFW rates when implementing exam rework opportunities (Libertini et al., 2016). Although these researchers did not differentiate between the fail and withdraw rates, instead looking at them as one percentage, Libertini et. al. found a similar decrease in instances of student lack of success as a result of implementing growth mindset exam techniques.

A number of general classroom structure differences can affect pass rates. The two major classroom structure differences between the three college algebra courses taught at Utah State University in the Spring semester of 2019 were the number of days the course was taught and the time of day that the courses were offered. Aggregate data for withdraw and fail rates was collected for these three large lecture sections at the end of the semester.

In a ten year longitudinal study, Henebry found that students are more likely to pass a class when the course meets three times a week compared to meeting two times a week (Henebry, 1997). Control class 2 met three times a week. The experimental class and control class 1 met two times a week. We should therefore expect that control class 2 will have higher pass rates than the experimental class and control class 1.

These three classes met in both the morning and afternoon. A study in 2006 found that although class time can have an impact on grades, this impact is dependent on the

circadian type of the student (McElroy & Mosteller, 2006). Since we did not collect data on student circadian type, we are not differentiating between time of day as an influencing factor on overall pass rates.

These results imply that students participating in the growth mindset structured assessments took charge of their learning in a measurable way. They were motivated by the opportunity to learn from their mistakes. That motivation led to higher pass rates and lower withdraw rates for the students that participated in the growth mindset structured assessments. Applications of the growth mindset methods we discussed in this study can contribute to improved student retention and completion.

Research Question Three

This research question states, "What is the effect on math anxiety of incorporating growth mindset structured assessments in large lecture college algebra courses?" Overall, students reported lower levels of anxiety as a result of the growth mindset structure of the assessments given. For two of the three Qulatrics survey questions about the group work portion of the assessment, 15% and 20% of the students reported lower anxiety levels as a result of participating in the group work. For the three Qualtrics survey questions about the rework portion of the assessments, 35%, 55% and 63% of the student responses showed lower levels of anxiety as a result of the rework opportunity. For the two questions about general test structure, 20% and 37% of the student responses showed lower levels of anxiety as a result of the growth mindset structure of the exams. The only sections that had responses that coded with higher anxiety levels were the question that asked about the student's feelings about math before this class (15%) and two of the questions in the group work set (5% each).

In 1978, Betz found that higher levels of math anxiety correlated to lower mathematics achievement and higher levels of test anxiety. Changing the structure of assessments from the traditional fixed mindset to a growth mindset lowers the general math anxiety and test anxiety of students. Lower anxiety is correlated to increased achievement. A previous study completed at Utah State University, the same university at which this study was completed,

found that math-related anxiety provided one of the largest and most statistically significant effects on students' percent of points earned and on student pass rates (Bagley, 2015). Reducing anxiety, while not lowering expectations, leads to student success as this current study demonstrates.

The rework portion of the growth mindset structured assessments had the greatest impact on lowering students anxiety of all the growth mindset methods implemented with two of these questions resulting in 50% and 55% growth mindset coded statements. Thus, I recommend when planning implementation of growth mindset assessing, begin with incorporating rework opportunities. Because the group portion of the exam had the next largest impact on lowering anxiety, incorporating this should be the next step.

Research Question Four

Question four says,"How does incorporating growth mindset structured assessments in a large lecture college algebra course affect student's mindset?" Results of the Likert scale survey did not show significant changes in mindset for any of the three participating classes. The participating students had pre-study mindset scores that were already so high, there was not room for measurable improvement. However, the post course Qualtrics survey in the experimental class showed a 21% increase in growth mindset statements when students were asked about their feelings about math before and after participation in the growth mindset structured assessments. Questions about the group portion of the exam resulted in 10% growth mindset responses such as " I actually think it (the groups) greatly improved my attitude". Questions regarding the rework opportunities resulted in 5%, 50%, and 55% growth mindset responses such as "Making mistakes is not bad, as long as you learn from them". General test structure questions resulted in 11%, 35%, and 28% growth mindset responses such as "(The test structure) gave you the chance to find and rework your mistakes so you actually learned something with tests". The only question that resulted in fixed mindset responses (10%) was the question asking how they felt about math before this class. This shows an increase in growth mindset as a result of participating in the growth mindset structured assessments.

Email communication with students differed in the experimental class and the control class 1. Emails from control class 2 were not available for analysis. These emails were a reflection of the mindset and anxiety levels of the students in those classes. Any email questions regarding class announcements, timing questions, or syllabus type questions were coded as logistical. After the logistical emails were analyzed for their impact on instructor time commitment, they were disregarded for this discussion. The experimental class had 57 non-logistical email chains and control class 1 had 28. Of these, 33% of the experimental section and 18% of control class 1 were students asking for advice on how to improve study techniques, asking for general feedback on study techniques, and asking what more they could do to improve performance in the class. Questions regarding disappointment in grades or how to improve their grade made up 14% of the email chains in the experimental class and 43% of the email chains in control class 1. Questions asking for help with specific math problems made up 53% of the email chains for the experimental class and 39% of email chains for control class 1. This shows students in the experimental section were emailing about how to improve their performance or specific math questions rather than asking how to improve their grade. Based on these observations it is recommended that further research focus on the correlation between types of email correspondence and mindsets of students.

An additional observation between the experimental section and control class 1 was the first class period after the first exam. Even though the material covered the same pages of notes, the classes were very different from each other. In the experimental class, there was a lot of participation, questions and comments during the 75 minute class period. However, during the control class 1, the same amount of material took only 60 minutes due to a lack of participation or questions. This could show the differences in the anxiety levels between the two classes directly following the first exam in the course.

This indicates that growth mindset attitudes can be improved using growth mindset structured assessments. These student attitudes were shown to have changed fairly early in the semester. Additionally, instructors can use the types of email correspondence that they receive from their students as a measure of the current mindset they are creating in

their classes. Based on this evidence, changes from a traditional exam structure to a growth mindset exam structure can change the mindsets of students.

In 2016, Hawe and Dixon studied the impact of implementing assessment for learning (similar to standards based grading) with undergraduate students. By just making this one change to a more growth mindset structure of assessment, shifts from a fixed to a growth mindset were found in the researchers qualitative analysis. VanDyke et. al. found fewer negative attitudes about mathematics when college students were asked to participate in writing math papers for the course (VanDyke, Malloy, & Stallings, 2013). In 2013 Yeager et al. found that providing wise feedback to students motivates them to correct and learn from their mistakes. In 2012 Sorensen found that students that participated in group quizzes had higher endurance (a growth mindset trait) than those without the group quizzes. The results of this study show that incorporating all of these techniques mirrors the results of these studies.

Quality feedback, creating and facilitating exam corrections, managing groups, and reading papers does take more time with a large lecture section. However, using the strategies that were laid out in this paper allowed the instructor to successfully incorporate growth mindset structured assessments without overtaxing the instructor and recitation leaders. The research on the results of using these strategies still showed a positive change in the mindsets of students.

Conclusion

In conclusion, growth mindset structured assessments implemented in large lecture sections can benefit students in the following ways. These students have high levels of growth mindset statements as well as higher pass rates and lower withdraw rates than non participating sections. Students have lower levels of math related anxiety and higher levels of growth mindset without instructors lowering course expectations as a result of participating in the growth mindset structured assessments. This study did not show a significant change in final exam scores between the participating sections. Further research is recommended to analyze student's overall semester GPA during the intervention semester as well as their

GPAs over a longer time period. Additionally, further research is recommended to compare the usefulness of traditional exams and growth mindset structured assessments.

Bibliography

Andersson, C., & Palm, T. (2017). The impact of formative assessment on student achievement: A study of the effects of changes to classroom practice after a comprehensive professional development programme. *Elsevier*, *49*, 92–102.

Aronson, J., Fried, C., & Good, C. (2002). Reducing the effect size of stereotype threat on african american college students by shaping theories of intelligence. *Journal of Experimental Social Psychology*, *38*(2), 113–125.

Auten, M. A. (2013). *Helping educators foster a growth mindset in community college classrooms* (Doctoral dissertation, Walden University).

Ayala, C. C., Shavelson, R. J., Ruiz-Primo, M. A., Brandon, P. R., Yin, Y., Furtak, E. M., ... Tomita, M. K. (2008). From fromal embedded assessments to reflective lessons: The development of formative assessment studies. *Applied Measurement In Education*, *21*, 315–334.

Ayala, C., Shavelson, R., Ruiz-Primo, M., Brandon, P., Yin, Y., Furtak, E., ... Tomita, M. (2008). From formal embedded assessments to reflective lessons: The development of formal assessment studies. *Applied Measurement in Education*, *21*, 315–334.

Bagley, J. (2015). *Factors related to successful completion of developmental mathematics courses* (Master's thesis, Utah State University).

Bangert-Drowns, R. L., Hurley, M. M., & Wilkinson, B. (2004). The effects of school based writing-to-learn interventions on academic achievement: A meta-analysis. *Review of Educational Research*, *74*(1), 29–58.

Banta, T. W., & Associates. (2002). *Building a scholarship of assessment*. Jossey-Bass.

Bayerlein, L. (2014). Students' feedback preferences: How do students react to timely and automatically generated assessment feedback? *Assessment and Evaluation in Higher Education*, *39*(8), 916–931.

Betz, N. E. (1978). Prevalence, distribution, and correlates of math anxiety in college students. *Journal of Counseling Psychology*, *25*(5), 441–448.

Black, P., Harrison, C., Lee, C., Marshall, B., & Wiliam, D. (2004). Working inside the black box: Assessment for learning in the classroom. *Phi Delta Kappan*, *86*(1), 9–21.

Black, P., & Wiliam, D. (2010). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan*, *92*(1), 81–90.

Blackwell, L. S., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development*, *78*(1), 246–263.

Boaler, J., & Confer, A. (2017). *Assessment for a growth mindset*. Retrieved 2017, from https://bhi61nm2cr3mkdgk1dtaov18-wpengine.netdna-ssl.com/wp-content/uploads/2017/03/1439422682-AssessmentPaper.pdf

Brilleslyper, M., Ghrist, M., Holcomb, T., Schaubroeck, B., Warner, B., & Williams, S. (2012). What's the point? the benefits of grading without points. *PRIMUS*, *22*(5), 411–427.

Brooks, R., & Goldstein, S. (2008). The mindset of teachers capable of fostering resilience in students. *Canadian Journal of School Psychology*, *23*(1), 114–126.

Brown, S. (2004). Assessment for learning. *Learning and Teaching in Higher Education*, *1*, 81–89.

Burton, R. F. (2004). Multiple choice and true/false tests: Reliability measures and some implications of negative marking. *Assessment & Evaluation in Higher Education*, *29*(5), 585–595.

Butera, F., Pulfrey, C., & Darnon, C. (2013). Autonomy and task performance: Explaining the impact of grades on intrinsic motivation. *Journal of Educational Psychology*, *105*(1), 39–57.

Butler, R. (1987). Task-involving and ego-involving properties of evaluation: Effects of different feedback conditions on motivational perceptions, interest, and performance. *Journal of Educational Psychology*, *79*(4), 474–482.

Butler, R. (1988). Enhancing and undermining intrinsic motivation: The effects of task-involving and ego-involving evaluation on interest and performance. *British Journal of Educational Psychology*, *58*, 1–14.

Cangelosi, J. (1999). *Assessment strategies for monitoring student learning* (1st ed.) (P. McGeehom, Ed.). Longman.

Cangelosi, J. (2003). *Teaching mathematics in secondary and middle school* (3rd) (L. A. Montgomery, Ed.). Merrill Prentice Hall.

Creswell, J. W., & Clark, V. L. P. (2007). *Disigning and conducting mised methods research* (C. Chilton, Ed.). Sage Publications.

Donohoe, C., Topping, K., & Hannah, E. (2012). The impact of an online intervention (brainology) on the mindset and resiliency of secondary school pupils: A preliminary mixed methods study. *Educational Psychology*, *32*(5), 641–655.

Dweck, C. (2007). The perils and promises of praise. *Educational Leadership*, *65*(2), 34–39.

Dweck, C. S. [Carol S]. (2006). *Mindset*. Retrieved 2006, from https://www.mindsetonline.com/testyourmindset/step1.php

Dweck, C. S. [Carol S.]. (2016). *Mindset: The new psychology of success* (2nd ed.). Ballantine Books.

Elwick, A. (2014). An awareness of neuroscience in education: Can learning about the brain transform pupils' motivation to learn? *Science Direct*.

Fung, D., & Lui, W.-m. (2016). Individual to collaborative: Guided group work and the role of teachers in junior secondary science classrooms. *International Journal of Science Education*, *38*(7), 1057–1076.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? results from a national sample of teachers. *American Educational Research Journal*, *38*(4), 915–945.

Granberg, C. (2016). Discovering and addressing errors during mathematics problem-solving-a productive struggle? *Elsevier*, *42*, 33–48.

Hawe, E., & Dixon, H. (2016). Assessment for learning: A catalyst for student self-regulation. *Assessment and Evaluation in Higher Education*, *42*(8), 1181–1192.

Henebry, K. (1997). The impact of class schedule on student performance in a financial management course. *Journal of Education for Business*, *73*(7), 114–120.

Holmes, V.-L., Miedema, C., Nieuwkoop, L., & Haugen, N. (2013). Data-driven intervention: Correcting mathematics students' misconceptions, not mistakes. *The Mathematics Educator*, *23*(1), 24–44.

Johnston, A. L. (2012). *Homework journaling in undergraduate mathematics* (Doctoral dissertation, Virginia Polytechnic Institute and State University).

Lewis, H., Tait, D. L., & Schneiter, K. (2018). *Developing growth mindset assessments for pre-calculus university courses.* in press.

Libertini, J., Krul, C., & Turner, E. (2016). Exam corrections: A dual-purpose approach. *PRIMUS*, *26*(9), 803–810.

MacCrindle, A. N. (2017). *Effective change: A case study of implementation of a standards based grading* (Doctoral dissertation, Concordia University - Chicago).

Martin, J. M. (2017). It just didn't work out: Examining nonreturning students' stories about their freshman experience. *Journal of College Student Retention Research Theory and Practice*, *19*(2), 176–198.

Maure, L. M., & Marimon, O. G. (2014). Examining the role of college student's approach to math. *Educational Research and Reviews*, *9*(19), 761–770.

McElroy, T., & Mosteller, L. (2006). The influence of circadian type, time of day and class difficulty on students' grades. *Electronic Journal of Research in Educational Psychology*, *4*(10), 611–622.

McMorran, C., Ragupathi, K., & Luo, S. (2017). Assessment and learning without grades? motivations and concerns with implementing gradless learning in higher education. *Assessment and Evaluation in Higher Education*, *42*(3), 361–377.

Miller, D., & Schraeder, M. (2015). Research on group learning and cognitive science: A study of motivation, knowledge, and self-regulation in a large lecture college algebra class. *The Mathematics Educator*, *24*(2), 27–55.

Moser, J. S. (2011). Mind your errors: Evidence for a neutral mechanism linking growth mindset to adaptive posterror adjustments. *Psychological Science*, *22*(12), 1484–1489.

Nolen, S. B. (2003). Learning environment, motivation, and achievement in high school science. *Journal of Research in Science Teaching*, *40*(4), 347–368.

Nolen, S. B. (2011). The role of educational systems in the link between formative assessment and motivation. *Theory Into Practice*, *50*, 319–326.

Paunesku, D., Walton, G. M., Romero, C., Smith, E. N., Yeager, D. S., & Dweck, C. S. (2015). Mind-set interventions are a scalable treatment for academic underachievement. *Psychological Science*, 1–10.

Roschelle, J., Rafanan, K., Bhanot, R., Estrella, G., Penuel, B., Nussbaum, M., & Claro, S. (2010). Scaffolding group explanation and feedback with handheld technology: Impact on students' mathematics learning. *Educational Technology Research and Development*, *58*.

Schraeder, M. (2018). *Impact of inquiry-based, question-and-answer instruction in high-enrollment classes* (Doctoral dissertation, West Virginia University).

Sorensen, I. (2012). The use of group quizzes in developmental mathematics courses. *MathAMATYC educator*, *4*(1), 17–21.

Sweller, J., van Merrienboer, J. G., & Paas, F. G. (1998). Cognitive architecture and instructional design. *Education Psychology Review*, *10*, 251–296.

Thorkildsen, T. A., Nolen, S. B., & Fournier, J. (1994). What is fair? children's critiques of practices that influence motivation. *Journal of Educational Psychology*, *86*(4), 475–486.

Utah State University. (2018).

VanDyke, F., Malloy, E. J., & Stallings, V. (2013). Conceptual writing in college-level mathematics courses and its impact on performance and attitude. *International Journal of Mathematical Education in Science and Technology*, *46*(2), 223–233.

Warshauer, H. (2015). Productive struggle in middle school mathematics classrooms. *Journal of Mathematics Teacher Education*, *18*, 375–400.

Web, N. (1997). Council of chief state school officers and national institute for science education research monograph. (Chap. Criteria for Alignment of Expectations ans Assessments in Mathematics and Science Education, Vol. 6). Madison University of Wisconsin: Wisconsin Center for Education Research.

Yeager, D. S., Purdie-Vaughns, V., Garcia, J., Apfel, N., Brzustoski, P., Master, A., ... Cohen, G. L. (2013). Breaking the cycle of mistrust: Wise interventions to provide critical feedback across the racial divide. *Journal of Experimental Psychology*, *143*(2), 804–824.

Yin, Y., Shavelson, R., Ayala, C., Ruiz-Primo, M., Brandon, P., & Furtak, E. (2008). On the impact of formative assessment on student motivation, achievement, and conceptual change. *Applied Measurement in Education*, *21*, 335–359.

Zeybek, Z. (2016). Productive struggle in a geometry class. *International Journal of Research in Education and Science*, *2*(2), 396–415.

Zhang, J., Kuusisto, E., & Tirri, K. (2017). How teachers' and students' mindsets in learning have been studied: Research findings on mindset and academic achievement. *Psychology*, *8*, 1363–1377.

APPENDICES

APPENDIX A

Course Goals and Learning Objectives

The following course goals are adapted from the National Council of Teachers of Mathematics's Process Standards as outlined in *Principles and Standards for School Mathematics* (2000).

1. **Problem Solving**

   Students will (a) build new mathematical knowledge through problem solving, (b) solve problems that arise in mathematics and in other contexts, (c) apply and adapt a variety of appropriate strategies to solve problems, and (d) monitor and reflect on the process of mathematical problem solving.

2. **Reasoning and Proof**

   Students will (a) recognize reasoning and proof as fundamental aspects of mathematics, (b) make and investigate mathematical conjectures, (c) develop and evaluate mathematical arguments and proofs, and (d) select and use various types of reasoning and methods of proof.

3. **Language and Communication**

   Students will (a) organize and consolidate their mathematical thinking through communication, (b) communicate their mathematical thinking coherently and clearly to colleagues, (c) analyze and evaluate the mathematical thinking and strategies of others, and (d) use the language of mathematics to express mathematical ideas precisely.

4. **Representation**

   Students will (a) formulate and use representations to organize, record, and communicate mathematical ideas, (b) select, apply, and translate among mathematical

representations to solve problems, and (c) use representations to model and interpret physical, social, and mathematical phenomena.

Unit 1 Goals and Objectives

Unit 1 100%

A.6 equations 17%.

A.6.1 Students will solve quadratic equations by factoring, the quadratic formula, and by completing the square. (Algorithmic Skill 6%)

A.6.2 Students will discover the relationship between the standard form of a quadratic equation and the solution in the form of the quadratic formula through completing the square. (Discover a Relation 5%)

A.6.3 Students will solve rational equations. (Algorithmic Skill 3%)

A.6.4 Students will solve equations involving radicals. (Algorithmic Skill 3%)

A.8 complex numbers 7%.

A.8.1 Students will construct the concept of a complex number. (Construct a Concept 3%)

A.8.2 Students will algebraically manipulate complex numbers. (Algorithmic Skill 4%)

1.3 intro to functions 22%.

1.3.1 Students will understand the language functional notation. (Comprehension and Communication 3%)

1.3.2 Students will find function values given an input. (Algorithmic Skills 2%)

1.3.3 Students will construct the concept of the domain and range of a function. (Construct a Concept 5 %)

1.3.4 Students will communicate information about a function from its graph.(Comprehension and Communication 3 %)

1.3.5 Students will find the average rate of change of a function. (Algorithmic Skill 2%)

1.3.6 Students will find the difference quotient of a function. (Algorithmic Skill 3%)

1.3.7 Students will apply functions to real world problems.(Application 4%)

1.4 a library of functions 15%.

1.4.1 Students will construct the concept of the types of polynomial functions.(Construct a Concept 3%)

1.4.2 Students will comprehend and communicate the important properties of functions. (Comprehension and Communication 3%)

1.4.3 Students will evaluate and graph piecewise functions.(Algorithmic Skill 4%)

1.4.4 Students will know the graphs of basic functions. (Simple Knowledge 5%)

1.5 transformations of functions 10%.

1.5.1 Students will discover the relation between graph transformations and the coefficients of quadratic functions. (Discover a Relation 3%)

1.5.2 Students will communicate what a transformation of a function is. (Comprehension and Communication 3%)

1.5.3 Students will shift functions using transformations. (Algorithmic Skill 4%)

1.6 composite functions 10%.

1.6.1 Students will form composite functions. (Algorithmic Skill 3%)

1.6.2 Students will find the domain of a composite function. (Algorithmic Skill 2%)

1.6.3 Students will discover the relationship between $f(g(x))$ and it's decomposition $f(x), g(x)$. (Discover a Relation 3%)

1.6.4 Students will use composite functions in real world problems. (Application 2%)

1.7 inverse functions 19%.

1.7.1 Students will comprehend and communicate the definition of inverse functions. (Comprehension and Communication 4%)

1.7.2 Students will discover the relationship between functions and their inverses. (Discover a Relation 3%)

1.7.3 Students will find the inverse of a function.(Algorithmic Skill 5%)

1.7.4 Students will use the inverse function to find the range of the original function. (Algorithmic Skill 4%)

1.7.5 Students will apply inverse functions to real world problems. (Application 3%)

Unit 2 Goals and Objectives

Unit 2 100%

2.1 quadratic functions 18%.

2.1.1 Students will discover the the relationship between the three basic forms of a quadratic function. (Discover a Relation 6%)

2.1.2 Students will graph a quadratic function in vertex form, standard form, and intercept form. (Algorithmic Skill 6%)

2.1.3 Students will solve problems modeled by quadratic functions. (Application 6%)

2.2 polynomial functions 22%.

2.2.1 Discover the relationship between the properties of the graphs of the polynomial functions and the polynomial functions. Discover a Relation 5%)

2.2.2 Students will determine the end behavior of a polynomial function. (Algorithmic Skill 3%)

2.2.3 Students will find the zeros of a polynomial function by factoring. (Algorithmic Skill 4%)

2.2.4 Discover the relationship between degrees, real zeros, and turning points of polynomial functions. (Discover a Relation 5%)

2.2.5 Student will comprehend and communicate about the graphs polynomial functions. (Comprehension and Communication 5%)

2.3 dividing polynomials and the rational zeros test 12%.

2.3.1 Students will use the division algorithm and synthetic division to divide polynomials. (Algorithmic Skill 4%)

2.3.2 Discover the relation between the remainder and factor theorems and factors of polynomials. (Discover a Relation 4%)

2.3.3 Students will use the rational zeros test. (Algorithmic Skill 4%)

2.4 rational functions 26%.

2.4.1 Students will construct the concept of a rational function. (Construct a Concept 3%)

2.4.2 Students will discover the relationship between the graphical representation of vertical and horizontal asymptotes and rational functions. (Discover a Relation 5%)

2.4.3 Students will graph translations of $f(x) = 1/x$. (Algorithmic Skill 4%)

2.4.4 Given a rational function, students will identify the vertical and horizontal asymptotes. (Algorithmic Skill 5%)

2.4.5 Students will graph rational functions with vertical, horizontal and oblique asymptotes. (Algorithmic Skill 5%)

2.4.6 Students will apply rational functions to revenue curves. (Application 4%)

2.5 polynomial and rational inequalities 8%.

2.5.1 Students will solve polynomial inequalities. (Algorithmic Skill 4%)

2.5.2 Students will solve rational inequalities. (Algorithmic Skill 4%)

2.6 zeros of a polynomial function 14%.

2.6.1 Discover the relationship between the possible number of positive and negative zeros of polynomials and the degree of the polynomial.(Discover a Relation 5%)

2.6.2 Students will find the real zeros of polynomials. (Algorithmic Skill 3%)

2.6.3 Students will learn the basic facts about the complex zeros of polynomials.(Simple Knowledge 3%)

2.6.4 Students will use the Conjugate Pairs Theorem to find zeros of polynomials. (Algorithmic Skill 3%)

Unit 3 100%

3.1 exponential functions 25%.

3.1.1 Students will construct the concept of an exponential function. (Construct a Concept 5%)

3.1.2 Students will graph an exponential function. (Algorithmic Skill 3%)

3.1.3 Discover the relationship between simple/compound interest and exponential functions. (Discover a Relation 6%)

3.1.4 Understand the history of the number e. (Creative Thinking 2%)

3.1.5 Construct the concept of the natural exponential function. (Construct a Concept 3%)

3.1.6 Apply exponential functions to real world problems. (Application 6%)

3.2 logarithmic functions 19%.

3.2.1 Students will construct the concept of logarithmic functions. (Construct a Concept 3%)

3.2.2 Students will discover the relationships basic properties of logarithmic functions. (Discover a Relation 4%)

3.2.3 Students will evaluate logarithms. (Algorithmic Skill 3%)

3.2.4 Students will find the domains of logarithmic functions. (Algorithmic Skill 3%)

3.2.5 Students will graph logarithmic functions. (Algorithmic Skill 3%)

3.2.6 Students will apply natural logarithms to real world problems. (Application 3%)

3.3 rules of logarithms 16%.

3.3.1 Students will comprehend and communicate the rules of logarithms. (Comprehension and Communication 4%)

3.3.2 Students will use log properties to evaluate, expand and condense logarithmic expressions. (Algorithmic Skill 6%)

3.3.3 Students will change the base of a logarithm. (Algorithmic Skill 2%)

3.3.4 Students will apply logarithms to growth and decay. (Application 4%)

3.4 exponential and logarithmic equations and inequalities 21%.

3.4.1 Students will solve exponential equations. (Algorithmic Skill 4%)

3.4.2 Students will apply problems involving exponential equations. (Application 6%)

3.4.3 Students will solve logarithmic equations. (Algorithmic Skill 4%)

3.4.4 Students will apply problems involving the logistic growth model. (Application 4%)

3.4.5 Students will use logarithmic and exponential inequalities. (Algorithmic Skill 3%)

3.5 logarithmic scales; modeling 19%.

3.5.1 Students will apply problems involving pH. (Application 4%)

3.5.2 **??** Students will apply problems involving the Richter scale. (Application 4%)

3.5.3 Students will apply problems involving the scale for measuring sound. (Application 4%)

3.5.4 Students will apply problems involving the magnitude of star brightness. (Application 4%)

3.5.5 Students will build models from data. (Application 3%)

Unit 4 Goals and Objectives

Unit 4 100%

7.1 system of equations in two variables 20%.

7.1.1 Students will verify a solution to a system of equations. (Algorithmic Skill 3%)

7.1.2 Students will discover the relationship between a graph and the solution of a system. (Discover a Relation 3%)

7.1.3 Students will solve a system of equations by the substitution and elimination method. (Algorithmic Skill 5%)

7.1.4 Students will compare and contrast the substitution and elimination method. (Comprehension and Communication 5%)

7.1.5 Students will apply system of equations to solve real world problems. (Application 4%)

7.4 matrices and systems of equations 20%.

7.4.1 Students will construct the concept of matrices. (Construct a Concept 4%)

7.4.2 Students will use matrices to solve a system of linear equations. (Algorithmic Skill 6%)

7.4.3 Students will use Gaussian elimination to solve a system. (Algorithmic Skill 5%)

7.4.4 Students will use Gauss-Jordan elimination to solve a system. (Algorithmic Skill 5%)

7.7 matrix algebra 16%.

7.7.1 Students will construct the concept of equality of two matrices. (Construct a Concept 4%)

7.7.2 Students will compute matrix addition and scalar multiplication. (Algorithmic Skill 4%)

7.7.3 Students will compute matrix multiplication. (Algorithmic Skill 5%)

7.7.4 Students will apply matrix multiplication to real world problems. (Application 3%)

7.8 the matrix inverse 23%.

7.8.1 Students will construct the concept of an inverse matrix. (Construct a Concept 5%)

7.8.2 Students will verify the multiplicative inverse of a matrix. (Algorithmic Skill 5%)

7.8.3 Students will find the inverse of a matrix including 2×2.(Algorithmic Skill 5%)

7.8.4 Students will use matrix inverses to solve systems of linear equations. (Algorithmic Skill 5%)

7.8.5 Students will apply matrix inverses to real world problems. (Application 3%)

7.6 partial-fraction decomposition 21%.

7.6.1 Students will discover the relationship between partial fractions and rational functions. (Discover a Relation 5%)

7.6.2 Students will decompose $\frac{P(x)}{Q(x)}$ when $Q(x)$ has only distinct linear factors. (Algorithmic Skill 4%)

7.6.3 Students will decompose $\frac{P(x)}{Q(x)}$ when $Q(x)$ has repeated linear factors. (Algorithmic Skill 4%)

7.6.4 Students will decompose $\frac{P(x)}{Q(x)}$ when $Q(x)$ has distinct irreducible quadratic factors. (Algorithmic Skill 4%)

7.6.5 Students will decompose $\frac{P(x)}{Q(x)}$ when $Q(x)$ has repeated irreducible quadratic factors. (Algorithmic Skill 4%)

APPENDIX B

Relevance Tables for Growth Mindset Structures Assessments

Fig. B.1. Relevance Table for Midterm Assessment One

Unit 1 Test

Subject Content	Learning Level									Point Total	Weight
	Simple Knowledge	Algorithmic Skill	Comprehension & Communication	Construct a Concept	Discover a Relationship	Application	Creativity	Appreciation	Willingness to Try		
Solve Various Equations		12			5					17	17%
Complex Numbers		4		3						7	7%
Functions		2	6	5		4				17	17%
Avg. Rate of Change		2								2	2%
Difference Quotient		3								3	3%
Polynomial Functions			3	3						6	6%
Piecewise Functions		4								4	4%
Graphing Basic Functions	5									5	5%
Transformations of Functions		4	3		3					10	10%
Composite Functions		5			3	2				10	10%
Inverse Functions		9	4		3	3				19	19%
Total	5	45	16	11	14	9	0	0	0	100	
Weight	5%	45%	16%	11%	14%	9%	0%	0%	0%		100%

Fig. B.2. Relevance Table for Midterm Assessment Two

Unit 2 Test

Subject Content	Learning Level									Point Total	Weight
	Simple Knowledge	Algorithmic Skill	Comprehension & Communication	Construct a Concept	Discover a Relationship	Application	Creativity	Appreciation	Willingness to Try		
Quadratic Functions		6			6	6				18	18%
Polynomial Functions		7	5		10					22	22%
Dividing Polynomials		4			4					8	8%
Rational Zeros Test		4								4	4%
Rational Functions		4		3		4				11	11%
Asymptotes of Rational Functions		10			5					15	15%
Polynomial Inequalities		4								4	4%
Rational Inequalities		4								4	4%
Zeros of Polynomial Functions	3	6			5					14	14%
Total	3	49	5	3	30	10	0	0	0	100	
Weight	3%	49%	5%	3%	30%	10%	0%	0%	0%		100%

Fig. B.3. Relevance Table for Midterm Assessment Three

Unit 3 Test

Subject Content	Learning Level									Point Total	Weight
	Simple Knowledge	Algorithmic Skill	Comprehension & Communication	Construct a Concept	Discover a Relationship	Application	Creativity	Appreciation	Willingness to Try		
Exponential Functions		3		5	6	3				17	17%
Natural Exponential Functions				3		3	2			8	8%
Logarithmic Functions		9		3	4					16	16%
Natural Logarithmic Functions						3				3	3%
Rules of Logarithms		8	4			4				16	16%
Exponential Equations		4				6				10	10%
Logarithmic Equations		4				4				8	8%
Exp. & Log. Inequalities		3								3	3%
Logarithmic Scales				16		3				19	19%
Total	0	31	4	27	10	26	2	0	0	100	
Weight	0%	31%	4%	27%	10%	26%	2%	0%	0%		100%

APPENDIX C

Protocol for Thematic Axial Coding

Table C.1

Protocol Table for Thematic Axial Coding

Open Code	Examples of Participant Phrases
Irrelevant	response doesn't answer the question
	response doesn't apply to any other category
Growth mindset	Learn from mistakes
	Hard work leads to improving
	Love of learning
Fixed Mindset	Always bad
	Not smart
	Can't do math
Less Anxiety	Confident
	Not anxious
	Not worried
	Comfortable
More Anxiety	Not confident
	Afraid
	Nervous
Positive Attitude	Like
	Happy with
	Love
	Enjoyed
Negative Attitude	Hate
	Dislike
	Annoying

APPENDIX D

Growth Mindset Structured Assessment One

Testing Center Portion

MATH1050 - Unit 1 Exam Part 1 Spring 2019 Instructor: **Hannah Lewis**

A# ____________________ Student Name (print): ____

Recitation time ____________________ Circle one: Lane Johnny

This portion of the exam contains 11 pages (including this cover page) and 16 questions. Enter your answers in the space provided. Write your final answer on the "Solution" line for each problem, where appropriate. Otherwise, draw a box around your final answer. Complete your solutions to the "show your work" problems on the page indicated.

- **Organize your work**, in a reasonably neat and coherent way, in the space provided. Work scattered all over the page without a clear ordering cannot be assessed accurately.
- **Mysterious or unsupported answers will not receive adequate feedback**. A correct answer, unsupported by calculations, explanation, or algebraic work doesn't show achievement of the objective; an incorrect answer supported by substantially correct calculations and explanations may show partial achievement of the objective.
- **Provide exact answers** unless otherwise instructed.
- **Simplify all answers as much as possible.** This means that you need to need to combine like terms, reduce fractions, etc. (You do not need to rationalize denominators.)
- **Be sure to state units for applied problems.**
- **Clearly identify your answer for each problem.**
- **Any questions left blank will not be eligible for exam retakes.**

Do not write in the table to the right.

Show your work. Clearly identify your answer.

1. Solve the following quadratic equation $2x^2 - 7x - 15 = 0$ for x by the given methods (useful: $15 \cdot 8 = 120$, $\sqrt{169} = 13$).

Factoring	Completing the Square	Quadratic Formula

Solution: +6 For using correct algebra to find 2 correct solutions for all three methods.
+4 For using correct algebra to find 2 correct solutions for two methods.
+2 For using correct algebra to find 2 correct solutions for one method.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)

Solve $6x^2 + x - 40 = 0$ by factoring, completing the square, and using the quadratic formula.

2. Solve the following equation for t

$$\sqrt{6t - 11} = 2t - 7$$

Solution: +3 for using correct algebra to find the correct solution of 6.
+2 for using correct algebra to find one correct solution of 6 but not eliminating the extraneous solution of 5/2.
+1 for attempting to solve using correct algebra.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Describe the steps to solving $\sqrt{5y^2 - 10y + 9} = 2y - 1$, solve it correctly,.

Solution:____________________

3. Put each number in all the boxes that apply. (simplify where applicable before classifying)

$$14, \quad 5+6i, \quad \sqrt{-25}, \quad \sqrt{2}+3, \quad 3i, \quad 5/3, \quad (2+3i)(2-3i)$$

Real Numbers	Imaginary Numbers	Complex Numbers	Rational Numbers	Irrational Numbers	Integers

Solution: +3 for 5-6 boxes correct.
+2 for 3-4 conceptual errors
+1 for trying to classify.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Draw the venn diagram for the 8 types of numbers with examples for each set.

4. Write the following in standard form $a + bi$

$$3i(2 - 5i) - (1 + 4i)$$

Solution: +4 for using correct algebra to find the correct answer in the correct form.
+3 for minor algebraic mistakes and the correct answer is in the correct form.
+2 for using correct algebraic tools, but final answer is in the wrong form.
+0 Otherwise

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Put the following in standard form:

$$\frac{3 + 2i}{2 + 5i}$$

Solution:____________________

5. Given the function $f(x) = 2x^2 - 3x + 4$, find and simplify

- $f(1)$
- $f(0)$
- $f(-1)$
- $f(2)$
- $f(b)$
- $f(x + h)$

Solution: +2 for all 6 correct
+1 for 3-5 correct.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Create your own quadratic function and find $f(1)$, $f(0)$, $f(-1)$, and $f(2)$ for the function you create.

Solution:____________________

6. Fill in the blanks from the list below. Words may be used twice or not at all:(The first and second prompts have different answers.)

The ________________ of a function is the complete set of possible values of the ________________ variable.

The ________________ of a function is the complete set of possible values of the ________________ variable.

The ________________ is the set of all possible ___-values which will make the function "work", and will output real ___-values.
x
y
quadratic
linear
domain
range
solution
independent
dependent

Solution: +5 for all correct responses of (domain, independent (or x), range (or y), dependent, domain (or solution), x, y)
+3 for 3-5 correct responses
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Draw a graph and a rule for the graph where the domain is $[-2,4)\cup(6,\infty)$ and the range is $(-\infty,5]$. Label the independent variable and the dependent variable.

7. Find the average rate of change of the function $f(x) = 1 + x^2$ as x changes from 2 to 4.

Solution: +2 for using the slope formula and correct algebra to get a correct answer of 6.
+1 for using the slope formula and getting an incorrect answer.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Give the formula for the average rate of change, describe what the formula does and then use the formula to find the average rate of change of the function $f(x) = \sqrt[3]{x^2 + 5x - 1}$ as it changes from 1 to 3.

Solution:____________________

8. Let

$$g(x) = \sqrt{x}$$

1. Find the difference quotient for $g(x)$.

Solution:____________________

2. What does this mean? Write at least one sentence.

Solution: +3 for using correct algebra to find the correct formula and writing a correct description.
+2 for correct algebra to find a correct formula without a correct description.
+ 1 for a correct formula.
+1 for a correct description.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Student will find the difference quotient for $f(x) = x^2 - x$ and $g(x) = \frac{5}{x-2}$. Then draw a picture of what the difference quotient represents for both $f(x)$ and $g(x)$. Label $x, f(x), x+h, f(x+h)$ and the slope of the secant line on both graphs.

9. Label the relations with the following descriptors:

- Linear Function
- Not a Function
- Quadratic Function

$f(x) = 8x^2 - 5$ $y^2 + x^2 = 4$ $y = (x-3)(5x-2)$

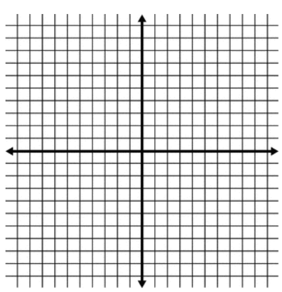
$2x - y = 6$ $y^2 + x = 4$ $f(x) = 2x - 3x + 6$

Solution: +3 for all labels done correctly.
+2 for 1 error.
+1 for 2-3 errors.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Create one example and two non-examples of linear functions. Then create one example and two non-examples of quadratic functions.

10. Graph the following function:

$$f(x) = \begin{cases} 2x+3 & x < -2 \\ x+1 & -2 \leq x < 1 \\ -x+3 & x \geq 1 \end{cases}$$



- What is the domain and range of $f(x)$?
- Find $f(-3)$, $f(0)$, $f(1)$, and $f(4)$.

Solution: +4 : +2 for the graph +1 for domain and range and +1 for finding $f(a)$'s

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Create a piecewise function that fits the following parameters:
Linear for $x < -3$, quadratic for $-3 \leq x \leq 4$ and linear for $x > 4$.
Graph your created function.

11. Sketch the general shape of the following functions:
    - $f(x) = x^2$
    - $f(x) = \sqrt[3]{x}$
    - $f(x) = |x|$
    - $f(x) = \frac{1}{x}$
    - $f(x) = x^3$
    - $f(x) = \sqrt{x}$

Solution: +5 for getting 5-6 graphs correct.
+3 for getting 2-4 graphs correct.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
State and graph all 10 of the memorized functions without notes.

12. Describe the transformation that produces the graphs of g and h from the graph of f.

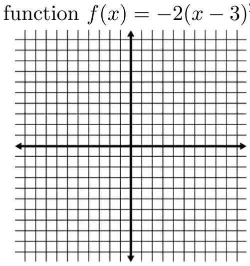
$$f(x) = \frac{1}{x^2}$$

- $g(x) = \frac{1}{(x-3)^2} + 2$
- $h(x) = \frac{-3}{x^2}$

Solution: + 1 for each shift communicated correctly. (total of 4)

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Create, describe and graph a function that shifts the absolute value function to the right 3, up 2, with a vertical stretch of 5.

13. Graph the function $f(x) = -2(x-3)^2 + 4$



Solution: +4 for graphing a parabola, and correctly applying all four shifts.
-1 for each error.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Manipulate the following for ideal shifting. The, graph describing each shift:

$$f(x) = -3|2x-3| + 5$$

14. Let $f(x) = \frac{x}{x-1}$ and $g(x) = 2 + 5x$.

- Find $(f \circ g)(x)$ **and** it's domain.
  a. $(f \circ g)(x) =$
  b. Domain
- Find $(g \circ f)(x)$ **and** it's domain.
  a. $(g \circ f)(x) =$
  b. Domain

Solution: + 3 for finding both composite functions correctly.
+1.5 for find one composite function correctly.

Solution: +2 for find both domains for the functions created correctly
+1 for finding one domain correctly.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Let $f(x) = \frac{x^2}{x-1}$ and $g(x) = \sqrt{x}$.

- Find $(f \circ g)(x)$ and it's domain.
- Find $(g \circ f)(x)$ and it's domain.

Explain how to find the composite functions and how to find each domain.

15. Is the function: $f(x) = \sqrt[3]{\frac{x-2}{3}} - 1$ a one-to-one function?

YES NO

If yes, find:

- Find $f^{-1}(x)$
- Verify your answer using composite functions.
- Find the domain and range of both f and f^{-1}

	Domain	Range
$f(x)$		
$f^{-1}(x)$		

Solution: Total of +5 distributed as follows: + 2 For finding the correct inverse
+1 $f \circ g$ or $g \circ f$ are used and x is the result
+2 The domain and range are correct.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
The function:

$$f(x) = \sqrt{\frac{3x}{2} + 5} - 4$$

is an one-to-one function. The student will find $f^{-1}(x)$ and verify your answer using composite functions. Find the domain and range of both f and f^{-1}

16. How can the inverse function be used to find the range of the original function? Write at least one sentence.

Solution: If they use the domain of the inverse to find the range of the original function.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Let $f(x) = \sqrt{2x+1} + 1$. Find $f(0)$. Without plugging anything else in, this means that what x value gives $f^{-1}(x) = 0$?
Find the value of a for which $f(a) = f^{-1}(a)$.

Rework Questions for Testing Center Portion of Exam 1

1. Which method is the hardest for you and why?
2. What is it called when a solution doesn't work? Does it happen for this problem? Why is it necessary to check for extraneous solutions?
3. Give me an example of a complex number that is not a real number or an imaginary number. Give me a non example of a complex number.
4. Why did you multiply by $2 - 5i$ on the bottom? Why did you also multiply it on the top?
5. How would you write one of these as a point?
6. Justify the domain and range of your graph.
7. What is the average rate of change formula used for?
8. Describe your graphs.
9. Give me an example of a relation that is not a function.
10. Justify that what you have done is still a function.
11. Ask student to draw a random choice of one of the 10 memorized graphs.
12. How would the graph change if we added a negative sign in front of the 5?
13. Why is it easier in this form?
14. How did you find the domain?
15. What are the steps fro finding an inverse of a function?
16. Why did you miss this problem?

Written Portion

MATH1050 - Unit 1 Exam Part 2 Spring 2019 Instructor: **Hannah Lewis**

A# ____________ Student Name (print): ______________________________

This portion of the exam has 4 questions. This is the paper portion of the exam. The final draft should be between 2-5 pages and will be turned in on Canvas. Have a rough draft available for peers to read on Wednesday February 6th and a final draft to be turned in on Friday February 8th. You will be required to to read 3 of your classmates final drafts and give feedback. This feedback will be assigned on Saturday February 9th and due on Monday February 11st.

- **Organize your explanations**, in a reasonably neat and coherent way.
- **Use APA** format.
- **Pictures** and other visuals may be helpful or necessary to complete this paper. Although the rest of the paper must be typed, math and other visuals can be either hand drawn in or imported as pictures.
- The final paper **needs to include this page as page 1**. Submit your final paper as pdf to canvas.

Prompt	exceeds expectations	meets expectations	needs work
1			
2			
3			
4			

1. In a couple of paragraphs discuss the following: Describe what the difference is between an independent and a dependent variable. Talk about the difference between a relation and a function. Discuss why the vertical line test for functions works.

2. Describe in a couple of paragraphs the properties of the function $f(x) = x^3 - 8x$. Include discussion of the function properties:
   - degree
   - increasing and decreasing
   - relative maximums and minimums
   - even and odd

3. 1. When a quadratic function is in the standard form, $f(x) = ax^2 + bx + c$, what is the relationship between how $a, b,$ and c change and the graph?
   2. When a quadratic function is in the vertex form, $f(x) = a(x-h)^2 + k$, what is the relationship between how $a, h,$ and k change and the graph?
   3. When a quadratic function is in the factored form, $f(x) = a(x-c)(x-d)$, what is the relationship between how $a, c,$ and d change and the graph?
   4. Which is your favorite to graph and why?

4. Write a couple of paragraphs addressing the following:
   - What does it mean for a function to be one-to-one?
   - Why is it the case that $(f^{-1} \circ f)(x) = x$
   - How are f and f^{-1} related graphically? Why does this happen?
   - What is the relationship between the domains and ranges of f and f^{-1}.

Group Portion

MATH1050 - Exam 1 Part 3 Spring 19 Instructor: **Hannah Lewis**

A# ____________________ Student Name (print): ____

Group Members (First and last name)____

This exam contains 13 pages and 5 questions. THIS IS THE GROUP PORTION OF THE EXAM.

- Each prompt will need to be assigned to 2-3 people in your group. This means that each problem will be completed by more than one person independently and each person will complete 3-4 problems.
- Assignments need to be made by **Friday February 1st** at midnight.
- The problems assigned need to be completed by **Wednesday February 6th**.
- Comments need to be completed by **Friday February 8th**. (You will get time in recitation to work on you comments). A comment of "looks great" or other such nonsense will result in no credit for the comment portion.
- The final write up completed on this outline (after edits based on the comments) due on **Friday February 8th at midnight** will be SCANNED and uploaded to the EXAM 1 assignment in canvas. It needs to include:
  - The solution to each problem written by you. Your group member may have been assigned the problem, but you need to be able to follow their work and use their solution to write up the solution in your words.
  - The comments made by your group members for each prompt that you were assigned. A comment of "looks great" or other such nonsense will result in no credit for the comment portion. Every member of the group need to make at least 5 total constructive comments.
  - A one paragraph personal narrative about your experience with your group.
- **Organize your work**, in a reasonably neat and coherent way. Work scattered all over the page without a clear ordering cannot be assessed accurately.
- **Mysterious or unsupported answers will not receive credit**. A correct answer, unsupported by calculations, explanation, or algebraic work doesn't show achievement of the objective; an incorrect answer supported by substantially correct calculations and explanations may show achievement of the objective.
- **Simplify all answers as much as possible.** This means that you need to need to combine like terms, reduce fractions, etc. (You do not need to rationalize denominators.)
- **Be sure to state units for applied problems.**
- **Clearly identify your answer for each problem.**

1. Assigned to:

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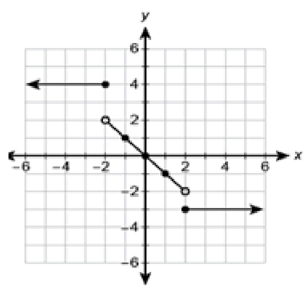

- Give two reasons you know this is a function.
  –
  –
- Write the piecewise function represented by the above graph:

  $f(x) = \begin{cases} \\ \\ \end{cases}$
- What is the domain? Justify your answer with at least one sentence.
- What is the range? Justify your answer with at least one sentence.
- Give one other thing you notice about this graph?

Comments from group members about this problem go here

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2. Assigned to:

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   A stone is thrown upward with an initial velocity of 128 feet per second will attain a height of h feet in t seconds, where

$$h(t) = 128t - 16t^2,\ 0 \le t \le 8$$

   - What is the domain of h?
   - Evaluate to find:
     - $h(2)$
     - $h(4)$
     - $h(6)$
     - Write a sentence explaining what this means in the context of this problem.
   - What would your strategy be to determine the length of time it will take for the stone to hit the ground?
   - Find out how long it will take for the stone to hit the ground.
   - Sketch a graph of $h(t) = 128t - 16t^2,\ 0 \le t \le 8$

Comments from group members about this problem go here

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3. Assigned to:

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   Let $H(x) = \frac{1}{\sqrt{x^2+5}}$. Find four ways to express $H(x)$ as a composition of two functions f and g such that $H(x) = (f \circ g)(x)$.

   1. - $f(x) =$
      - $g(x) =$
   2. - $f(x) =$
      - $g(x) =$
   3. - $f(x) =$
      - $g(x) =$
   4. - $f(x) =$
      - $g(x) =$

Comments from group members about this problem go here

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4. Assigned to:

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   Professor Linear gave a test to his college algebra class, and nobody got more than 80 points (out of 100) on the test. One problem worth 8 points had insufficient data, so nobody could solve that problem. The professor adjusted the grades for the class by

   1. increasing everyone's score by 10 %
   2. giving everyone 8 bonus points

   Let x represent the original score of a student

   - Write statements (1) and (2) as functions $f(x)$ and $g(x)$, respectively.
     - $f(x) =$
     - $g(x) =$
   - Find $(f \circ g)(x)$ and explain what it means.
     - $(f \circ g)(x) =$
     - Explanation:
   - Find $(g \circ f)(x)$ and explain what it means.
     - $(g \circ f)(x) =$
     - Explanation:

- Evaluate
  - $(f \circ g)(70) =$
  - $(g \circ f)(70) =$
- Does $(f \circ g)(x) = (g \circ f)(x)$?
- Suppose a score of 90 or better results in an *'A'* grade. What is the lowest original score that will result in an *'A'* if the professor uses
  - $(f \circ g)(x)$?
  - $(g \circ f)(x)$?

Comments from group members about this problem go here

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5. Assigned to:

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   Due to an increase in demand, a manufacturer of organic cereal is expanding its production facility. The number of **kilograms** of cereal, N, being produced each day will be increased to reflect the changing daily demand. After x **days**, the number of kilograms that will be produced each day will be approximated by the model:

   $$N(x) = \frac{-800}{x+1} + 1000, \text{ where } 1 < x \leq 100.$$

   1. Determine the inverse function $N^{-1}(x)$.

   2. Identify the range of $N^{-1}(x)$, and give your answer using interval notation . (No work required.)

   3. In the context of this problem, what does the output from the inverse function $N^{-1}(x)$ represent? One brief sentence is all that is needed, but be specific . NOTE: Your response should relate to this particular problem, not inverse functions in general.

Comments from group members about this problem go here

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Personal narrative here:

APPENDIX E

Traditional Assessment One

SPRING 2019 **MATH 1050 EXAM I** Name(PRINT)____

Recitation Instructor Name/Time____

PART I: MULTIPLE CHOICE. Each problem has only **one correct answer.** Each problem is worth 6 points. ***PLEASE PLACE YOUR ANSWER IN THE SPACE PROVIDED.*** **No partial credit**. Provided information is on the last page of the exam.

____1. Given the function $f(x) = \frac{\sqrt{x-1}}{x-2}$, use **interval notation** to specify the **domain** of the function.

(a) $[1, \infty)$ (b) $[1, 2) \cup (2, \infty)$ (c) $(-\infty, 2) \cup (2, \infty)$ (d) $(2, \infty)$ (e) $[0, 2) \cup (2, \infty)$

____2. Which of the following statements is TRUE concerning the function $f(x) = \frac{1}{x^2+4}$ Choose the most appropriate response.

(a) $f(x)$ is an even function.
(b) $f(x)$ is an odd function.
(c) The graph of $f(x)$ is symmetric with respect to the y-axis.
(d) $f(x)$ is neither an even function nor an odd function.
(e) **BOTH** statements (a) and (c) are TRUE..

____3. The **range** of the function $f(x) = x^2$ is $[0, \infty)$. Using **interval notation**, identify the **range** of the function: $g(x) = -(x + 50)^2$. (You may want to consider the concept of transformations of a graph.)

(a) $(-\infty, 0]$ (b) $[50, \infty)$ (c) $[-50, \infty)$ (d) $(-\infty, 50]$ (e) $(-\infty, -50]$

____ 4. The graph of the function $f(x) = \sqrt{x}$ will first be shifted horizontally 3 units to the left, then reflected about the ***x*-axis**, and finally shifted 2 units vertically downward. Which of the following functions would be appropriate for the graph that results from these transformations?

(a) $g(x) = \sqrt{-x+3} - 2$ (b) $g(x) = -\sqrt{x-3} - 2$ (c) $g(x) = -\sqrt{x+3} - 2$ (d) $g(x) = \sqrt{-x-3} + 2$

(e) $g(x) = \sqrt{-3-x} - 2$

____5. Given the functions $f(x) = \frac{1}{x-2}$ and $g(x) = x^2 + 4$, the **domain** of $(f \circ g)(x)$ is given by which of the following?

(a) $(-\infty, -2) \cup (-2, \infty)$ (b) $(-\infty, 0) \cup (0, \infty)$ (c) $(-\infty, \infty)$ (d) $(-\infty, 2) \cup (2, \infty)$ (e) $(-2, \infty)$

____6. Given the functions $f(x) = \sqrt{x-5}$ and $g(x) = x^2 + 6$, evaluate the following: $(\boldsymbol{f} \circ \boldsymbol{g})(0) =$

(a) $\sqrt{5}$ (b) 1 (c) 11 (d) $6\sqrt{5}$ (e) 0 is not in the domain of $(f \circ g)(x)$

____7. The function $f(x) = \sqrt{x+10}$ is a one-to-one function. Determine the **range** of the inverse function $f^{-1}(x)$.

(a) $(-\infty, \infty)$ (b) $[0, \infty)$ (c) $[10, \infty)$ (d) $[-10, \infty)$

(e) The function $f(x)$ does not have an inverse function.

____ 8. Given the function $f(x) = x^2 - 4$, determine the **inverse** function $f^{-1}(x)$ if it exists:

(a) $f^{-1}(x) = x^2 + 4$ (b) $f^{-1}(x) = \sqrt{x} + 4$ (c) $f^{-1}(x) = \sqrt{x+4}$ (d) $f^{-1}(x) = \sqrt{x} - 4$

(e) The function $f(x)$ does not have an inverse function.

PART II: ***READ THESE INSTRUCTIONS!!*** Do ***ANY 2*** and ***ONLY 2*** of the 3 problems. **Cross out completely the problem that is NOT to be graded.** ***SHOW YOUR WORK*** in a clear and organized format if you expect to receive full or partial credit. ***IDENTIFY YOUR ANSWERS.*** No work = no credit.
Provide the units on your answers where applicable. Each problem is worth **20 points**.

1. A forest has become infested with a beetle that is killing healthy trees. The region of dead trees is expanding in a **circular** pattern. The radius, $\boldsymbol{r}$, (measured in meters) of this circular region has been observed to be growing over time, $\boldsymbol{t}$, (measured in **days**) and the relationship is given by the function: $\boldsymbol{r(t) = \sqrt{50t + 100}\ meters}$. Forest Service officials want to predict the **area** of the region of dead trees at future points in time if the beetles continue to attack the trees. Recall that the area of a circle is a function of the radius of the circle: $\boldsymbol{A(r) = \pi r^2}$.

   (a) (12 points) Using the concept of **composition of functions**, determine a function $\boldsymbol{A(t)}$ that provides a prediction of the **total area** (output) of the region of dead trees at a point in **time $\boldsymbol{t}$ days** (input) from the present. Simplify your answer and leave it in terms of $\boldsymbol{\pi}$.

   (b) (8 points) **USING YOUR RESULT FROM PART (a)**, determine the **time** at which the total area of the region of dead trees will be equal to 5000 square meters. Round your answer to **ONE** decimal place.

2. (points) Due to the recent outbreak of an infectious disease, wildlife biologists believe the **population, P**, of elk in a mountainous region of a national park will decrease over time. The model used to predict the population size at a **time x months** from the present is given by the function: $\boldsymbol{P(x) = \frac{1000}{x} + 500\ elk;\ 1 \leq x \leq 18}$.

   (a) (12 points) Determine the **inverse** function $\boldsymbol{P^{-1}(x)}$.

   (b) (8 points) **USING YOUR RESULT FROM PART (a)**, determine the **time** at which the population of elk is predicted to be equal to 580.

3. Starting with the graph of the function $\boldsymbol{f(x) = \sqrt{x}}$ (see graph below), which of the transformations below **would be used** to obtain the graph of the function $\boldsymbol{g(x) = -3\sqrt{x - 10} + 20}$? (No order in which the transformations are performed is implied in the list below.) Place an "**X**" next to the transformations that WOULD BE USED.

(a) (12 points)

____ A horizontal shift 20 units left.

____ A vertical shift 10 units downward.

____ A vertical stretch by a factor of 3.

____ A vertical compression by a factor of 3.

____A vertical shift 10 units upward.

____A reflection across the x-axis.

____A reflection across the y-axis.

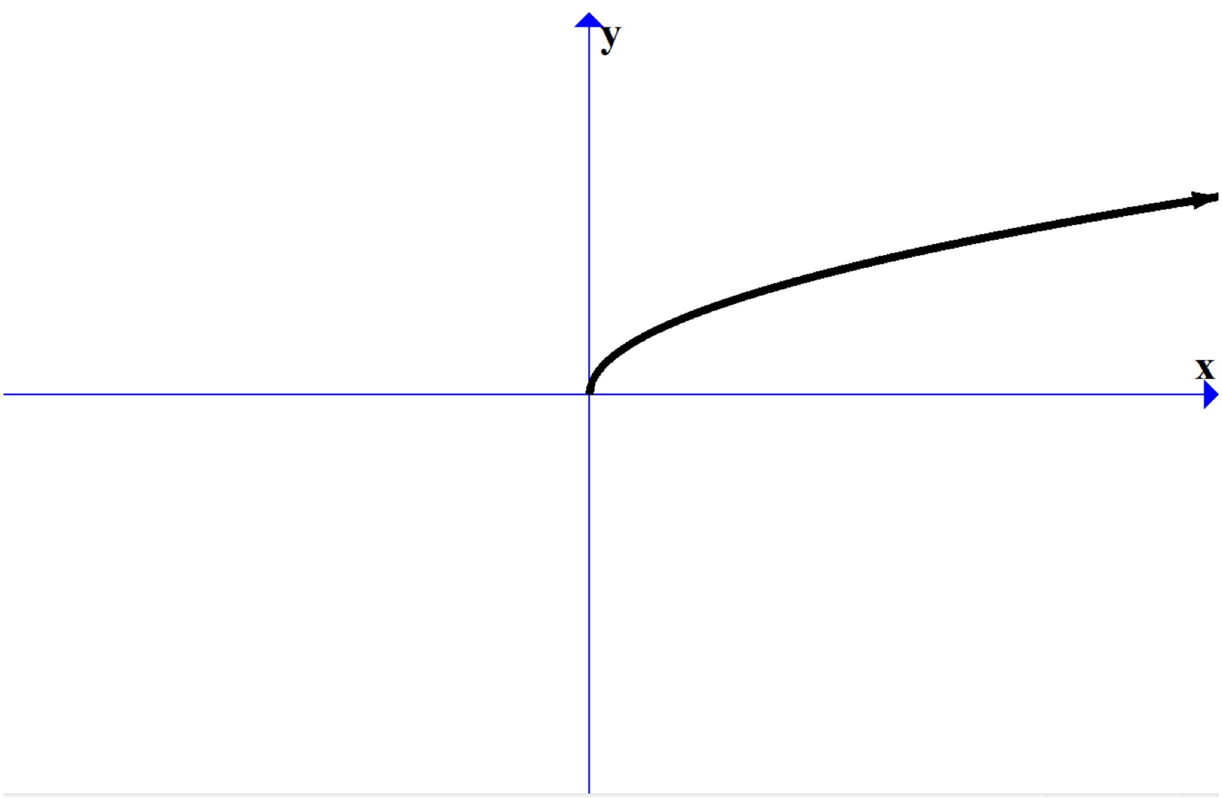
____A vertical shift 20 units upward.

____A horizontal shift 10 units right.

____A horizontal shift 20 units right.

(b) (6 points) **Using interval notation**, identify the **domain and range** of $g(x)$. (No work necessary.)

DOMAIN____________________ RANGE_____________________________



Even function: The function must satisfy this condition: $\boldsymbol{f(x) = f(-x)}$
Odd function: The function must satisfy this condition: $\boldsymbol{f(-x) = -f(x)}$
Composition of functions: $(f \circ g)(x) = f(g(x))$; $(g \circ f)(x) = g(f(x))$
Inverse functions: Domain of $f^{-1}(x)$ = Range of $f(x)$; Range of $f^{-1}(x)$ = Domain of $f(x)$
Quadratic functions: $f(x) = ax^2 + bx + c$; vertex: $x = \frac{-b}{2a}$; $y = f(\frac{-b}{2a})$;
$f(x) = a(x-h)^2 + k$; vertex (h, k)

APPENDIX F

Growth Mindset Structured Assessment Two

Testing Center Portion

MATH1050 - Unit 1 Exam Part 1 Spring 2019 Instructor: **Hannah Lewis**

A# ____________________ Student Name (print): ____

Recitation time ____________________ Circle one: Lane Johnny

This portion of the exam contains 11 pages (including this cover page) and 16 questions. Enter your answers in the space provided. Write your final answer on the "Solution" line for each problem, where appropriate. Otherwise, draw a box around your final answer. Complete your solutions to the "show your work" problems on the page indicated.

- **Organize your work**, in a reasonably neat and coherent way, in the space provided. Work scattered all over the page without a clear ordering cannot be assessed accurately.
- **Mysterious or unsupported answers will not receive adequate feedback**. A correct answer, unsupported by calculations, explanation, or algebraic work doesn't show achievement of the objective; an incorrect answer supported by substantially correct calculations and explanations may show partial achievement of the objective.
- **Provide exact answers** unless otherwise instructed.
- **Simplify all answers as much as possible.** This means that you need to need to combine like terms, reduce fractions, etc. (You do not need to rationalize denominators.)
- **Be sure to state units for applied problems.**
- **Clearly identify your answer for each problem.**
- **Any questions left blank will not be eligible for exam retakes.**

Do not write in the table to the right.

Show your work. Clearly identify your answer.

1. Solve the following quadratic equation $2x^2 - 7x - 15 = 0$ for x by the given methods (useful: $15 \cdot 8 = 120$, $\sqrt{169} = 13$).

Factoring	Completing the Square	Quadratic Formula

Solution: +6 For using correct algebra to find 2 correct solutions for all three methods.
+4 For using correct algebra to find 2 correct solutions for two methods.
+2 For using correct algebra to find 2 correct solutions for one method.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)

Solve $6x^2 + x - 40 = 0$ by factoring, completing the square, and using the quadratic formula.

2. Solve the following equation for t

$$\sqrt{6t - 11} = 2t - 7$$

Solution: +3 for using correct algebra to find the correct solution of 6.
+2 for using correct algebra to find one correct solution of 6 but not eliminating the extraneous solution of 5/2.
+1 for attempting to solve using correct algebra.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Describe the steps to solving $\sqrt{5y^2 - 10y + 9} = 2y - 1$, solve it correctly,.

Solution:____________________

3. Put each number in all the boxes that apply. (simplify where applicable before classifying)

$$14, \quad 5+6i, \quad \sqrt{-25}, \quad \sqrt{2}+3, \quad 3i, \quad 5/3, \quad (2+3i)(2-3i)$$

Real Numbers	Imaginary Numbers	Complex Numbers	Rational Numbers	Irrational Numbers	Integers

Solution: +3 for 5-6 boxes correct.
+2 for 3-4 conceptual errors
+1 for trying to classify.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Draw the venn diagram for the 8 types of numbers with examples for each set.

4. Write the following in standard form $a + bi$

$$3i(2 - 5i) - (1 + 4i)$$

Solution: +4 for using correct algebra to find the correct answer in the correct form.
+3 for minor algebraic mistakes and the correct answer is in the correct form.
+2 for using correct algebraic tools, but final answer is in the wrong form.
+0 Otherwise

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Put the following in standard form:

$$\frac{3 + 2i}{2 + 5i}$$

Solution:____________________

5. Given the function $f(x) = 2x^2 - 3x + 4$, find and simplify
   - $f(1)$
   - $f(0)$
   - $f(-1)$
   - $f(2)$
   - $f(b)$
   - $f(x + h)$

Solution: +2 for all 6 correct
+1 for 3-5 correct.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Create your own quadratic function and find $f(1)$, $f(0)$, $f(-1)$, and $f(2)$ for the function you create.

Solution: ________________

6. Fill in the blanks from the list below. Words may be used twice or not at all:(The first and second prompts have different answers.)

The ________________ of a function is the complete set of possible values of the ________________ variable.

The ________________ of a function is the complete set of possible values of the ________________ variable.

The ________________ is the set of all possible ___-values which will make the function "work", and will output real ___-values.
x
y
quadratic
linear
domain
range
solution
independent
dependent

Solution: +5 for all correct responses of (domain, independent (or x), range (or y), dependent, domain (or solution), x, y)
+3 for 3-5 correct responses
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Draw a graph and a rule for the graph where the domain is $[-2, 4) \cup (6, \infty)$ and the range is $(-\infty, 5]$. Label the independent variable and the dependent variable.

7. Find the average rate of change of the function $f(x) = 1 + x^2$ as x changes from 2 to 4.

Solution: +2 for using the slope formula and correct algebra to get a correct answer of 6.
+1 for using the slope formula and getting an incorrect answer.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Give the formula for the average rate of change, describe what the formula does and then use the formula to find the average rate of change of the function $f(x) = \sqrt[3]{x^2 + 5x - 1}$ as it changes from 1 to 3.

Solution:____________________

8. Let

$$g(x) = \sqrt{x}$$

   1. Find the difference quotient for $g(x)$.

   Solution:____________________

   2. What does this mean? Write at least one sentence.

Solution: +3 for using correct algebra to find the correct formula and writing a correct description.
+2 for correct algebra to find a correct formula without a correct description.
+ 1 for a correct formula.
+1 for a correct description.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Student will find the difference quotient for $f(x) = x^2 - x$ and $g(x) = \frac{5}{x-2}$. Then draw a picture of what the difference quotient represents for both $f(x)$ and $g(x)$. Label $x, f(x), x+h, f(x+h)$ and the slope of the secant line on both graphs.

9. Label the relations with the following descriptors:

- Linear Function
- Not a Function
- Quadratic Function

$f(x) = 8x^2 - 5$ $y^2 + x^2 = 4$ $y = (x-3)(5x-2)$

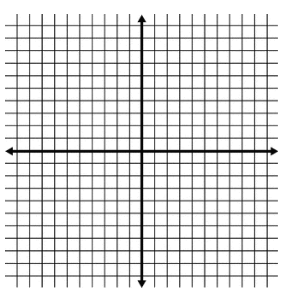
$2x - y = 6$ $y^2 + x = 4$ $f(x) = 2x - 3x + 6$

Solution: +3 for all labels done correctly.
+2 for 1 error.
+1 for 2-3 errors.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Create one example and two non-examples of linear functions. Then create one example and two non-examples of quadratic functions.

10. Graph the following function:

$$f(x) = \begin{cases} 2x+3 & x < -2 \\ x+1 & -2 \le x < 1 \\ -x+3 & x \ge 1 \end{cases}$$



- What is the domain and range of $f(x)$?
- Find $f(-3)$, $f(0)$, $f(1)$, and $f(4)$.

Solution: +4 : +2 for the graph +1 for domain and range and +1 for finding $f(a)$'s

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Create a piecewise function that fits the following parameters:
Linear for $x < -3$, quadratic for $-3 \leq x \leq 4$ and linear for $x > 4$.
Graph your created function.

11. Sketch the general shape of the following functions:
    - $f(x) = x^2$
    - $f(x) = \sqrt[3]{x}$
    - $f(x) = |x|$
    - $f(x) = \frac{1}{x}$
    - $f(x) = x^3$
    - $f(x) = \sqrt{x}$

Solution: +5 for getting 5-6 graphs correct.
+3 for getting 2-4 graphs correct.
+0 Otherwise.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
State and graph all 10 of the memorized functions without notes.

12. Describe the transformation that produces the graphs of g and h from the graph of f.

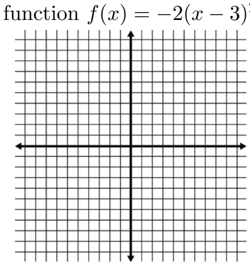
$$f(x) = \frac{1}{x^2}$$

- $g(x) = \frac{1}{(x-3)^2} + 2$
- $h(x) = \frac{-3}{x^2}$

Solution: + 1 for each shift communicated correctly. (total of 4)

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Create, describe and graph a function that shifts the absolute value function to the right 3, up 2, with a vertical stretch of 5.

13. Graph the function $f(x) = -2(x-3)^2 + 4$



Solution: +4 for graphing a parabola, and correctly applying all four shifts.
-1 for each error.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Manipulate the following for ideal shifting. The, graph describing each shift:

$$f(x) = -3|2x-3| + 5$$

14. Let $f(x) = \frac{x}{x-1}$ and $g(x) = 2 + 5x$.

- Find $(f \circ g)(x)$ **and** it's domain.
  a. $(f \circ g)(x) =$
  b. Domain
- Find $(g \circ f)(x)$ **and** it's domain.
  a. $(g \circ f)(x) =$
  b. Domain

Solution: + 3 for finding both composite functions correctly.
+1.5 for find one composite function correctly.

Solution: +2 for find both domains for the functions created correctly
+1 for finding one domain correctly.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Let $f(x) = \frac{x^2}{x-1}$ and $g(x) = \sqrt{x}$.

- Find $(f \circ g)(x)$ and it's domain.
- Find $(g \circ f)(x)$ and it's domain.

Explain how to find the composite functions and how to find each domain.

15. Is the function: $f(x) = \sqrt[3]{\frac{x-2}{3}} - 1$ a one-to-one function?

YES NO

If yes, find:

- Find $f^{-1}(x)$
- Verify your answer using composite functions.
- Find the domain and range of both f and f^{-1}

	Domain	Range
$f(x)$		
$f^{-1}(x)$		

Solution: Total of +5 distributed as follows: + 2 For finding the correct inverse
+1 $f \circ g$ or $g \circ f$ are used and x is the result
+2 The domain and range are correct.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
The function:

$$f(x) = \sqrt{\frac{3x}{2} + 5} - 4$$

is an one-to-one function. The student will find $f^{-1}(x)$ and verify your answer using composite functions. Find the domain and range of both f and f^{-1}

16. How can the inverse function be used to find the range of the original function? Write at least one sentence.

Solution: If they use the domain of the inverse to find the range of the original function.

Solution: RETAKE
Rework the original problem describing your mistake. (use sentences)
Let $f(x) = \sqrt{2x+1} + 1$. Find $f(0)$. Without plugging anything else in, this means that what x value gives $f^{-1}(x) = 0$?
Find the value of a for which $f(a) = f^{-1}(a)$.

Rework Questions for Testing Center Portion of Exam 2

1. Tell me the first three steps for completing the square/ac factoring (whichever one(s) the student missed).
2. Tell me how to find the vertex in ____________________(whichever one(s) the student missed).
3. Show me with your arms the end behavior for ____________________ (Pick one randomly).
4. What would the zeros be if $b = 3$ and if $b = -2$.
5. Which method do you prefer and why?
6. Can there be a slant and a horizontal asymptote at the same time? Why not?
7. How did you come up with this answer?
8. Why is the first step to get a 0 on one side of the equation?
9. Describe your method of getting a common denominator?
10. How many real and how many imaginary zeros does your function have?
11. What is the name of the theorem used here?
12. What made this problem doable for you?

Written Portion

MATH1050 - Unit 2 Exam Part 2 Spring 2019 Instructor: **Hannah Lewis**

A# ____________________ Student Name (print): ____

This portion of the exam has 3 questions. This is the paper portion of the exam. The final draft should be between 2-5 pages and will be turned in on Canvas. Have a rough draft available for peers to read on Friday March 1st and a final draft to be turned in on Tuesday March 5th. You will be required to to read 3 of your classmates final drafts and give feedback. This feedback will be assigned on Wednesday March 6th and due on Friday March 8th at midnight.

- **Organize your explanations**, in a reasonably neat and coherent way.
- **Use APA** or **MLA** format.
- **Pictures** and other visuals may be helpful or necessary to complete this paper. Although the rest of the paper must be typed, math and other visuals can be either hand drawn in or imported as pictures.
- The final paper **needs to include this page as page 1**. Submit your final paper as pdf to canvas.

Show your work. Clearly identify your answer.

1. In a couple of paragraphs discuss the relationship between the graph of a polynomial, its degree, number of turning points, the end behavior.
2. State the Remainder Theorem and the Factor Theorem. How is the Remainder Theorem used with the Division Algorithm to get the Factor Theorem?
3. - Describe with an example the relationship between vertical asymptotes and a rational function.
   - Describe with an example the relationship between holes and a rational function.
   - Describe with an example the relationship between horizontal asymptotes and a rational function.
   - Describe with an example the relationship between oblique asymptotes and a rational function.

Group Portion

MATH1050 - Unit 2 Exam Part 3 Spring 2019 Instructor: **Hannah Lewis**

A# ________________ Student Name (print): ____

Group Members (First and last name)____

This exam contains 13 pages and 5 questions. THIS IS THE GROUP PORTION OF THE EXAM.

- Each prompt will need to be assigned to 2-3 people in your group. This means that each problem will be completed by more than one person independently and each person will complete 3-4 problems.
- Assignments need to be made by **Wednesday February 27th** at midnight.
- The problems assigned need to be completed by **Friday March 1st** for recitation.
- Comments need to be completed by **Saturday March 2nd**. (You will get time in recitation to work on you comments). A comment of ”looks great” or other such nonsense will result in no credit for the comment portion.
- The final write up completed on this outline (after edits based on the comments) due on **Tuesday March 5th** will be SCANNED and uploaded to the EXAM 1 Group Portion assignment in canvas. It needs to include:
  - The solution to each problem written by you. Your group member may have been assigned the problem, but you need to be able to follow their work and use their solution to write up the solution in your words.
  - The comments made by your group members for each prompt that you were assigned. A comment of “looks great” or other such nonsense will result in no credit for the comment portion. Every member of the group need to make at least 3-5 total constructive comments.
  - A one paragraph personal narrative about your experience with your group.
- **Organize your work**, in a reasonably neat and coherent way. Work scattered all over the page without a clear ordering cannot be assessed accurately.
- **Mysterious or unsupported answers will not receive credit**. A correct answer, unsupported by calculations, explanation, or algebraic work doesn’t show achievement of the objective; an incorrect answer supported by substantially correct calculations and explanations may show achievement of the objective.
- **Simplify all answers as much as possible.** This means that you need to need to combine like terms, reduce fractions, etc. (You do not need to rationalize denominators.)
- **Be sure to state units for applied problems.**
- **Clearly identify your answer for each problem.**

Show your work. Clearly identify your answer.

1. Assigned to:

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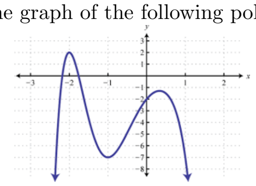
   Analyze the graph of the following polynomial:

   - What is the minimum degree?
   - Is the degree even or odd?
   - How many zeros are there?
   - Is the leading coefficient positive or negative?

Comments from group members about this problem go here

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2. Assigned to:

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   Let $f(x) = (x^2 + 1)(x - 1)(3x - 2)^2$

   - Find all real zeros.
   - State the multiplicity of each zero
   - Tell whether each zero crosses or touches the x-axis.
   - What is the degree of $f(x)$?
   - What are the possible number of turning points for $f(x)$?

Comments from group members about this problem go here

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3. Assigned to:

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   Give 2 examples and 3 non examples of rational functions. Label your non examples with the type of functions they are.

   - Example:
   - Example:
   - Non-Example:
   - Non-Example:
   - Non-Example:

Comments from group members about this problem go here

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4. Assigned to:

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   The city of Salt Lake City decides to be crime free. The estimated cost of catching and convicting $x\%$ of the criminals is given by

   $$C(x) = \frac{1000}{100 - x} \text{ million dollars}$$

   (a) Find and interpret (with at least one sentence) $C(50), C(75), C(90),$ and $C(99)$.

   (b) Sketch a graph of $C(x), 0 \leq x \leq 100$.

   (c) What happens to $C(x)$ as x gets closer and closer to 100 from the left?

   (d) What percentage of the criminals can be caught and convicted for \$30 million dollars?

Comments from group members about this problem go here

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5. Assigned to:

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    For the following function $f(x) = 2x^5 + 3x^4 - 22x^3 + 30x^2 - 160x + 75$

    1. Find the maximum number of real zeros by using the degree of the polynomial function.
    2. Find the possible number of positive and negative zeros by using Descartes's Rule of Signs.
    3. Write a set of possible rational zeros.
    4. Using synthetic division test the numbers above until a zero is found.

5. Test numbers until you have reduced to a quadratic function.

6. Factor, complete the square, or use the quadratic formula to find the last two zeros.

Comments from group members about this problem go here

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Personal narrative here:

APPENDIX G

Traditional Assessment Two

SPRING 2019 **MATH 1050 EXAM** II Name____________________________________

Recitation Instructor Name/Time________________________________

PART I: MULTIPLE CHOICE. Each problem has only **one correct answer.** Choose the answer that is most appropriate. Each problem is worth 6 points. ***PLEASE PLACE YOUR ANSWER IN THE SPACE PROVIDED.*** **No partial credit.**
The provided information is on the last page.

____1. A projectile is fired vertically upward from the ground. The **height,** $\boldsymbol{h}$ (measured in meters), of the projectile at a **time** $\boldsymbol{t}$ **seconds** after it is fired is given by the function: $\boldsymbol{h(t) = -16t^2 + 128t\ meters}$. What is the **maximum height** that the projectile will reach?

(a) 128 meters (b) 256 meters (c) 4 meters (d) 768 meters (e) 112 meters

____2. The quadratic function $f(x) = 3(x - 20)^2 + 10$ has NO maximum value.

(a) TRUE (b) FALSE

____3. Given the 5th degree polynomial function: $\boldsymbol{f(x) = (x - 120)^2(x + 200)^3}$, which of the following statements is TRUE?

(a) The graph of the function **touches** (without crossing) the x-axis two times.
(b) The graph of the function **crosses** the x-axis at the point (120, 0).
(c) The graph of the function has only 2 x-intercepts.
(d) The function has only one **real** zero.
(e) All statements (a) – (d) are FALSE .

____4. Given the polynomial function $\boldsymbol{f(x) = x^4 - 3x^2 - 4}$, which of the following statements is TRUE? (NOTE: This problem DOES NOT require the use of synthetic division.)

(a) The function has one positive zero.
(b) The function has one negative real zero.
(c) The function has 2 nonreal zeros.
(d) All statements (a) – (c) are TRUE.

____5. The graph of a 4th degree polynomial will **always** touch **or** cross the x-axis.

(a) TRUE (b) FALSE

____6. Given that $x = -3$ is a **zero** of the polynomial function $f(x) = x^3 + 3x^2 + 9x + 27$. Which of the following statements is TRUE about this function? Choose the most appropriate response.

(a) $f(x)$ can be written as a product of linear factors.
(b) The zero of $f(x)$ given by $x = -3$ has multiplicity 2.
(c) $x = 3i$ is a zero of $f(x)$.
(d) The graph of $f(x)$ has two x-intercepts.
(e) Both statements (a) and (c) are true.

____7. A **5th degree** polynomial function has **among its zeros** the values $x = 3$ with **multiplicity 2**, and $x = 2i$. How many x-intercepts will the graph of this function have?

(a) 1 (b) 2 (c) 3 (d) 5

(e) There is no 5th degree polynomial that has this combination of values among its zeros.

____8. A **4th degree** polynomial function $f(x)$ has a nonzero constant term and has **3 variations in sign**; $f(-x)$ has **one variation in sign** . Consider the following statement:

"All of the zeros of the function MUST be **real** numbers."

(a) The statement is TRUE. (b) The statement is FALSE.

____9. Which of the following statements is **FALSE** concerning the rational function $f(x) = \frac{200x}{x^3+100x}$? Choose the most appropriate response.

(a) The graph of the function has **only one vertical** asymptote.
(b) The graph of the function has a **horizontal** asymptote given by $y = 0$.
(c) The **domain** of the function is given by $(-\infty, 0) \cup (0, \infty)$.
(d) As $x \to \infty, f(x) \to 0$.
(e) The graph of the function DOES NOT have a **slant** asymptote.

____10. Which of the following statements is **TRUE** concerning the rational function $f(x) = \frac{400x^3}{x^2+1}$? Choose the most appropriate response.

(a) The graph of the function has a **slant** asymptote and two **vertical** asymptotes.
(b) As $x \to \infty$, $f(x) \to 400$.
(c) The **domain** of the function is given by $(-\infty, \infty)$.
(d) The graph of the function has only one **vertical** asymptote.
(e) The graph of the function has a **slant** asymptote and a **horizontal** asymptote.

____11. Which of the following represents the solution to the rational inequality: $\frac{x^2+1}{x+2} \geq 0$?

(a) $(-2, \infty)$ (b) $(-\infty, -2) \cup (-2, \infty)$ (c) $(-\infty, -2) \cup (-2, -1) \cup (-1, \infty)$ (d) $[-1, \infty)$ (e) $(-2, -1) \cup (-1, \infty)$

<u>**PART II**</u>**:** ***<u>READ THESE INSTRUCTIONS!!</u>*** Do ***<u>BOTH</u>*** problems. ***SHOW YOUR WORK*** in a <u>clear</u> and <u>organized</u> format if you expect to receive full or partial credit. ***<u>IDENTIFY YOUR ANSWERS.</u>*** <u>No work</u> = <u>no credit.</u> **Provide the <u>units</u> on your answers where applicable**. Each problem is worth **<u>20 points.</u>**

1. A large construction company frequently hires new welders. The **percentage, P**, of defective welds made by a new welder tends to decrease over time. The company uses the following model to predict the **percentage** of defective welds made by a new welder as a **function of time, t**: $\boldsymbol{P(t) = \frac{6t+12}{4t+1}}$ **%**, $t \geq 0$, where **t is the time (in months)** that the welder has been employed at the company.

(a) (4 points) According to this function, what percentage of defective welds will a new employee be producing when they first begin working at time $t = 0$ months?

(b) (8 points) According to this function, after how many months will a newly-hired welder be making **2%** of their welds as defective?

(c) (8 points) In the "long run" (mathematically, **as $t \to \infty$),** what value will the percentage of defectives approach? Fill in the

blank: As $\boldsymbol{t \to \infty, P(t)} \to$____________. **Indicate below exactly how you reached your answer; that is, <u>JUSTIFY</u> your answer with <u>computations</u> AND by <u>using properties of rational functions</u>.** NOTE: Plugging numbers into the function will NOT justify your result.

2. Consider the polynomial function $\boldsymbol{f(x) = x^4 - 1}$.

(a) (4 points) Determine the set of possible rational zeros of the function.

(b) (4 points) Determine all the possibilities for the number of positive zeros and the number of negative zeros.

(c) (8 points) Determine ALL zeros of the function. (NOTE: Use the result in part (a) as a starting point.)

(d) (4 points) Write the function in a factored form as a product of **linear factors**.

Factor Theorem: If $\boldsymbol{P(a) = 0}$, then $\boldsymbol{x - a}$ is a factor of $\boldsymbol{P(x)}$.

Horizontal Asymptotes: If $\boldsymbol{n}$ = degree of numerator and $\boldsymbol{m}$ = degree of denominator: 1. $\boldsymbol{n < m} \Rightarrow$ H.A. given by $y = 0$; 2. $\boldsymbol{n = m} \Rightarrow$ H.A. given by the ratio of the leading coefficients in the numerator and denominator; 3. $\boldsymbol{n > m} \Rightarrow$ No H.A.

Descartes' Rule of Signs: If $p(x)$ is a polynomial function with real coefficients and the constant term is not zero, then: (i) The number of positive real zeros is either equal to the number of variations in sign of $p(x)$, or less than that number by an even integer; (ii) the number of negative real zeros is either equal to the number of variations in sign of $p(-x)$, or less than that number by an even integer.

Complex Conjugate Zeros Theorem: If a polynomial function $P(x)$ has real coefficients, and if $\boldsymbol{a + bi}$ is a zero of $P(x)$, then its complex conjugate $\boldsymbol{a - bi}$ is also a zero of $P(x)$.

Characteristics of exponential functions: $f(x) = b^x$; Domain: $(-\infty, \infty)$; Range: $(0, \infty)$; Horizontal Asymptote: $y = 0$ (x-axis)

APPENDIX H

Growth Mindset Structured Assessment Three

Testing Center Portion

MATH1050 - Unit 3 Exam Part 1 Spring 19 Instructor: **Hannah Lewis**

A# ___________________ Student Name (print): ____

This portion of the exam contains 8 pages (including this cover page) and 16 questions. Enter your answers in the space provided. Write your final answer on the "Solution" line for each problem, where appropriate. Otherwise, draw a box around your final answer. Complete your solutions to the "show your work" problems on the page indicated.

- **Organize your work**, in a reasonably neat and coherent way, in the space provided. Work scattered all over the page without a clear ordering cannot be assessed accurately.
- **Mysterious or unsupported answers will not receive adequate feedback**. A correct answer, unsupported by calculations, explanation, or algebraic work doesn't show achievement of the objective; an incorrect answer supported by substantially correct calculations and explanations may show partial achievement of the objective.
- **Provide exact answers** unless otherwise instructed.
- **Simplify all answers as much as possible.** This means that you need to need to combine like terms, reduce fractions, etc. (You do not need to rationalize denominators.)
- **Be sure to state units for applied problems.**
- **Clearly identify your answer for each problem.**

Do not write in the table to the right.

Show your work. Clearly identify your answer.

1. (11 points) Given the following types of functions:

Rational Function
Radical Function
Logarithmic Function
Natural Logarithmic Function
Exponential Function
Natural Exponential Function
Polynomial Function
Quadratic Function
Cubic Function
Not a Function

Label this list of equations with the appropriate type. (Some may have more than one label.)

$$f(x) = \sqrt{2x-1}+3 \qquad g(x) = 3x^2+5x-2$$
$$h(x) = 2x^7-5x+4 \qquad j(x) = 2e^{x-5}+3$$
$$k(x) = \ln(3x-2)+4 \qquad m(x) = \log_3(2x-1)+4$$
$$n(x) = \frac{3x^3-1}{2x^2+5} \qquad p(x) = 3\cdot 4^{3x}$$
$$q(x) = 4x^3+2 \qquad x^2 = -y^2+1$$

Solution: +11 for 1 error.
+8 for 2-4 errors
+5 for 5-7 errors

Solution: RETAKE
Rework the original problem and describe your mistake. Give 2 examples and 2 non-examples of exponential functions, natural exponential functions, logarithmic functions, and natural logarithmic functions. Label your non examples with the type of function they are.

2. (4 points) Tell whether the following is in exponential or logarithmic form, then convert to the other form.
$3^x = 9$
$\log_2 x = 3$

Solution: +1 for each label correct.
+1 for each conversion done correctly.

Solution: RETAKE
Rework the original problem and describe your mistake. Show how the "triangle of power" can help facilitate converting between exponential and logarithmic form.

3. (3 points) Evaluate the following:

$$\log_2 \sqrt{8} =$$

$$\log_{16} 2 =$$

$$\log_5 25 =$$

$$\log_{42} 1$$

Solution: +1 for each correct evaluation.

Solution: RETAKE
Rework the original problem and describe your mistake. Create a logarithm that is equivalent to 0.
Create a logarithm that is equivalent to 1.
Create a logarithm that is equivalent to e.

4. (3 points) Graph the exponential function $f(x) = e^{x-2} + 3$

Solution: +1 for each shift executed correctly
+1 for at least one point of reference.

Solution: RETAKE
Rework the original problem and describe your mistake.
Write the equation of an exponential function that are shifted 3 units to the left, 5 units up and reflected across the x- axis. Draw the graph of both of these functions.

5. (3 points) Find the domain of the following logarithmic functions:
$f(x) = 2\log(3x-1)$
$g(x) = 5x\log\left(\frac{x+1}{x-3}\right)$
$h(x) = \frac{\log(x-2)}{x-3}$

Solution: +1 for each correct domain

Solution: RETAKE
Rework the original problem and describe your mistake. Create a logarithmic function that also has domain restrictions with fractions and square roots. Then find the domain of your function.

6. (3 points) Graph the function $f(x) = \log_3(x-1) + 2$

Solution: +1 for each shift executed correctly
+1 for at least one point of reference.

Solution: RETAKE
Rework the original problem and describe your mistake.
Write the equation of a logarithmic function that are shifted 3 units to the left, 5 units up and reflected across the x- axis. Draw the graph of both of these functions.

7. (6 points) • Expand the function $f(x) = \ln\left(\frac{\sqrt{2x-3}}{(x-5)^3(x)}\right)$
   • Condense the function $g(x) = \ln(x-1) + 2\ln(x) - 5\ln(3x-21)$

Solution: +1 for each part of the expansion or contraction executed correctly.

Solution: RETAKE
Rework the original problem and describe your mistake.
Is the function $f(x) = \ln(x+1)^2 + \log_2(x-8)^3 - 5\ln(\sqrt{2x+8}) + \log_2(5x)$ fully expanded, fully contracted, or neither. Show the complete expansion and contraction of $f(x)$.

8. (2 points) Using the change of base formula, rewrite $\log_2 3$ into a form that can easily be typed into most calculators.

Solution: +2 for a correct change of base.

Solution: RETAKE
Rework the original problem and describe your mistake.
Show three equivalent change of basis for $log_8 6$

9. (4 points) Tritium is used in nuclear weapons to increase their power. It decays at the rate of 5.5% per year. Calculate the half life of Tritium. Leave your answer in exact form.

Solution: +4 for using a correct formula to find the correct half life
+2 for using an incorrect formula but a correct method to find the half life

Solution: RETAKE
Rework the original problem and describe your mistake.
How long will it take for a 40.0 gram sample of I-131 (half-life = 8.040 days) to decay to $\frac{1}{100}$th of its original mass?

10. (4 points) Solve the following equations for x
    - $9^x = 3^{x+1}$
    - $5^{2x-3} = 3^{x+1}$

Solution: +2 for each solution found correctly using correct algebra. (minor arithmetic errors ok)
+1 each for correct algebra heading in the right direction.

Solution: RETAKE
Rework the original problem and describe your mistake.
Solve the following describing every step: $\frac{4}{2+3^x} = 1$

11. (4 points) Solve for x

$$\log(x-1) + \log(x+2) = 1$$

Solution: +4 for the solution found correctly using correct algebra.(minor arithmetic errors ok)
+2 for correct algebra heading in the right direction.

Solution: RETAKE
Rework the original problem and describe your mistake.
Solve the following describing every step: $\log_2 |x+1| = 3$.

12. (3 points) Solve for x. Give your answer in interval notation.

- $\ln(x-5) \geq 1$
- $23 - 2e^{4x} < 20$

Solution: +2 for each solution found correctly using correct algebra. (minor arithmetic errors ok)
+1 each for correct algebra heading in the right direction.

Solution: RETAKE
Rework the original problem and describe your mistake.
Solve the following describing every step: $\frac{40}{1+3e^{-2x}} \leq 25$

13. (4 points) The concentration $[H^+]$ of a substance is 10^{-12} . Calculate the pH value and classify it as an acid or a base.

Solution: +4 if pH is found correctly and identified as basic.
+2 for minor errors or no classification
+1 for attempting the problem

Solution: RETAKE
Rework the original problem and describe your mistake.
Give the correct formula. Suppose the hydrogen ion concentration of a solution is increased 50 times. How much change does this represent in the pH value of this solution? Does this increase in $[H^+]$ make the solution more acidic or more basic?

14. (4 points) The magnitude M of an earthquake is given as $M = 2$.

a. Find the earthquake intensity I in terms of the zero-level earthquake intensity I_0.

b. Find the energy released by the earthquake.

Solution: +4 if I is found correctly with respect to I_0 and energy is found correctly
+2 for minor errors
+1 for attempting the problem

Solution: RETAKE
Rework the original problem and describe your mistake.
Give the correct formula. Suppose the earthquake A registers one point more on the Richter scale than earthquake B. How are their corresponding intensities AND energies related?

15. (4 points) The intensity I of a sound is $I = 10^{-10}\frac{W}{m^2}$. Find the loudness L of the sound if $I_0 = 10^{-12}\frac{W}{m^2}$.
The loudness of the sound is ______ decibels.

Solution: +4 if correct decibels are found correctly .
+2 for minor errors
+1 for attempting the problem

Solution: RETAKE
Rework the original problem and describe your mistake.
Give the correct formula. Suppose a sound is 1000 times as intense as one at the threshold of pain for the human ear. Find the loudness of this sound in decibels.

16. (4 points) The magnitudes of two stars, A and B, are 5 and 15, respectively. Compare the brightness of these stars.

Star A is approximately ______ times brighter than star B.

Solution: +4 if comparison value is correct
+2 for minor errors
+1 for attempting the problem

Solution: RETAKE
Rework the original problem and describe your mistake.
Give the correct formula. If the magnitude of the sun is $M_s = -27$ and the full moon is $M_m = -13$, then how many times brighter is the sun than the full moon?

Rework Questions for Testing Center Portion of Exam 3

1. Give me an example of a function that is not logarithmic or exponential.
2. How can the triangle of power help convert the form?
3. How did you come up with the log that is equivalent to e?
4. Draw the base graph for the exponential function and the log function.
5. What are the 3 domain restrictions?
6. Draw the base graph for the exponential function and the log function.
7. What are the three log rules for expanding and contracting?
8. How many different ways can you write a log using the change of base formula?
9. What is the difference between the formula for exponential decay and exponential growth?
10. What are two ways to start solving the first problem on the exam?
11. When do you need to check for extraneous solutions (in general)?
12. What is the inverse operation to an ln?
13. How do you remember which formula to use?
14. How do you remember which formula to use?
15. How do you remember which formula to use?
16. How do you remember which formula to use?

Written Portion

MATH1050 - Unit 3 Exam Part 2 Fall 18 Instructor: **Hannah Lewis**

A# ____________ Student Name (print): ______________________________

This portion of the exam has 5 questions. This is the paper portion of the exam. The final draft should be between 2-5 pages and will be turned in on Canvas. Have a rough draft available for peers to read on Friday March 29th and a final draft to be turned in on Tuesday April 2nd. You will be required to to read 3 of your classmates final drafts and give feedback. This feedback will be assigned on Wednesday April 3rd and due on Friday April 5th at midnight.

- **Organize your explanations**, in a reasonably neat and coherent way.
- **Use APA** or **MLA** format.
- **Pictures** and other visuals may be helpful or necessary to complete this paper. Although the rest of the paper must be typed, math and other visuals can be either hand drawn in or imported as pictures.
- The final paper **needs to include this page as page 1**. Submit your final paper as pdf to canvas.

1. Using the formula $A = P + Prt$, we can take a simple interest problem to a more real world problem where interest is compounded, meaning that interest is paid on both the principal and the previously earned interest. Suppose that if we were to deposit an amount of money P into the bank with an interest rate of r, what amount of money would we have after one year? Let's express this amount as A_1:
   Now taking this amount A_1 to be our new principal amount going into the second year, what would the amount be after one years' time? Represent this amount as A_2.
   Using A_2 as our new principle, how much money would we have after another years' time? Represent this as A_3.
   In a couple of sentences, write down any patterns that you are noticing.
   What do you think our amount of money would be after t years? Represent this as A_t.
   Is this equation similar to an exponential function? Explain your reasoning in a couple sentences.
2. What are 3 interesting things you can find about the number e that relate to your life or future career?
3. Tell me about a large dream purchase of yours (more than \$5000). Say you have \$5000 to invest at an annual interest rate of 11%. When would you have enough to purchase your item if the interest is compounded:
   - Yearly
   - Quarterly
   - Monthly
   - Daily
   - Continuously

   Show ALL of your by hand calculations.
4. Tell me about the main three rules of expanding and contracting logarithms. How do you remember them and how do they relate to the rules of exponentials?
5. 20,000 people at Utah State University are susceptible to the Ebola virus. Assume that 1000 people were infected initially and 9000 had been infected by the end of the fourth week.
   - Find the formula for the logistic model that describes the number of students who become infected after t weeks. Describe how you got each piece of the formula.
   - Find the number of people infected after 8 weeks.
   - How many weeks will it take for everyone that is susceptible on campus to become sick? How do you know?

Group Portion

MATH1050 - Unit 3 Exam Part 3 Spring 2019 Instructor: **Hannah Lewis**

A# ____________________ Student Name (print): ____

Group Members (First and last name)____

Group Project/Presentation: Apply exponential functions to real world problems.

In groups of 3, you are going to be doing a financial project and presenting on it (briefly) in class. Here are the details of what the project will require:

Important Details/Requirements:

- As a group, decide how much money each of you would be willing/able to invest and put all of that collective money into a Certificate of Deposit (CD).
- Conduct an investigation to see which of your respective banks/credit unions have the highest interest rates and how often CD accounts are compounded in a given year.
- Decide on which bank/credit union you want to invest your group's money in and why you chose that institution.
- Provide details on how much money your group would have if you put your money into a 1 yr, 2yr, 3yr, 4yr and 5 yr CD.
- After having all of this information, compile it neatly into one power point or google slide.
- Submit this slide to your recitation leader and be prepared to present briefly in recitation.

APPENDIX I

Statement 1

You have a certain amount of intelligence, and you can't really do much to change it.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Statement Disagree

Strongly disagree

Statement 2

Your intelligence is something about you that you can't change very much.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 3

No matter who you are, you can significantly change your intelligence level.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 4

To be honest, you can't really change how intelligent you are.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 5

You can always substantially change how intelligent you are.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 6

You can learn new things, but you can't really change your basic intelligence.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 7

No matter how much intelligence you have, you can always change it quite a bit.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 8

You can change even your basic intelligence level considerably.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 9

You have a certain amount of talent, and you can't really do much to change it.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 10

Your talent in an area is something about you that you can't change very much.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 11

No matter who you are, you can significantly change your level of talent.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 12

To be honest, you can't really change how much talent you have.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 13

You can always substantially change how much talent you have.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 14

You can learn new things, but you can't really change your basic level of talent.

Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 15

No matter how much talent you have, you can always change it quite a bit. Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

Statement 16

You can change even your basic level of talent considerably Strongly Agree

Agree

Mostly agree

Neither agree nor disagree

Mostly disagree

Disagree

Strongly disagree

APPENDIX J

Question 1

How did you feel about math before this class?

Question 2

Do you feel differently about math now? Explain.

Question 3

How is the test structure different than a typical math class? How is it the same?

Question 4

What did you like about group work in class?What did you not like?

Question 5

How comfortable were you with group work for this class?

Question 6

How did group work affect your feelings and attitudes toward the class and math in general?

Question 7

What did you learn from the group work? **Question 8**

What did you like about writing papers for this class? What did you not like?

Question 9

How comfortable were you with writing papers for this class?

Question 10

What did you learn from writing papers about math?

Question 11

What did you like about the exam re-work opportunities? What did you not like?

Question 12

How comfortable were you coming in to re-work exam problems?

Question 13

What did you learn from the exam re-work process?

Question 14

How did knowing you would have the opportunity to rework in-class exam questions affect your study habits?

Question 15

How did knowing you would have the opportunity to rework in-class exam affect your feelings and attitudes?

Question 16

What did you like about the scoring and rubrics for this class? What did you not like?

Question 17

How comfortable were you with the scoring and rubrics for this class?

Question 18

What did you learn from the scoring and rubrics about math?

Question 19

How do you think this test structure affected your attitude toward mathematics?

Question 20

Which part of this test structure did you learn the most from and why?

Question 21

Which part of this test structure did you learn the least from and why?

APPENDIX K

Traditional Assessment Three

Spring 2019 **MATH 1050 EXAM** III Name____________________________________

Recitation Instructor Name/Time________________________________

PART I: MULTIPLE CHOICE. Each problem has only **one correct answer.** Choose the answer that is most appropriate. Each problem is worth 7 points. ***PLEASE PLACE YOUR ANSWER IN THE SPACE PROVIDED.*** **No partial credit.**
The provided information is on the last page.

____1. The graph of $f(x) = e^x$ is to be transformed by first reflecting the graph across the x-axis, then stretched vertically by a factor of 2, and then shifted vertically downward 5 units. Which of the following functions would be appropriate for the resulting graph? Note: The graph of the basic function $f(x) = e^x$ is provided on the formula sheet on the last page.

(a) $g(x) = -2e^x - 5$ (b) $g(x) = 5e^{-x} + 2$ (c) $g(x) = -2e^{x+5}$ (d) $g(x) = 2e^{-x} - 5$ (e) $g(x) = -e^{2x} + 5$

____2. Solve the equation for x: $\frac{2}{1+e^x} = 4$

(a) $x = \ln(-\frac{1}{2})$ (b) $x = -\frac{1}{2}$ (c) $x = \frac{\ln(-1)}{2}$ (d) $x = \frac{4}{\ln 2} - 1$ (e) The equation has no solution.

____3. Re-write the expression using a **single natural log** term (condensed form): $\mathbf{2\ln(x) + \ln\left(\frac{x}{2}\right)} =$

(a) $\ln(\frac{x^6}{27})$ (b) $\ln(x^2 + \frac{x}{2})$ (c) $\ln(\frac{x^3}{2})$ (d) $\ln(3)$ (e) $\ln[(x + \frac{x}{2})^2]$

____4. Solve the equation for x: $\ln(3x) + \ln 2 = 3$

(a) $x = \frac{e^3}{6}$ (b) $x = \frac{e^3-2}{3}$ (c) $x = \frac{\ln(3)}{6}$ (d) $x = \frac{2e^3}{3}$ (e) $x = \frac{1}{3}$

_____5. Solve the equation for x: $\log(x-1)+\log(x+2)=1$

(a) $x=3; x=-4$ (b) $x=-3;\ x=4$ (c) $x=3$ (d) $x=-4$ (e) The equation has no solution.

____6. The following transformations will be used on the graph of the function $f(x)=\ln(x)$: A horizontal shift 2 units to the right, followed by a vertical shift 5 units upward. Which of the following functions would be appropriate for the resulting graph?

(a) $g(x)=\ln(x-2)-5$ (b) $g(x)=\ln(x+5)-2$ (c) $g(x)=\ln(x-2)+5$

(d) $g(x)=5\ln(x)-2$ (e) $g(x)=\ln(5x+2)$

____7. Identify the **range** of the function $g(x)=e^x+15$. (You may want to consider transformations of a graph.)

(a) $(-\infty,15)$ (b) $(-\infty,0)$ (c) $(-\infty,\infty)$ (d) $(15,\infty)$ (e) $(-15,\infty)$

PART II: ***READ THESE INSTRUCTIONS!!*** Do ***ANY 2*** and ***ONLY 2*** of the 3 problems. **Cross out completely the problem that is NOT to be graded.** ***SHOW YOUR WORK*** in a clear and organized format if you expect to receive full or partial credit. ***IDENTIFY YOUR ANSWERS.*** No work = no credit.
Provide the units on your answers where applicable. Each problem is worth **20 points**.

1. A patient is given an injection of a new drug which results in an **initial concentration** of the drug in the bloodstream of 150 milligrams per liter. The doctor assumes that the **concentration of the drug, C**, in the patient's bloodstream **t hours** later can be predicted using an exponential decay model: $\boldsymbol{C(t) = 150e^{kt}\ mg. per\ liter; t \geq 0}$. The value for the **decay constant, k**, is to be determined. (Note that $k < 0$ for this model.)
   (a) (10 points) At time $\boldsymbol{t = 2}$ hours later, the concentration of the drug in the patient's bloodstream is found to be **109 mg. per liter**. Use this information to determine the appropriate **value of the decay constant** for the function given above. Give the **exact value** for k, and then round your answer to **2 decimal places**.)

   (b) (10 points) The next day the patient is going to be given an injection of a different drug for which the concentration can be predicted by the exponential decay model: $\boldsymbol{C(t) = C_0e^{-.2t}\ mg. per\ liter; t \geq 0}$, where $\boldsymbol{C_0}$ represents the **initial concentration** of the drug (at time $t = 0$ hours). (NOTE: The exponent is: $-\ .2t$) The doctor would like the **initial concentration** to be large enough so that the concentration has a value of **90 mg. per liter at time $t = 4$ hours**. What must the initial concentration be equal to in order to achieve this goal? Round your answer to the **nearest whole number**.

$\boldsymbol{C_0}$ =________________________

2. Given the function $\boldsymbol{g(x) = -e^{x+2} + 10}$, provide the information below. NOTE: It may help to consider the concept of transformations on the graph of $f(x) = e^x$. **Use interval notation**. NO WORK IS REQUIRED.

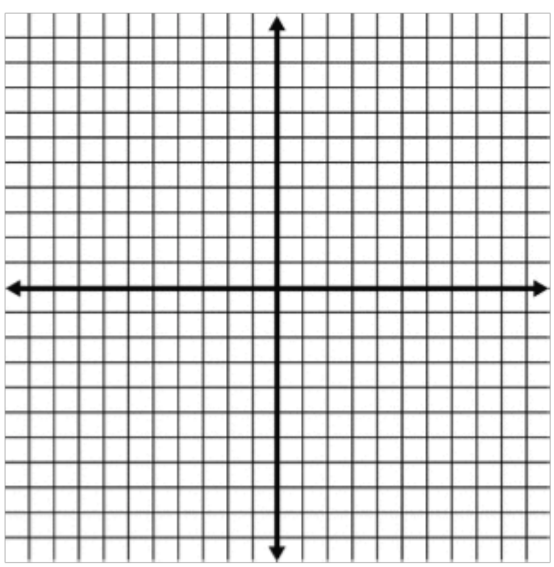
(3 points) Describe the shifts:

(4 points) DOMAIN:

(4 points) RANGE:

(6 points) HORIZONTAL ASYMPTOTE:
(An asymptote is a ***line,*** so give the ***equation*** of the line.)

(3 points) Draw a sketch of the graph labeling at least 2 points:



3.
(8 points) **The concentration $[H^+]$ of a substance is 10^{-12} . Calculate the pH value and classify it as an acid or a base.**

The magnitude M of an earthquake is given as M = 2.
(6 points) Find the earthquake intensity I in terms of the zero-level earthquake intensity I_0 .

(6 points) Find the energy released by the earthquake.

<u>Factor Theorem</u>: If $P(a) = 0$, then $x - a$ is a factor of $P(x)$.

<u>Horizontal Asymptotes</u>: If n = degree of numerator and m = degree of denominator: 1. $n < m \Rightarrow$ H.A. given by $y = 0$; 2. $n = m \Rightarrow$ H.A. given by the ratio of the leading coefficients in the numerator and denominator; 3. $n > m \Rightarrow$ No H.A.

<u>Descartes' Rule of Signs</u>: If $p(x)$ is a polynomial function with real coefficients and the constant term is not zero, then: (i) The number of positive real zeros is either equal to the number of variations in sign of $p(x)$, or less than that number by an even integer; (ii) the number of negative real zeros is either equal to the number of variations in sign of $p(-x)$, or less than that number by an even integer.

<u>Complex Conjugate Zeros Theorem</u>: If a polynomial function $P(x)$ has real coefficients, and if $a + bi$ is a zero of $P(x)$, then its complex conjugate $a - bi$ is also a zero of $P(x)$.

<u>Characteristics of exponential functions</u>: $f(x) = b^x$; Domain: $(-\infty, \infty)$; Range: $(0, \infty)$; Horizontal Asymptote: $y = 0$ (x-axis)

<u>Characteristics of log functions</u>: $f(x) = \log_b(x)$; Domain: $(0, \infty)$; Range: $(-\infty, \infty)$;

Richter Scale Magnitude of an earthquake: $M = \log(\frac{I}{I_0})$, where I is the intensity of the earthquake.

Energy, E, released by an earthquake: $E \approx (2.5 \cdot 10^4) \cdot 10^{1.5M}$

$pH = -\log[H^+]$, Substances with a pH greater than 7 are basic and a pH less than 7 are acidic

APPENDIX L

Institutional Review Board Approval Letter

Institutional Review Board

USU Assurance: FWA#00003308

UtahState University
OFFICE OF RESEARCH AND GRADUATE STUDIES

Expedite #7

Full Accreditation

Letter of Approval

FROM:

Melanie Domenech Rodriguez, IRB Chair

Nicole Vouvalis, IRB Administrator

To:	Kady Schneiter, Hannah Lewis
Date:	January 10, 2019
Protocol #:	9779
Title:	Growth Mindset Assessments For Math 1050 Effect On Mindset And Achievement
Risk:	Minimal risk

Your proposal has been reviewed by the Institutional Review Board and is approved under expedite procedure #7 (based on the Department of Health and Human Services (DHHS) regulations for the protection of human research subjects, 45 CFR Part 46, as amended to include provisions of the Federal Policy for the Protection of Human Subjects, November 9, 1998):

> Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.This approval applies only to the proposal currently on file for the period of one year. If your study extends beyond this approval period, you must contact this office to request an annual review of this research. Any change affecting human subjects must be approved by the Board prior to implementation. Injuries or any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Institutional Review Board.

This approval applies only to the proposal currently on file for the period of one year. If your study extends beyond this approval period, you must contact this office to request an annual review of this research. Any change affecting human subjects must be approved by the Board prior to implementation. Injuries or any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Institutional Review Board.

Prior to involving human subjects, properly executed informed consent must be obtained from each subject or from an authorized representative, and documentation of informed consent must be kept on file for at least three years after the project ends. Each subject must be furnished with a copy of the informed consent document for their personal records.

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Hannah Mae Lewis

Curriculum Vitae

Business Address:
Utah State University
Department of Mathematics and Statistics
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(435) 797-2808

Home Address:
210 S 400 E
Logan, Utah 84321
(435) 703-3409
hannah.lewis@aggiemail.usu.edu

EDUCATION

Ph.D. Expected graduation Summer 2019
ABD Interdisciplinary Studies with Concentrations in Lie Algebras/Differential Geometry and Teacher Education and Leadership, Utah State University.
Impact of Growth Mindset Structured Assessments in Large Lecture College Algebra Classes: Mindset, Achievement, and Anxiety.

M.S. August 2017
Master of Mathematics, Utah State University.
Real Simple Lie Algebras: Cartan Subalgebra, Cayley Transform, and Classification.

B.S. May 2012
Mathematics, Dixie State University.
Magna cum Laude; Mathematics Department *Valedictorian*

TEACHING

LARGE LECTURE INSTRUCTOR

Math 1050 Pre-Calculus, Fall 2018 & Spring 2019
Completed weighted objectives, course notes, and exams for the course. Supervised recitation leaders for three large lecture courses over two semesters.
Innovations: Wrote exams based on weighted objectives and structured with a growth mindset ideology. Exams included essays, group projects, and testing center parts with rework opportunities. Successfully implemented these exams in a large lecture setting and small lecture setting.

INSTRUCTOR

Math 1010 Intermediate Algebra, Fall 2013
Math 1050 Pre-Calculus, Summer 2016, Summer 2018 (1st & 2nd seven week sessions)
Math 1210 Calculus 1, Spring & Fall 2014, Spring, Summer, & Fall 2015, Spring 2017
Math 2210 Multivariable Calculus, Summer & Fall 2017
Responsibilities included writing exams, constructing lesson plans, grading, and tutoring students in all math and statistics courses. All five Summer classes were taught with distance students. Developed detailed Canvas pages that improve and incorporate more Canvas capabilities every semester.

RECITATION LEADER / TEACHING ASSISTANT / GRADER

Math 5810 Intro to Maple, Teaching Assistant, Spring 2016, Fall 2017
Math 2250 Linear Algebra/ Differential Equations, Recitation Leader, Spring 2016
Math 1210 Calculus 1, Recitation Leader, Fall 2016
Math 6210 Differential Geometry, Grader, Spring 2015
Responsibilities included creating detailed rubrics, grading and providing feedback for students. Attended lecture and answered questions during class. Lead recitation classes.

SUBSTITUTE TEACHER

Kelly Support Services, Washington County School District, 2012-2013
Stat 1040 Intro to Statistics. Preferred substitute teacher for concurrent enrollment course at Pine View High School. Wrote lesson plans, graded quizzes and taught class.
Math 7,8,9. Preferred substitute teacher for math teachers at Desert Hills Middle School. Wrote lesson plans, reviewed for exams, taught classes.

EMPLOYMENT HISTORY

UTAH STATE UNIVERSITY

Instructor/Recitation Leader/Teaching Assistant Fall (2013-present)
Mathematics and Statistics Department
Responsibilities include writing exams, constructing lesson plans, developing class notes, grading, and tutoring students in all math and statistics courses. Many of these classes were distance courses. Participated in over 70 hours of professional development training for graduate student teachers.

KELLY EDUCATIONAL STAFFING

Substitute Teacher (2005-06, 2012-13)
Responsibilities included writing lesson plans for regular substitute positions, implementing existing lesson plans, overseeing classroom activities, assigning homework, following the full time teacher's instructions, and grading tests. Taught grades K-12 for Provo City School District and Washington County School District.

SELF-EMPLOYED

Private Math Tutor (2009-present)
Washington County School District grades 5-12
Dixie State University 1000-4000 level mathematics and statistics courses
Logan City School District grades 6-12
Responsibilities include ACT, ALEKS, AP Calculus, and AP Statistics preparation, developing tutoring resources, monitoring student progress, identifying areas needing improvement, helping with homework, and preparing students for tests. Specialize in online tutoring and working with students who have ADD, ADHD, and math anxiety.
Group math tutor for Pine View High School football team players (2010-2012).

DIXIE STATE COLLEGE

Math Tutor (2009-12)
Student Support Services
Responsibilities included identifying areas needing improvement, helping with homework, and preparing students for tests. Specialized in helping students dealing with ADD, ADHD, and math anxiety.

AWARDS & PROFESSIONAL RECOGNITION

- **Excellence in Teaching,** Utah State University, Department of Mathematics (2017-18)
- **Excellence in Teaching,** Utah State University, Department of Mathematics (2016-17)
- **Excellence in Teaching,** Utah State University, Department of Mathematics (2015-16)
- **Math Student of the Year**, Dixie State College of Utah (2011-12)
- **Award of Excellence**, Dixie State College of Utah, Department of Mathematics (2011-12)
- **Math Student of the Year**, Dixie State College of Utah (2010-11)
- **Award of Excellence**, Dixie State College of Utah, Department of Mathematics (2010-11)
- **Math Student of the Semester**, Dixie State College of Utah, (2011)
- **Academic Scholarship**, Dixie State College of Utah (2009-2012)
- **Award of Excellence**, Dixie State College of Utah, Department of Mathematics (2009-10)
- **Award of Excellence**, Dixie State College of Utah, Department of Mathematics (2008-09)

RESEARCH

Utah State University, Logan Utah (Summer 2018)

In partnership with Dr. Kady Schneiter and Lane Tait, researched the relevance, reliability, and validity of growth mindset assessments for college algebra. This included the development of 220 pages of classroom guided notes for the course, and three unit exams. Each of these exams consisted of an essay portion, a group portion, and a testing center portion.

Utah State University, Logan, Utah (Summer 2018)

In partnership with Dr. David Brown and Derrick Harkness, developed and organized a two day teaching conference for Utah State graduate student teaching assistants and undergraduate recitation leaders. This included the analysis of abstracts for approval, organization of presenters, logistical organization, and preparing and presenting keynote talks.

Utah State University, Logan, Utah (Spring 2018)

In partnership with Dr. David Brown, developed a research-based professional development course and mentorship program for graduate student teaching assistants at Utah State University. This included researching successful professional development programs, developing material for weekly meetings, coordinating appropriate guest speakers, and developing guidelines for growth moving forward.

Utah State University, Logan, Utah (Summer 2017)

In partnership with Dr. Ian Anderson, wrote a series of Maple mini-programs that culminated in a program that classifies simple Lie algebras using the Cayley transform. This work resulted in a plan A master's thesis detailing the process of this Cayley transform using Cartan subalgebras.

Boise State University, Boise, Idaho (Summer 2011)

Collaborated with a group of students and professional researchers to make progress in solving the word and conjugacy problem in the pure braid group of three strands and the braid group of three strands.

CURRENT RESEARCH PROJECTS

- Development of weighted objectives and growth mindset structured assessments for Intro to Statistics and Statistics for Scientists. Collaborating with Dr. Kady Schneiter.

- Impact of graduate student teaching assistant professional development on teaching changes. Collaborating with Dr. Dave Brown.

RESEARCH INTERESTS

- Graduate student professional development.
- Growth mindset structured assessing and effect on achievement.
- Growth mindset structured lessons and effect on achievement.
- Educational technology and impact on student achievement.
- Educational technology and impact on growth mindset.
- Classification of exceptional cases of real simple Lie algebras.
- Classification of real solvable Lie algebras.

PUBLICATIONS

1. Lewis, Hannah; Schneiter, Kady, and Tait, David Lane (submitted) University Pre-calculus Growth Mindset Structured Assessments: Development, Analysis, and Effects

2. Lewis, Hannah (2017). Real Simple Lie Algebras: Cartan Subalgebra, Cayley Transform, and Classification*. Master's Plan A Thesis. Utah State University*

PRESENTATIONS

Lewis, Hannah; Schneiter, Kady and Tait, Lane. (2018, October). *Developing Growth Mindset Assessments for Pre-Calculus Courses,* 50 minute presentation, Utah Council of Teachers of Mathematics (UCTM), Draper, Utah.

Lewis, Hannah and Harkness Derrrick. (2018, August). *How to Write Objectives at Appropriate Learning Levels.* 110-minute presentation, Together We Teach First Annual Conference (TWeT), Utah State University, Logan, Utah.

Lewis, Hannah and Harkness Derrrick. (2018, August). *How to Write Lesson Plans.* 110-minute presentation, Together We Teach First Annual Conference (TWeT), Utah State University, Logan, Utah.

Lewis, Hannah; Schneiter, Kady and Tait, David Lane. (2018, August). *Improving Growth Mindset Assessments in Mathematics Classrooms,* Poster presentation, Together We Teach First Annual Conference (TWeT), Utah State University, Logan, Utah.

Lewis, Hannah; Schneiter, Kady, (2018, October). *Growth Mindset Assessments in Mathematics Classrooms,* Poster presentation, Research in Undergraduate Mathematics Education (RUME), San Diego, California.

Lewis, Hannah and Schneiter Kady (2018 March), *Graduate Student Professional Development on Writing Assessments for Undergraduate Mathematics Classrooms,* Mathematical Association of America, Utah State University, Logan, Utah.

Lewis, Hannah (2017 September) *Why is it SO Hard for Women in STEM?*, Invited 50 minute presentation, PhysX, Utah State University, Logan, Utah.

Lewis, Hannah (2017 May) *Be Smart.* Invited 20-minute presentation, Be Attitude Evening, Larkspur Ward, Logan, Utah.

Lewis, Hannah (2012 May) *Valedictorian Speech,* Convocation, Dixie State University, St. George, Utah.

SKILLS

- Geogebra
- Maple
- Desmos
- LaTeX
- Microsoft Office

LEADERSHIP & SERVICE

- Adult Sunday School Instructor, Logan, Utah (2018)
- Youth Sunday School Instructor, Logan, Utah (2013-2018)
- Community Youth Group Volunteer, St. George, Utah (2009-12)
  ACT preparation and tutoring for high school aged young women

- Volunteer Classroom Aide, Dixon Middle School, Provo, Utah (2004)
  Helped students successfully complete English and math assignments