GAMIFICATION AND ALGEBRA 1: WILL A GAMIFIED CLASSROOM INCREASE STUDENT ACHIEVEMENT AND MOTIVATION?

A Thesis

Presented

to the Faculty of

California State University, Chico

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Mathematics Education

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by

Kathleen Urrutia

Summer 2014

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ABSTRACT

GAMIFICATION AND ALGEBRA 1: WILL A GAMIFIED CLASSROOM INCREASE STUDENT ACHIEVEMENT AND MOTIVATION?

by

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Master of Science in Mathematics Education

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This study investigated how implementing the mastery learning model with gamification techniques affected student achievement and motivation. At Inspire School of Arts and Sciences, many math teachers are challenged by students who are unmotivated and unengaged.

In this study, an Algebra 1 teacher at Inspire implemented mastery learning with gamification into her class. Average test scores of 13 exams of students in a gamified Algebra 1 class were compared to the average test scores of 13 of the same exams in the traditional Algebra 1 class. Each Algebra 1 test consists of the following types of questions: Knowledge, Comprehension, Application, and Analysis, Synthesis, Evaluation. A statistical test was used to compare each category of the test between the gamified (treatment) group and the traditional group. The exam data was analyzed to determine the following:

- How do the students' average test scores in the gamified classroom compare to those of students in the traditional classroom?
- Does the gamified approach have a larger impact on test performance with either the higher or lower block of students?

A "Feelings About Mathematics" survey was also administered to all Algebra 1 students receiving the gamification treatment at the beginning of the school year with 23 Likert Score questions. The same survey was subsequently administered at the end of the year to all Algebra 1 students (gamification and traditional groups. The data was analyzed to determine if there was a difference between students' attitude towards mathematics in the gamified classroom and the traditional classroom at the end of the school year and whether the gamified course opinions changed from the beginning of the school year to the end.

The results of this study indicate the following:

1. Students in the gamified group scored significantly higher on average test scores throughout the school year.
2. Students in the gamified group scored significantly higher on the knowledge, comprehension, and application sections of the tests. There was no difference between the two groups on the synthesis, analysis, and evaluation section.
3. Students in the gamified group had a more positive attitude about mathematics than they did at the beginning of the year.
4. At the end of the school year students in the gamified group had a more positive attitude about mathematics than the traditional group.

CHAPTER I

INTRODUCTION

Background of Study

Too often mathematics instruction focuses on rote drill, practice, and memorization facts (Lesser, 2000, p. 372) causing students to not have an inherent interest in mathematics. Specifically, the Algebra 1 proficiency levels have historically been low at Inspire. Data from the past three years indicate that in the 2010-2011 school year, 12% of Algebra 1 students were proficient or advanced, 10% in the 2011-2012 school year, and 29% in the 2012-2013 school year. Although there was a jump from 10% proficiency to 29% in one year, there was still room for improvement (California Department of Education, 2013a).

It is evident that many children and adults spend a great amount of time playing video games (Griffiths, 2002). One reason that kids love playing video games is that they "are learning a new interactive language that grants them access to virtual worlds that are filled with intrigue, engagement and meaningful challenges" (Levasseur, 2011).

Although video games can often have a negative connotation, evidence suggests that gaming can be beneficial. There are many reasons why gaming in education can be useful (Griffiths, 2002):

- Videogames attract participation by individuals across many demographic boundaries (e.g., age, gender, ethnicity, educational status)
- Videogames can assist children in setting goals, ensuring goal rehearsal, providing feedback, reinforcement, and maintaining records of behavioral change.
- Videogames can be useful because they allow the researcher to measure performance on a very wide variety of tasks, and can be easily changed, standardized and understood.
- Videogames can be used when examining individual characteristics such as self-esteem, self-concept, goal setting and individual differences.
- Videogames are fun and stimulating for participants.

Video games also reinforce to players that it is okay to be wrong and to try and try again. Sir Ken Robinson discusses in his TED talk, "How Schools Kill Creativity," that our educational system has stigmatized mistakes (Robinson, 2006). Our students are terrified of being wrong or making a mistake (Robinson, 2006). We must be prepared to be wrong, as it helps us come up with creative solutions or solve complex problems. Video games embed trial and error into the foundation of the game. (Levassaeur, 2011).

Statement of the Problem

Algebra 1 at the high school level is a course that has many different types of students enrolled. Some of these students are freshmen entering their first year of high school, who are eager and ready to learn. Some of these students are seniors who need the Algebra credit to graduate and are retaking the class for possibly their second or third time. For some students, the learning comes quickly and they are ready to keep moving

through the course. For others, it is very difficult and they are pushed to higher levels before they are ready. There is a wide range of experiences, abilities, and needs that students in Algebra 1 at the high school level bring with them. Regardless of their differences, students are expected to learn the same material and master the same concepts. Teaching and helping all students succeed is a challenging and requires differentiating instruction. Differentiated instruction is a method in which teachers structure the learning environment addressing a variety of learning styles, abilities, and interests in a classroom (Willoughby, 2005). Each student is somewhat unique and may need to move through the Algebra 1 curriculum at a different pace than their peers. Gamification is a way of differentiation that can be used in any classroom to promote learning at the right pace for each student.

This study examines the impact gamification in the Algebra 1 class has on student performance and motivation. It focuses on two research questions:

1. Does implementing the mastery learning model and gamification techniques into the classroom increase student achievement?
2. Does implementing the mastery learning model and gamification techniques into the classroom improve student engagement, motivation, and attitude toward mathematics?

Purpose of Study

The purpose of this study was to determine if implementing gamification techniques into an Algebra 1 class will increase student achievement and general disposition toward mathematics. The study began at the start of the fall semester 2013.

On the first day of school, students in the treatment group were introduced to gamification and given a description of how it would work in class.

Gamified Treatment

The Algebra 1 curriculum for the semester was broken into levels. Each level had a learning target consisting of two to three objectives. Objectives were written by the math department at Inspire based on the CPM curriculum, California state standards, and common core standards. A level does not correlate with a chapter or unit in the book. Each level had a set of tasks that the student must complete before taking the level test.

All levels and level tasks were outlined on the teacher website for students to view at their convenience. The following are level tasks:

- *Missions:* These are assignments that students must complete. They may be an assignment out of the textbook, a worksheet, etc.
- *Quest:* An exploration that students did in class. They had the option to work by themselves, with a partner, or with a group. Quests are student lead with the teacher as a facilitator.
- *Multi-Player Quest*: An exploration that must be done in groups or with a partner in class. Students were directed to the discussion board forum on the teacher's website to help them form groups or pairs.
- *Tutorial*: A screencast video that students can view to get information on the objective they are learning. This takes the place of the typical lecture. Some screencasts were created by other Algebra 1 teachers at Inspire, or consist of additional resources such as Khan Academy or YouTube.

- *Checkpoint*: A mini quiz that students could take online. These mini quizzes had a time limit, were multiple choice, and students could retake the quiz up to 3 times.
- *SubBoss*: A quiz that students took in class. This included prerequisite skills needed to learn the current objective. If a student did not pass the "SubBoss", then they were required to remediate and retake it.
- *BossBattle:* The test at the end of the level

The level test, *BossBattle*, was a set of questions based on the objective(s) for the level. Each level test was broken into four parts based on Blooms Taxonomy: Knowledge (0-1 points), Comprehension (0-2 points), Application (0-4 points), and Analysis/Synthesis/Evaluation (0-3 points). If a student got a score of a 7 or higher, they could move on to the next level. If the student received anything lower, they were required to remediate. Remediation consisted of extra practice and instruction. When ready, the student could retake a different version of the level test. The higher of the two test scores was used for the student's grade.

Students were able to move through the Algebra 1 course as quickly as they preferred. Students were not all working in the same level at the same time; therefore they were working on different tasks during class time. On any given day, some students were watching a *tutorial* on the computer, some were working on a *quest*, and others were fighting the *bossbattle*. Class started and ended everyday as a whole group. This time included whole class discussion, reflection and writing in their learning logs.

Students' grades in the class were dependent on how many Experience Points (XP) they achieved in the semester. Experience points were earned by completing

missions, quests, multi-player quests, tutorials, checkpoints, sub-bosses, and boss battles. Since students were moving at their own pace, there was a suggested pacing guide given to students by the teacher to help them plan their learning. Students would know before they started the level the last possible day that they could take the level test. If a student was still having difficulty completing all assignments during that time, they would work one-on-one during class with the teacher or a student aide that was also present in class. The student was also advised to come in during lunch or after school for additional support.

Control Group Treatment

The Algebra 1 sections that did not receive the gamification treatment took the same 16 exams throughout the semester. The exams from all of the classes were graded on a common rubric by any of the three Algebra 1 teachers. In the traditional classroom, students worked through the material of a given unit together with their class within the same time frame. They all took the exam at the end of the unit. The teacher graded the exam and the following day the class was split into two groups. The first group, being those students who were successful on the exam, did an enrichment activity. The other group that did not perform on the exam and received a grade less than 7 out of 10 remediated and retook a different version of the exam.

In the gamified classroom, students did not all take the exam on the same given day. They took the exam when they had completed all given assignments for the unit (level) and felt adequately prepared (or on the last possible date allowed). Some students took the exam before the traditional classes took it and some took it after. The teacher graded the exam and the following day if they needed to remediate, they would

do so and then retake a different version of the test. Students were not given an enrichment activity like the traditional class. Indeed, if they passed the exam, they moved on to the next level.

Definition of Terms

Gamification

The use of game mechanics, dynamics, and frameworks to promote desired behaviors, has found its way into domains like marketing, politics, health and fitness, with analysts predicting that it will become a multi-billion dollar industry by 2015 (MacMillan, 2011). Gamification is not the actual use of video games, rather using the techniques of video games to drive user behavior.

Mastery Learning Model

Mastery learning uses differentiated and individualized instruction, progress monitoring, formative assessment, feedback, corrective procedures, and instructional alignment to minimize achievement gaps (Bloom, 1971; Zimmerman & Dibenedetto, 2008).

Traditional Model

In this study, the traditional model refers to students in the two Algebra 1 classes who are not receiving the gamification as a treatment.

Blooms Taxonomy

A way of organizing levels of thinking in order to promote higher levels of thinking in education. There are six major categories that can be thought of as degree of difficulty:

- Knowledge: Recall data or information
- Comprehension: Understand the meaning, translation, interpolation, and interpretation of instructions and problems. State a problem in one's own words.
- Application: Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the classroom into novel situations in the work place.
- Analysis: Separates material or concepts into component parts so that its organizational structure may be understood. Distinguishes between facts and inferences.
- Synthesis: Builds a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure.
- Evaluation: Make judgments about the value of ideas or materials.

For this study, the analysis, synthesis, and evaluation categories have been grouped together.

California Standardized Test (CST)

The California Standardized Test (CST) is a state mandated test up through the school year 2012-2013 which measures a student's skills in English Language Arts and Mathematics and if their skills are at grade level. For this study, we will only be focusing on the math section.

Differentiated Instruction

A method in which teachers structure learning environments that address the variety of learning styles, interests, and abilities within a classroom.

CHAPTER II

LITERATURE REVIEW

What is Gamification?

Gamification is starting to become very popular all over the world and can be applied in most industries (MacMillan, 2011). Gamification, defined as the use of game mechanics, dynamics, and frameworks to promote desired behaviors, has found its way into domains like marketing, politics, health and fitness, with analysts predicting that it will become a multi-billion dollar industry by 2015 (MacMillan, 2011). Gamification is not the actual use of video games, rather using the techniques of video games to drive user behavior.

What Makes Games Motivating?

Games are designed for success otherwise they would not be played. They activate intrinsic motivation by offering clear (compelling, uncertain, desirable, worthwhile) goals combined with an intense and varied feedback system (McGonigal, 2011). Video games stimulate the development of mastery through leveling up, having challenges and tasks that adapt to the players skills and abilities. The tasks are not too hard where one would give up or too easy, where one is not challenged. This is what gets people to continue playing (Whyte, 2013).

People are engaged when their brain is rewarded which evokes positive emotions. Games give off a range of powerful emotions including wonder, curiosity, frustration, and joy that impacts a player's attention and facilitates learning (Lazarro, 2004). When learners participate in challenges at individual achievable levels, their brains give more effort and make them more responsive to feedback (Whyte, 2013)

Gamification in Education

Schools already have several game-like elements. Students get points for completing assignments, which transfer to a letter grade; which can be a badge in a game. Students are rewarded for positive behavior and if they perform well enough they "level-up" at the end of the academic year. With these features, it would appear that schools already have a gamified experience. However, "something about this environment fails to engage students… The default environment of schools often results in undesirable outcomes such as disengagement, cheating, learned helplessness, and dropping out" (Lee & Hammer, 2011). Video games, on the other hand create high engagement. *Angry Birds* has been downloaded over 200 million times (Kovach, 2011) and *Farmille 2* is played by about 8 million users a day only 6 months after its release (Bort, 2013).

Gamification attempts to capture the motivational power of games and apply it to real-world problems –such as, in our case, the motivational problems in schools. Motivation and engagement are major challenges for the American educational system (Bridgeland, Dilulio, & Morison, 2006).

Reasons to Gamify

Educators are realizing that students are not responding anymore to old-school lectures and are looking for something new and innovative that will engage all students. Educators are beginning to implement gamification because games are something that many people of all ages take interest in. The blog; "Best Practices: Gamify Your Class with Moodle" states five reasons to gamify the classroom (Hayman, 2013):

1. Engagement: Video games focus on quests, challenges, dungeons, levels, etc. that hold the student's attention while they are learning the content.

2. Safe Failure: Games teach students that failure is acceptable and they can try and try again until they master the level without any real-world penalty. The same is true in a gamified classroom. Students make mistakes and learn from it in the educational process. Students can retake a test or assignment until they master or complete it. The teacher's role is to guide student learning and offer constructive feedback.

3. Alternative rewards: Not all students are motivated by a letter grade in class or on their report card. In a gamified classroom, there is a different reward system such as experience points (XP), badges, achievement titles, leveling up, etc. that represents student achievement and learning. Knowledge, skills, achievement, and other learning accomplishments can be validated with rewards other than a letter grade.

4. Student choice: Students have a choice of what they can do within the context of a gamified classroom, which can motivate them. They have the opportunity to learn the content depending on their skill and move at their own pace. That being said, not all students will be on the same level, learning the same thing, at the same time.

5. Collaboration: Some students can have a difficult time working in groups in the classroom. This is mitigated when games have the aspects of working together in small groups, guilds, families, or houses in which they have similar goals and identify with each other.

Mastery Learning Model

Mastery learning uses differentiated and individualized instruction, progress monitoring, formative assessment, feedback, corrective procedures, and instructional alignment to minimize achievement gaps (Bloom, 1971; Zimmerman & Dibenedetto, 2008). The strategy is based on Benjamin Bloom's Learning for Mastery Model which incorporates differentiated instruction including remediation to increase student achievement. Bloom believed that nearly all students, when provided with the more favorable learning conditions of mastery learning, could truly master academic content (Bloom, 1976; Guskey, 1997a)

Teachers who use the mastery learning model determine important concepts and skills and organize them into smaller learning units requiring one to two weeks of instructional time. Following instruction, teachers use formative assessment to identify what students have learned and what they still need work on (Bloom, 1971). "In mastery learning, assessments are not a one-shot, do-or-die experience; instead, they are part of an ongoing effort to help students learn. It also serves as a powerful motivational tool by offering students a second chance to succeed" (Guskey, 2010).

Mastery Learning allows students to work at their own pace through the curriculum. When they complete a unit they must demonstrate that they have learned the

content by taking an exam (Overmyer, 2012). When students learning in the mastery model are compared with those in a traditional classroom, students in well-implemented mastery learning classes consistently reach higher levels of achievement (Guskey, 2010).

CHAPTER III

METHODOLGY

Design of Investigation and Treatment

This study focused on two questions:

1. Does implementing the mastery learning model and gamification techniques into the classroom increase student achievement?

- Does implementing the mastery learning model and gamification techniques into the classroom improve student engagement, motivation, and attitude toward mathematics?

The following tests were used to answer the first research question:

- Independent t-tests were performed to determine:
    - If there was a significant difference of performance on level tests of the students involved in the treatment compared to the students who were not involved in the treatment.
    - If there was a statistically significant difference between the average scores within each category of questions on the test between the gamified (treatment) and traditional groups.

To get at the second main question of this thesis we collected data regarding student perceptions and attitude.

A “Feelings about Mathematics” survey was administered to all Algebra 1 students receiving the gamified treatment at the beginning of the school year with 23 Likert Score statements. The same survey was subsequently administered at the end of the year to all Algebra 1 students. The questions on the survey explored students’ perceptions on mathematics; how much they enjoyed it, their difficulty with the subject, how important they thought it was, and how comfortable they are in a mathematics classroom. The students were asked to what extent they agree or disagree with each of 23 statements on a scale from 1 (“Strongly Disagree) to 5 (“Strongly Agree”). A high Likert score on questions 4, 5, 6, 7, 19, and 21 imply a negative attitude toward mathematics whereas for the other questions a high score implied a positive attitude. The Likert Scores for the 6 negative questions were reversed in order that high scores would consistently indicate a positive attitude. A score of 5- strongly agree was switched with a score of 1- strongly disagree. The same was done for a score of 2- agree and 4- disagree. A score of 3 did not change because it was neutral. A paired *t*-test was performed on each question of the survey to determine if the attitudes of students in the gamified course had changed from the beginning of the school year to the end. An independent *t*-test was also performed on each question of the survey to determine if there was an attitude difference at the end of the school year between students’ in the gamified classroom compared to those in the traditional classroom.

Sample

Eighty-five students participated in this study from the three total Algebra 1 classes at Inspire School of Arts and Sciences, a charter school within Chico Unified

School District. Inspire School has a population of about 440 students with the following breakdown. See Table 1.

Table 1

Student Groups by Percent

Group	Percent
Black or African American	2.9
American Indian or Alaska Native	1.3
Asian	1.8
Filipino	0.8
Hispanic or Latino	10.2
Native Hawaiian/Pacific Islander	0
White	78.5
Socioeconomically Disadvantaged	26.4

The curriculum used for all of the Algebra 1 classes at Inspire is College Preparatory Math (CPM), Core Connections Algebra. This curriculum was also used in the 2011-2012 school year and addresses the current California State Standards as well as the Common Core Algebra 1 standards. Each Algebra 1 course was taught by a different instructor. Students only participated in the study with permission forms signed by parents/guardians.

Data Collection

The data collection for this study was quantitative and taken over the entire 2013-2014 school year. All three Algebra 1 classes took the exact same exams throughout the year and also used the same curriculum and textbook. The exams were

created in collaboration by the three Algebra 1 teachers. Each student took a total of 16 exams throughout the year. Student performance was evaluated by comparing exam scores between the three classes using the common exams, and as an aggregate using overall exam averages. The exams were all scored consistently against the same rubric. Care was taken so that exam grading was independent of the teacher who did the scoring. The goal was to determine if there are significant differences in student performance between the two types of classes. See Figure 1.

	Exam #1 Average	Exam #2 Average	Exam #3 Average	Exam #4 Average	….	Exam #16 Average
Class # 1 (Treatment-Gamified)						
Class # 2 & 3 (No Treatment-Traditional)						

Figure 1. Data collection procedure.

These same exams were also be broken into four sections based on Blooms Taxonomy:

1. Knowledge
2. Comprehension
3. Application
4. Analysis, Synthesis, Evaluation

Each student had a knowledge score, comprehension score, application score, and analysis, synthesis, evaluation score on each exam. An overall score in each category was given by taking an average of all individual scores.

All students took a “Feelings about Mathematics” survey at the end of the school year. Students in the treatment (gamified) group also took the same survey at the beginning of the year. Analysis included looking at how scores differed from the beginning of the year to the end of the year within the treatment group only. Analysis was also done to compare end of the year scores between the traditional and treatment group. The data for each individual question was analyzed.

Data Analysis Procedures:

The following statistical analysis procedures were used in this study: paired *t*-tests, and independent *t*-tests.

Each Algebra 1 test consists of the following types of questions:

Knowledge (1 point)

Comprehension (2 points)

Application (4 points)

Analysis, Synthesis, Evaluation (3 points)

An independent *t*-test was used to determine if there is a difference between the average score within each category of the tests as well as the overall test averages. The following hypotheses were tested:

Hypothesis Test 1:

There is no difference in the overall mean test scores of students in the gamified classroom and students in the traditional classroom vs. the mean test score for the gamified students was greater than the mean for the traditional classroom students

$H_0: \mu_G = \mu_T$ G = mean test scores of students in the gamified Algebra 1 class (treatment).
$H_A: \mu_G > \mu_T$ T= mean test scores of students in the traditional Algebra 1 class.

(1)

Hypothesis Test 2:

There is no difference in mean knowledge scores between the gamified and traditional group vs. the gamified mean knowledge score was greater than the mean for the traditional students

$H_0: \mu_{GK} = \mu_{TK}$ GK= Gamified groups' knowledge score
$H_A: \mu_{GK} > \mu_{TK}$ TK= Traditional groups' knowledge score

(2)

Hypothesis Test 3:

There is no difference in mean comprehension scores between the gamified and traditional group vs. the mean comprehension score was greater for the gamified students than for the traditional students

$H_0: \mu_{GC} = \mu_{TC}$ GC= Gamified groups' comprehension score
$H_A: \mu_{GC} > \mu_{TC}$ TC= Traditional groups' comprehension score

(3)

Hypothesis Test 4:

There is no difference in mean application scores between the gamified and traditional group vs. the mean application score was greater for the gamified students than for the traditional students

$H_0: \mu_{GA} = \mu_{TA}$ GC= Gamified groups' application score
$H_A: \mu_{GA} > \mu_{TA}$ TC= Traditional groups' application score

(4)

Hypothesis Test 5:

There is no difference in mean analysis, synthesis, evaluation scores between the gamified and traditional group vs. the mean analysis, synthesis, evaluation scores are greater for the gamified students than for the traditional students

$H_0: \mu_{GS} = \mu_{TS}$
$H_A: \mu_{GS} > \mu_{TS}$

GC= Gamified groups' analysis, synthesis, evaluation score
TC= Traditional groups' analysis, synthesis, evaluation score

(5)

Hypothesis Test 1 helps answer the first research question. This test helps us determine if students in the treatment (gamified) group scored significantly higher when averaged overall sections of the level tests than those in the traditional group. If data support rejection of the null hypothesis, it will be concluded that students in the gamified group scored, on average, significantly higher on the level tests than students in the traditional group. If data also support rejection of any of the remaining null hypotheses, it will also be concluded that students in the gamified group scored, on average, significantly higher on the knowledge, comprehension, application, or analysis/synthesis/evaluation parts of each level test.

To address the second research question, each student in Algebra 1 took a survey with 23 Likert Scale questions at the end of the school year. Each of the 23 Likert Scale Choices were assigned a number. As explained earlier, some scores were reversed so that a 5 would always indicate a positive attitude toward mathematics.

1. Strongly Disagree
2. Disagree
3. Neutral

4. Agree
5. Strongly Agree

A paired *t*-test was used to determine if there was a difference of opinion at the beginning of the school year and the end of the school year within the gamified (treatment) group, under the assumption that the distribution of paired differences was normal. Each survey in the first sample (beginning of the year survey) was paired by student with the survey in the second sample (end of the year survey). The next three hypotheses were tested to answer the second research question regarding an improvement in students' motivation, engagement, and attitude toward mathematics of students in the gamified group.

Hypothesis Test 6:

There is no difference between survey scores at the beginning and the end of the year vs. the scores at the end of the year were higher than at the beginning of the year.

$H_0: \mu_d = 0$
$H_A: \mu_d > 0$

d=difference in survey scores at the beginning and end of the year where the difference = end score – beginning score

(6)

If data support null hypothesis 6 to be rejected, it will be concluded that student's in the gamified group had improved feelings about mathematics at the end of the school year than they did at the beginning of the school year.

An independent *t*-test determined if there was a difference in opinion at the end of the school year based on the "Feelings about Mathematics" survey between the gamified (treatment) group and the traditional group. The following hypothesis was tested:

Hypothesis Test 7:

There is no difference between the mean differences in opinion between the two groups vs. the gamified group had more positive feelings about mathematics than the traditional group.

$$H_0: \mu_{GL} = \mu_{TL} \qquad H_A: \mu_{GL} > \mu_{TL} \tag{7}$$

GL= Gamified groups' Likert survey score
TL= Traditional groups' Liker survey score

If data indicates rejection of null hypothesis 7, it will be concluded that students in the gamified group have more positive feelings about mathematics than those of students in the traditional group at the end of the school year.

An independent *t*-test was used to determine if there was a difference in opinion on each question on the "Feelings about Mathematics" survey between the gamified (treatment) group and the traditional group. The following hypothesis was tested:

Hypothesis Test 8:

There is no difference in opinion on each question between the two groups vs. the gamified group had more positive feelings on the question than the traditional group

$$H_0: \mu_{GQ} = \mu_{TQ} \qquad H_A: \mu_{GQ} > \mu_{TQ} \tag{8}$$

GQ= Gamified groups' individual score on each Likert question
TQ= Traditional groups' individual score on each Likert question.

If data allows null hypothesis 8 to be rejected, it will be concluded that students in the gamified group have more positive feelings about mathematics than those of the traditional group.

Anticipated Results

It was anticipated that the independent t-test would show that students in the gamified (treatment) group performed significantly higher than traditional students on the exams throughout the year. Within the independent *t*-test of average scores broken down by category, it was predicted that students in the gamified (treatment) group performed higher in knowledge, comprehension, application and analysis, synthesis, evaluation questions than traditional Algebra 1 students.

It was also expected that students in the gamified class had more positive opinions about mathematics and were more engaged than they were at the beginning of the school year based on the paired *t*-test of the "Feelings about Mathematics" survey.

Similarly, it was predicted that students in the gamified class would have more positive feelings about mathematics than students in the traditional class at the end of the school year based on the independent *t*-test.

Limitations

There are limitations in this study that should be considered:

- Algebra 1 is a course needed to graduate from high school. There is no guarantee that a homogeneous cross-section was enrolled in each course section. The assumption is that students were randomly distributed across the course sections. Since our school is small, it is possible that students were placed in each course section based on convenience of scheduling. This could have led to an unanticipated bias among students. For example, sophomores in Algebra 1 could have been placed in a specific section due to conflict with another sophomore level class needed.

- Although each section of Algebra 1 uses a common textbook, similar assignments, and the same exams, the three Algebra 1 classes were taught by three different teachers. By the nature of personality, it is assumed that each teacher conducted the class in a slightly different manner. However, the teachers planed lessons, quizzes, assignments, and tests together to make it as uniform as possible.
- The sample size was small. Inspire School of Arts and Sciences has a population of about 430 students. Because of this, there are only 3 Algebra 1 sections. This gave a total sample of 81 students.
- This was the first time that the teacher had done a gamified approach in Algebra 1 or any other class.

No pretesting was used to establish whether or not the one group or the other was better prepared to begin with. It was assumed that they were equally prepared.

CHAPTER IV

FINDINGS

RQ1

Does implementing the mastery learning model and gamification techniques into the classroom increase student achievement?

Null hypothesis 1 states that there is no difference in mean test scores between the gamified and traditional group. The alternative hypothesis states that the mean test score for the gamified group is larger than the mean test score of the traditional group.

$H_0: \mu_G = \mu_T$ G = average test scores of students in the gamified Algebra 1 class (treatment).
$H_A: \mu_G > \mu_T$ T= average test scores of students in the traditional Algebra 1 class. (9)

A two-sample t-test was done on the mean test scores for both groups assuming unequal variances. The test gave a *t*-statistic of 1.584 and a *p*-value of 0.0585. With this p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is not sufficient evidence to conclude there was a statistically significant difference between the mean test performances of the two groups with 95% confidence. However, we can be 94.15% confident that the mean test scores of students in the gamified group are significantly greater than the mean test scores of students in the traditional group. The average test score for the traditional group was 7.44, while the mean score for the gamified group was 7.837. See Table 2.

Table 2

t-Test: Two Sample Assuming Unequal Variances

	Gamified Average Score	Traditional Average Score
Mean	7.837	7.44
Standard Deviation	0.898	1.17
Observations	20	61
Pooled Standard Deviation		
Hypothesized Mean Difference	0	
df	41.92	
T Stat	1.584	
p-value	0.0585	

Null hypothesis 2 states that there is no difference in mean knowledge scores between the gamified and traditional group. The alternative hypothesis states that the mean knowledge scores for the gamified group is larger than the mean knowledge score of the traditional group. See Table 3.

$$H_0: \mu_{GC} = \mu_{TC} \qquad \text{GC= Gamified groups' knowledge score}$$
$$H_A: \mu_{GC} > \mu_{TC} \qquad \text{TC= Traditional groups' knowledge score} \tag{10}$$

A two-sample *t*-test was done on the mean knowledge scores for both groups assuming unequal variances. The test gives a *t*-statistic of 1.746 and a *p*-value of 0.0444. With this p-value and a significance level $\alpha = 0.05$, we reject the null hypothesis. We can conclude that there is a statistically significant difference between the mean test performances on the comprehension section of the two groups with 95% confidence. The mean comprehension score for the traditional group was 0.812, while the mean score for the gamified group was statistically higher at 0.8542.

Table 3

t-Test: Two Sample Assuming Unequal Variances

	Gamified Knowledge Score	Traditional Knowledge Score
Mean	0.8542	0.812
Standard Deviation	0.0932	0.102
Observations	21	61
Pooled Standard Deviation		
Hypothesized Mean Difference	0	
df	37.75	
T Stat	1.746	
p-value	0.0444	

Null hypothesis 3 states that there was no difference in mean comprehension scores between the gamified and traditional groups. The alternative hypothesis states that the mean comprehension score for the gamified group is larger than the mean comprehension scores of the traditional group. See Table 4.

$$H_0: \mu_{GC} = \mu_{TC} \qquad \text{GC= Gamified groups' comprehension score}$$
$$H_A: \mu_{GC} > \mu_{TC} \qquad \text{TC= Traditional groups' comprehension score} \tag{11}$$

mean score for the gamified group was 0.776. The traditional group's average comprehension test score was significantly lower, indicating that the traditional group was not able to perform at the same level as the gamified group with 95% confidence.

Null hypothesis 4 states that there is no difference in mean application score between the gamified and traditional groups. The alternative hypothesis states that the mean application score for the gamified group is larger than the mean application scores of the traditional group. See Table 5.

Table 4

t-Test: Two Sample Assuming Unequal Variances

	Gamified Comprehension Score	Traditional Comprehension Score
Mean	0.776	0.700
Standard Deviation	0.158	0.155
Observations	20	61
Pooled Standard Deviation		
Hypothesized Mean Difference	0	
df	31.88	
T Stat	1.87	
p-value	0.035	

$H_0: \mu_{GA} = \mu_{TA}$ GC= Gamified groups' application score
$H_A: \mu_{GA} > \mu_{TA}$ TC= Traditional groups' application score

(12)

Table 5

t-Test: Two Sample Assuming Unequal Variances

	Gamified Application Score	Traditional Application Score
Mean	**3.576**	**3.068**
Standard Deviation	0.639	0.453
Observations	20	61
Pooled Standard Deviation		
Hypothesized Mean Difference	0	
df	25.56	
T Stat	3.294	
p-value	0.0014	

A two-sample *t*-test was done on the mean application scores for both groups assuming unequal variances. The test gave a *t*-statistic of 3.30 and a *p*-value of 0.001. With this p-value and a significance level of $\alpha = 0.05$, we reject the null hypothesis. We can say with 95% confidence that the mean application score for the gamified group is significantly greater than the mean application score for the traditional group. The mean application score for the traditional group was 3.068, while the mean score for the gamified group was 3.576.

Null hypothesis 5 states that there is no difference in mean analysis, synthesis, evaluation scores between the gamified and traditional groups. The alternative hypothesis states that the mean analysis, synthesis, evaluation score for the gamified group is larger than the mean analysis, synthesis, evaluation score of the traditional group. See Table 6.

$H_0: \mu_{GS} = \mu_{TS}$ GC= Gamified groups' analysis, synthesis, evaluation score
$H_A: \mu_{GS} > \mu_{TS}$ TC= Traditional groups' analysis, synthesis, evaluation score

(13)

Table 6

t-Test: Two Sample Assuming Unequal Variances

	Gamified Synthesis Score	Traditional Synthesis Score
Mean	2.203	2.189
Standard Deviation	0.292	0.346
Observations	20	61
Pooled Standard Deviation		
Hypothesized Mean Difference	0	
df	37.97	
T Stat	0.1774	
p-value	0.4300	

A two-sample *t*-test was done on the mean analysis, synthesis, evaluation scores for both groups assuming unequal variances. The test gave a *t*-statistic of 0.1774 and a *p*-value of 0.4300. With this p-value and a significance level of $\alpha = 0.05$, we fail to reject the null hypothesis. There is not sufficient evidence to conclude that the mean gamified score is greater than the mean for the traditional group. The mean analysis, synthesis, evaluation score for the traditional group was 2.189, while the mean score for the gamified group was 2.203.

RQ2

Does implementing the mastery learning model and gamification techniques into the classroom improve student engagement and motivation?

Null hypothesis 6 states that there is no difference in the opinions or attitudes toward math of students between the beginning of the school year and the end of the school year after students have been exposed to the gamified treatment. The alternative hypothesis states that the opinions of students in the gamified group are more positive after they have been exposed to the gamified treatment for an entire year than at the beginning of the year. See Table 7.

$$\begin{aligned} H_0&: \mu_d = 0 \\ H_A&: \mu_d > 0 \end{aligned} \tag{14}$$

A paired *t*-test was applied using the totals from each student's survey at the beginning of the year and then at the end of the school year (difference = post – beginning). The test gave a t-statistic of 4.74 and a *p*-value of 0.0, causing a rejection of the null hypothesis. There is a statistically significant improvement between student

Table 7

paired t-Test

	Gamified Beginning Survey	Gamified Post Survey
Mean	70.21	88.64
Standard Deviation	8.24	8.88
Observations	15	15
Mean Difference (post-beginning)	18.43	14.55
df	14	
T Stat	4.74	
p-value	0.0	
95% Confidence Interval for Difference:	(10.03, 26.83)	

opinions at the beginning of the year and at the end of the year based on a Likert survey. The 95% confidence interval shows that the post survey scores are much higher than then the pre survey scores.

Null hypothesis 7 states that there is no difference in mean opinion at the end of the school year based on the "Feelings about Mathematics" survey between the gamified and traditional group. The alternative hypothesis states that the mean opinions of students in the gamified group at the end of the year are more positive than those of students in the traditional group. See Table 8.

$$H_0: \mu_{GL} = \mu_{TL} \qquad \text{GL= Gamified groups' Likert survey score}$$
$$H_A: \mu_{GL} > \mu_{TL} \qquad \text{TL= Traditional groups' Likert survey score} \tag{15}$$

A two-sample t-test was done on the average of total Likert survey scores for both groups assuming unequal variances. The test gave a *t*-statistic of 3.12 and a *p*-value of 0.002. With this p-value and a significance level $\alpha = 0.05$, we reject the null

Table 8

t-Test: Two Sample Assuming Unequal Variances

	Gamified Likert Survey Score	Traditional Likert Survey Score
Mean	87.9	77
Standard Deviation	12.3	12.4
Observations	17	12.4
Pooled Standard Deviation		
Hypothesized Mean Difference	0	
df	29	
T Stat	3.12	
p-value	0.002	
95% Confidence Interval for Difference:	(3.77, 18.12)	

hypothesis. We have sufficient evidence to conclude that opinions of students in the gamified group are statistically more positive than those of students in the traditional group. The average Likert score of students in the gamified group was 87.9 and the average score of students in the traditional group was 77.

Null hypothesis 8 states that there is no difference in mean attitude on each of the 23 questions between the two groups. See Table 9

$H_0: \mu_{GQ} = \mu_{TQ}$
$H_A: \mu_{GQ} > \mu_{TQ}$

GQ= Gamified groups' individual score on each Likert question
TQ= Traditional groups' individual score on each Likert question.

(16)

A two-sample *t*-test was done on the mean score for each of the 23 Likert Score Questions for both groups assuming unequal variances. Based on the *p*-values, it

Table 9

t-Test: Two Sample Assuming Unequal Variances on Multiple Questions

Question	*N*	Mean	StDev	*T*-Value	*p*-value	*DF*
G1	17	4.0	0.197	0.49	0.313	29
T1	45	3.889	0.804			
G2	17	3.529	0.874	1.48	0.074	36
T2	45	3.13	1.10			
G3	17	3.82	1.01	1.0	0.163	29
T3	45	3.53	1.04			
G4	17	1.88	1.05	2.85	0.004	30
T4	45	2.76	1.13			
G5	17	2.12	1.05	-1.51	.072	25
T5	45	2.556	0.918			
G6	17	1.941	0.748	-0.93	0.179	36
T6	45	2.156	0.952			
G7	17	1.882	0.781	2.14	0.020	32
T7	45	2.378	0.886			
G8	17	4.059	0.827	2.07	0.023	31
T8	45	3.553	0.918			
G9	17	3.882	0.928	2.59	0.007	34
T9	45	3.16	1.13			
G10	17	3.294	0.920	2.08	0.023	35
T10	45	2.71	1.14			
G11	17	3.588	0.870	3.20	.001	36
T11	45	2.73	1.10			
G12	17	3.647	0.786	3.10	.002	31
T12	45	2.933	0.863			
G13	17	3.59	1.62	0.61	0.274	27
T13	45	3.31	1.55			
G14	17	3.41	1.06	1.05	0.150	29
T14	45	3.09	1.10			
G15	17	3.18	1.13	0.79	0.219	24
T15	45	2.933	0.939			
G16	17	3.71	1.05	1.70	.050	28
T16	45	3.20	1.04			
G17	17	3.882	0.928	2.35	0.013	31
T17	45	3.24	1.03			
G18	17	4.06	1.20	0.92	0.182	25
T18	45	3.76	1.03			
G19	17	2.412	0.618	2.93	0.003	48
T19	45	3.04	1.04			
G20	17	3.88	1.27	0.84	0.205	22
T20	45	3.60	0.915			
G21	17	2.176	0.728	2.66	0.006	37
T21	45	2.778	0.951			
G22	17	4.529	0.717	2.09	0.022	36
T22	45	4.067	0.915			
G23	17	4.294	0.772	2.18	0.018	36
T23	45	3.778	0.974			

was concluded that the students in the Gamified Group have a significantly improved attitude on the following statements:

#4: Math makes me feel uncomfortable.

#7: It makes me nervous to think about having to do a math problem.

#8: I am able to solve math problems without too much difficulty.

#9: I expect to do well in any math class I take.

#10: I have usually enjoyed studying mathematics in school.

#11: I have a lot of self-confidence when it comes to mathematics.

#12: I like to solve new problems in mathematics

#16: I believe studying math helps me problem solve in other areas

#17: I am comfortable answering questions in class.

#19 I get worried I will be called on in math class.

#21 I understand what is taught during math class, but forget it when I come home.

#22: It helps when my teacher demonstrates how to do the math.

#23: It helps when I can practice working out the math.

There is not a statistically significant difference on the following statements:

#1: Mathematics is a very worthwhile and necessary subject.

#2: I get a great deal of satisfaction out of solving a math problem.

#3: Math is important in everyday life.

#5: My mind goes blank and I am unable to think clearly when working with mathematics.

#6: I am always under a terrible strain in a math class.

#13: I prefer to do a math assignment than write an essay.

#14: I really like mathematics.

#15: I like the challenge of mathematics

#18: A strong math background could help me in my professional life.

#20: It helps me understand math when I can talk about it with others

CHAPTER V

DISCUSSION

Initial Findings

The results of this study indicated that implementing gamification with the mastery learning model into the Algebra 1 classroom increased student achievement. The two-sample *t*-test in Table 2 showed that we can be 94.15% confident that the mean test scores in the gamified group were significantly higher than those of the traditional group. Not only did the students in the gamified group score significantly higher on average test scores than the traditional group, but they also scored higher on three out of four individual sections of the test. Each test was broken into the four sections: Knowledge, Comprehension, Application, and Analysis/Synthesis/Evaluation. The two-sample *t*-tests in Tables 3, 4, and 5 showed that students in the gamified group scored significantly higher on the knowledge, comprehension, and application sections of each test. There was not a statistically significant difference on the analysis/synthesis/evaluation section of the test. With this evidence we conclude that students in the gamified group had higher levels of thinking in three of the major categories of Bloom's Taxonomy. These students can recall data or information and understand the meaning, translation, interpolation, and interpretation of instructions and problems better than students in the traditional group. The gamified group can better state a problem in their own words. These students can

also apply what they know about a certain algebraic or mathematical concept to a new situation or problem.

Students benefited the most in the knowledge and comprehension sections. The students were given as much time as they needed to understand the basic skills of a topic. The knowledge and comprehension skills are needed when doing application and analysis/synthesis/evaluation. Gamification also helped students in application. Once they had a solid foundation of the basic skills in the knowledge and comprehension categories, they were able to apply it to real world contexts. Gamification did not conclusively improve learning in the area of analysis/synthesis/evaluation. It is not easy to explain why no significant improvement occurred in this area as opposed to all of the others. One reason for this may be that it incorporates prior knowledge to answer more difficult questions. This prior knowledge is more than just what they have learned in this course, but also information and skills they may have previously acquired in mathematics and other disciplines. Adjustments in the gamification structure will be made that specifically target this component of learning. For example, there will be certain days in class where students will all be doing the same task. The tasks will be outlined for them ahead of time within the level objectives. These tasks will be inquiry type investigations and a class discussion will occur. With more inquiry and whole class discussion, hopefully analysis/synthesis/evaluation scores will improve.

This study also provides evidence to answer the second research question. Implementing gamification with the mastery learning model into the Algebra 1 classroom improved student engagement, motivation, and attitude toward mathematics. Students in the gamified group took the same “Feelings about Mathematics” survey at the beginning

of the school year and the end of the school year. The results of the paired t-test in Table 7 show that there was a significant improvement in student attitude and feelings about mathematics from the beginning to the end of the school year. We are 95% confident that post scores increased anywhere from 10.03 to 26.83 points on average.

Students in the traditional group took the same survey but only at the end of the year. They did not take the survey at the beginning of the course. The results of the two-sample *t*-test in Table 8 show that the students in the gamified group had a significantly more positive attitude toward mathematics than those from the traditional group. Each question on the survey was analyzed between the two groups at the end of the year. The results in Table 9 show that students in the gamified group were more engaged and held a more positive attitude toward mathematics than students in the control group. Data analysis shows that students in the gamified course have greater self-confidence when it comes to math; they enjoy learning about math in school, they like solving new problems in mathematics, and they are more comfortable answering questions in math class than students in the control group. The results also show that students in the gamified group do not feel as uncomfortable with math as students in the traditional group, they do not get as nervous when thinking about doing a math problem, and they are not as worried that they are going to get called on in class.

As pointed out earlier, April Hayman provides five reasons to gamify the classroom; engagement, safe failure, alternative rewards, student choice, and collaboration (Hayman, 2013). The researcher felt that the improved attitudes could relate directly to engagement and safe failure. Gamification in the Algebra 1 classroom provides immediate student engagement. Because students could work at their own pace,

the more advanced students were never bored. They always had a task to be working on and if they finished early, they could move to the next task. In contrast, the student in the traditional Algebra class who finished a class activity early could be left with down time while waiting for the rest of the class to complete an activity.

The students in particular who struggled more in the gamified class likely felt safe failure as predicted by Hayman. The students who were at lower levels or worked slower than a majority of the class did not feel the extra pressure to keep moving forward. They were allowed the time to fully understand and grasp the material before moving on. If they didn't pass a test the first time around, they could always retake it. They also never experienced that moment in class where the teacher handed back all of the tests and the student who failed looked around feeling ashamed of himself, wondering if everyone knew he had failed. Since the students took each test when they were ready, they did not all take the test at the same time. The test was graded almost immediately after they took it and the student got instant one on one feedback.

After implementing one year of gamification and the mastery model in an Algebra 1 classroom, several adjustments were planned for the future to improve the program. Other adjustments were made as the class progressed. For example, although it was not originally anticipated that the teacher would impose a final deadline to complete each level, the teacher did so on a few occasions. Having a concrete deadline helped students who were the most behind with time management. In the future, the classroom teacher will give a final deadline to complete each level. The deadline will still allow students an appropriate amount of time to complete each level, and at the same time provide more leeway than a traditional Algebra 1 class.

Another finding observed by the researcher besides the increase in student achievement and an improvement of student engagement was also an increase in the number of assignments that students in the gamified classroom completed. Students were required to do all of the assignments in a given level before taking the level test and moving forward. Because of this policy, students completed more work and seemed to use their time more productively than in the traditional treatment.

Although gamified students were completing more assignments, it was observed that they may not have been doing as much homework as expected. Because the students were not given a specific homework assignment each night that was graded immediately, students often worked their hardest in class but not necessarily at home. In the future, to help increase the amount of work students do at home, they will be given a goal sheet to help monitor their progress. Each day when a student walks into class they will fill out what their goal for the day is and what they would like to complete. At the end of the class period, they will indicate if they completed their goal, and if not, they will briefly explain. Finally, they will state what they plan to do for homework. The teacher will check the goal sheets daily. If students do not do what they assigned themselves for homework, they will not receive participation points. If a student often fails to complete assignments they will be required to attend a math support session during their lunch period at school.

As a result of the findings for this study, all math teachers at Inspire School of Arts and Sciences have decided to implement gamification into their Algebra 1 classroom. The same model that the researcher used in this study will be used with some of the accommodations mentioned above to improve the program. The implementation of

gamification will be strongly considered for other math courses as the school moves into the new Common Core curriculum within the next couple of years.

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APPENDIX A

“Feelings about Mathematics” Survey Given at Beginning and End of School Year

	Question:	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
1	Mathematics is a very worthwhile and necessary subject.					
2	I get a great deal of satisfaction out of solving a math problem.					
3	Math is important in everyday life.					
4	Math makes me feel uncomfortable.					
5	My mind goes blank and I am unable to think clearly when working with mathematics.					
6	I am always under a terrible strain in a math class.					
7	It makes me nervous to think about having to do a math problem.					
8	I am able to solve math problems without too much difficulty.					
9	I expect to do well in any math class I take.					
10	I have usually enjoyed studying mathematics in school.					
11	I have a lot of self-confidence when it comes to mathematics.					
12	I like to solve new problems in mathematics					
13	I prefer to do a math assignment than write an essay.					
14	I really like mathematics.					
15	I like the challenge of mathematics					
16	I believe studying math helps me problem solve in other areas					
17	I am comfortable answering questions in class.					
18	A strong math background could help me in my professional life.					
19	I get worried I will be called on in math class.					
20	It helps me understand math when I can talk about it with others					
21	I understand what is taught during math class, but forget it when I come home.					
22	It helps when my teacher demonstrates how to do the math.					
23	It helps when I can practice working out the math.					

APPENDIX B

CONSENT LETTER

Dear Parent or Guardian,

Your child's class is being asked to participate in a voluntary research survey. The purpose of the survey is to determine students' reactions to the gamified classroom experience. All questions relate to teaching practices, and no personal questions will be asked. There are no foreseeable risks or discomforts to the participants. A copy of the survey will be available in the school office.

The survey will be administered in your child's Algebra 1 class towards the end of the 1st semester. The survey will take a portion of the class period. If your child does not return his/her permission slip, he/she will not be able to participate. Each child's participation is voluntary. There is no penalty for non-participation. Students not participating in the survey will be given an alternate activity while the survey is being administered.

All information gathered will be strictly confidential. Surveys will only be viewed by me, the researcher. Follow-up interviews will be conducted for selected participants solely for the purpose of gaining further understanding to survey responses.

Data for this survey will be used in a master's thesis at Chico State University. If you have any further questions, please contact me at kraymond@chicousd.org.

Please sign the bottom of this page and have your child turn it in during Algebra 1 class. Thank you very much for your cooperation.

Sincerely,

Katie Raymond
Mathematics Teacher
Inspire School of Arts and Sciences
www.raymondsclass.com

I have read the above information and understand that my student,
_____, is being invited to participate in the above study.
_____ I DO give permission for my student to participate
_____I DO NOT give permission for my student to participate

_____ _____ _____
Parent/Guardian Signature Student Signature Date

APPENDIX C

Data Collection Part 1 For Treatment (Gamified) Group

	Knowledge	Comprehension	Application	Synthesis
Student 1	0.896212121	0.83974359	3.836	2.238461538
Student 2	0.88548951	0.746153846	2.993333333	1.8
Student 3	0.762563131	0.551282051	2.98	2.438461538
Student 4	0.829487179	0.814102564	4.22	2.369230769
Student 5	0.830128205	0.916666667	2.85	2.226923077
Student 6	0.861538462	0.903846154	3.566666667	2.1875
Student 7	0.896212121	0.908974359	4.033333333	2.415384615
Student 8	0.858333333	0.804166667	2.776923077	1.916666667
Student 9	0.961174242	0.967948718	4.116666667	1.895833333
Student 10	0.977564103	0.35	2.527777778	2.046153846
Student 11	0.636363636	0.825	4.276923077	2.363636364
Student 12	0.894230769	0.833333333	2.721428571	1.607692308
Student 13	0.844155012	0.933333333	4.186666667	2.546153846
Student 14	0.844871795	0.807692308	4.420833333	2.39
Student 15	0.9125	0.897435897	3.056666667	2.446153846
Student 16	0.867365967	0.891025641	4.133333333	2.619230769
Student 17	0.8504662	0.576923077	3.163333333	2.373076923
Student 18	0.645454545	0.692307692	3.873333333	1.838461538
Student 19	1	0.647222222	4.375	1.855
Student 20	0.929166667	0.619047619	3.4245	2.48

	Average	CST Block
Student 1	8.234615385	High
Student 2	7.026923077	Low
Student 3	6.357692308	NA
Student 4	8.180769231	NA
Student 5	7.788461538	High
Student 6	7.661538462	High
Student 7	8.573076923	High
Student 8	8.4375	High
Student 9	5.25	NA
Student 10	9.007692308	NA
Student 11	8.277272727	High

Table Continued

	Average	CST Block
Student 12	7.783333333	NA
Student 13	8.307692308	High
Student 14	8.27	High
Student 15	7.653846154	Low
Student 16	8.484615385	NA
Student 17	6.912307692	Low
Student 18	7.642307692	Low
Student 19	7.954545455	High
Student 20	8.941666667	High

Data Collection Part 2 for Treatment (Gamified) Group

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
Student 1	4	3	3	3	4	3	3	2	4	4	2	4	1	3	1
Student 2	3	4	4	2	3	2	2	4	3	2	3	4	1	3	2
Student 3	3	4	3	2	2	2	1	3	3	3	3	3	5	3	3
Student 4	4	2	4	2	2	3	3	4	3	3	3	3	3	2	3
Student 5	4	3	3	1	3	3	3	3	2	2	2	2	1	1	1
Student 6	4	3	4	2	2	2	2	4	4	4	4	4	4	3	3
Student 7	5	5	5	5	4	3	1	5	4	4	5	5	5	5	5
Student 8	3	3	1	1	1	1	1	5	5	5	4	3	5	3	3
Student 9	5	4	4	2	1	2	2	4	5	4	4	4	2	5	4
Student 10	4	3	4	3	3	2	3	4	5	3	4	4	5	4	3
Student 11	3	2	4	1	2	2	2	4	4	3	4	4	2	3	4
Student 12	5	4	4	1	1	1	1	5	3	3	3	3	5	4	4
Student 13	5	5	5	1	1	1	1	5	5	5	5	5	5	5	5
Student 14	4	4	4	1	1	2	2	4	4	3	4	3	4	3	4
Student 15	5	3	5	1	1	1	2	5	4	2	4	3	5	4	3
Student 16	3	4	3	2	2	1	1	4	5	3	4	4	5	4	3
Student 17	4	4	5	2	3	2	2	4	3	3	3	4	3	3	3

	#16	#17	#18	#19	#20	#21	#22	#23
Student 1	4	3	4	3	5	2	4	3
Student 2	3	4	1	2	4	3	4	4
Student 3	3	4	4	2	5	2	5	5
Student 4	3	3	5	3	3	3	5	4
Student 5	3	2	4	3	3	3	3	3
Student 6	3	3	3	2	4	2	4	4
Student 7	5	5	5	3	1	3	5	5
Student 8	1	4	2	3	1	1	5	5
Student 9	5	5	5	2	5	3	5	5
Student 10	4	3	3	3	5	2	5	5
Student 11	4	4	5	2	4	2	5	4
Student 12	4	3	5	3	5	1	5	5
Student 13	5	5	5	1	5	1	5	5
Student 14	4	4	4	2	4	2	4	4
Student 15	5	5	5	2	4	2	5	4
Student 16	4	4	4	2	4	2	5	5
Student 17	3	5	5	3	4	3	3	3

APPENDIX D

Data Collection Part 1 for Traditional Group

	Knowledge	Comprehension	Application	Synthesis
Student 1	0.899242424	0.784848485	3.14545455	2.51
Student 2	0.731404959	0.605769231	2.26363636	2.015909
Student 3	0.788842975	0.490384615	2.55833333	1.889583
Student 4	0.87037037	0.700757576	3.42	2.5625
Student 5	0.577651515	0.497222222	2.68888889	1.538889
Student 6	0.740909091	0.622222222	3.29	2.3725
Student 7	0.696280992	0.548076923	2.17272727	2.136364
Student 8	0.803030303	0.608974359	3.33	2.045455
Student 9	0.847727273	0.596153846	3.44	2.545
Student 10	0.996280992	0.703846154	3.4	1.972727
Student 11	0.818181818	0.326923077	2.2875	1.71875
Student 12	0.784090909	0.520833333	2.67142857	1.828125
Student 13	0.894570707	0.815972222	3.6	2.425
Student 14	0.683712121	0.347222222	2.5125	1.75
Student 15	0.825126263	0.66025641	2.71923077	1.384615
Student 16	0.768065268	0.695512821	3	2.319231
Student 17	0.576806527	0.474358974	2.06923077	1.169231
Student 18	0.839646465	0.81474359	3.36666667	2.2125
Student 19	1	0.730769231	3.23636364	2.727273
Student 20	0.904356061	0.638888889	3.625	2.454545
Student 21	0.847796143	0.855769231	3.44545455	2.704545
Student 22	0.66017316	0.409722222	2.51666667	2.142857
Student 23	0.866792929	0.742948718	3.70833333	2.466667
Student 24	0.761655012	0.639102564	2.62307692	2.023077
Student 25	0.902146465	0.772435897	3.62727273	2.491667
Student 26	0.825174825	0.826923077	2.70769231	2.076923
Student 27	0.782051282	0.841666667	3.03846154	2.230769
Student 28	0.922979798	0.858974359	3.49166667	2.225
Student 29	0.781313131	0.822222222	2.91666667	2.108333
Student 30	0.756410256	0.554487179	3.03076923	2.00625
Student 31	0.920454545	0.897435897	3.57083333	2.45
Student 32	0.819949495	0.685897436	3.1125	2.45
Student 33	0.77972028	0.762820513	2.71818182	2.363636

Table Continued

	Knowledge	Comprehension	Application	Synthesis
Student 34	0.864801865	0.801282051	3.35	2.108333
Student 35	0.807692308	0.823717949	3.15	1.991667
Student 36	0.791666667	0.583333333	2.92083333	2.383333
Student 37	0.864685315	0.740384615	3.59545455	2.277273
Student 38	0.978535354	0.857692308	3.34583333	2.608333
Student 39	0.77979798	0.717948718	3.60454545	2.445455
Student 40	0.89957265	0.891666667	3.12777778	1.755556
Student 41	0.619463869	0.820512821	3.05	2.570833
Student 42	0.893356643	0.432692308	2.17916667	1.533333
Student 43	0.826430976	0.840277778	3.66666667	2.266667
Student 44	0.817866162	0.529861111	2.74444444	2
Student 45	0.961538462	0.492424242	3.01428571	1.9
Student 46	0.713498623	0.804487179	3.24583333	2.366667
Student 47	0.925505051	0.701388889	3.505	2.555
Student 48	0.731157731	0.923611111	3.45	2.477273
Student 49	0.873737374	0.698717949	2.90416667	1.883333
Student 50	0.967365967	0.83974359	3.27083333	2.066667
Student 51	0.846736597	0.929487179	3.05833333	2.391667
Student 52	0.854895105	0.878205128	3.66666667	2.275
Student 53	0.86013986	0.903846154	3.2875	2.575
Student 54	0.951631702	0.833333333	3.46666667	2.545833
Student 55	0.6121633	0.858974359	3.82272727	2.833333
Student 56	0.788510101	0.487179487	2.39090909	1.772727
Student 57	0.777146465	0.480769231	2.4	1.763636
Student 58	0.669386169	0.769230769	2.61363636	1.922727
Student 59	0.771173271	0.666666667	3.33181818	2.375
Student 60	0.83270202	0.75	3.05	2.333333
Student 61	0.583333333	0.8125	2.62	2.23

	Average	CST Block
Student 1	7.472727273	Low
Student 2	6.668181818	Low
Student 3	6.422727273	NA
Student 4	9.416666667	NA
Student 5	5.325	Low
Student 6	8.19	High
Student 7	6.077272727	NA

Table Continued

	Average	CST Block
Student 8	7.377272727	NA
Student 9	8.14	Low
Student 10	8.231818182	High
Student 11	5.9	Low
Student 12	6.8125	Low
Student 13	8.429166667	Low
Student 14	5.575	Low
Student 15	5.653846154	Low
Student 16	7.469230769	NA
Student 17	4.865384615	Low
Student 18	8.0375	Low
Student 19	8.927272727	High
Student 20	7.565	Low
Student 21	8.804545455	High
Student 22	5.133333333	High
Student 23	8.6125	NA
Student 24	6.523076923	Low
Student 25	8.654166667	Low
Student 26	7.484615385	Low
Student 27	8	High
Student 28	8.8	Low
Student 29	7.4	NA
Student 30	7.459090909	NA
Student 31	8.472727273	NA
Student 32	9	High
Student 33	7.395454545	NA
Student 34	8.25	NA
Student 35	6.990909091	Low
Student 36	7.459090909	NA
Student 37	8.165	NA
Student 38	8.272727273	Na
Student 39	7.872727273	Low
Student 40	7.63125	NA
Student 41	8.222727273	Low
Student 42	5.345454545	Low
Student 43	8.790909091	Low
Student 44	6.275	NA
Student 45	6.114285714	NA
Student 46	8.222727273	NA
Student 47	7.081818182	Low
Student 48	8.71	High

Table Continued

	Average	CST Block
Student 49	6.931818182	NA
Student 50	7.913636364	Low
Student 51	8.431818182	Low
Student 52	8.081818182	NA
Student 53	8.495454545	Low
Student 54	8.586363636	High
Student 55	8.909090909	NA
Student 56	5.727272727	NA
Student 57	6.340909091	NA
Student 58	6.913636364	NA
Student 59	8.009090909	NA
Student 60	6.477777778	NA
Student 61	5.0875	High

Data Collection Part 2 for Traditional Group

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
Student 1	4	5	5	3	3	3	4	3	3	3	1	3	4	3	3
Student 2	5	4	5	1	3	3	3	4	3	3	3	3	4	3	3
Student 3	3	1	1	1	2	1	1	3	3	5	5	2	5	3	2
Student 4	4	3	3	3	4	4	3	3	2	2	3	3	2	2	2
Student 5	4	3	4	3	3	2	1	3	2	1	4	3	3	2	4
Student 6	4	4	5	1	1	1	1	4	4	3	4	3	5	3	3
Student 7	5	4	3	1	2	1	2	4	4	4	4	3	3	3	3
Student 8	5	3	5	2	1	1	1	4	3	3	4	4	5	3	3
Student 9	3	3	4	3	2	2	2	4	5	3	2	4	5	4	3
Student 10	4	3	3	2	2	2	2	4	4	3	3	4	3	5	4
Student 11	4	3	4	4	2	2	3	4	3	2	2	3	3	2	3
Student 12	4	3	3	4	2	3	2	3	3	4	1	3	3	3	3
Student 13	4	4	4	5	3	3	4	1	1	1	1	1	1	1	3
Student 14	3	3	3	4	3	3	2	4	3	1	1	3	4	2	3
Student 15	3	4	4	2	2	2	2	4	4	4	4	4	4	4	4
Student 16	5	3	4	1	4	2	2	4	3	2	3	4	5	4	3
Student 17	4	5	3	4	4	3	3	2	3	4	3	4	5	5	5
Student 18	3	4	2	2	2	2	2	4	3	3	4	3	1	4	3
Student 19	3	2	3	4	4	4	4	2	1	1	1	1	1	1	1
Student 20	4	5	4	3	2	3	3	3	5	4	3	4	3	4	3
Student 21	5	4	3	2	2	1	2	4	5	4	4	3	5	4	4
Student 22	4	4	5	4	3	3	3	3	2	2	2	2	4	2	2
Student 23	5	4	4	1	3	1	1	3	4	5	3	4	5	5	4
Student 24	4	3	2	4	4	3	3	4	2	2	2	4	1	5	5
Student 25	4	3	3	3	4	2	2	3	4	1	2	2	5	3	3
Student 26	5	4	4	2	3	5	3	2	2	3	2	3	5	4	3
Student 27	3	2	1	3	3	2	4	3	3	2	3	2	1	3	2
Student 28	3	2	4	3	2	2	3	4	4	3	3	2	1	2	2
Student 29	3	1	3	3	2	2	2	5	4	1	3	2	4	3	1
Student 30	3	2	3	5	3	2	3	4	1	2	1	2	1	1	4
Student 31	2	1	3	3	2	2	2	4	3	2	3	2	3	2	2
Student 32	4	3	4	3	2	2	2	4	4	3	2	3	2	3	3
Student 33	4	3	3	2	4	3	3	2	3	2	2	2	3	2	2
Student 34	3	1	4	3	3	2	3	2	1	3	2	3	2	3	3

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
Student 35	4	3	3	2	2	1	2	3	3	4	3	3	4	3	3
Student 36	3	2	3	5	4	3	4	3	2	1	1	3	1	1	3
Student 37	5	3	5	1	1	1	1	5	5	5	5	3	1	5	3
Student 38	4	4	5	3	2	1	2	5	5	3	4	3	5	3	3
Student 39	5	2	5	2	3	2	3	4	2	2	3	3	5	3	2
Student 40	4	3	4	2	1	1	1	5	3	2	3	4	5	4	3
Student 41	3	3	2	4	3	1	3	4	3	2	2	3	5	3	1
Student 42	5	5	5	3	3	3	2	5	5	3	4	3	5	4	3
Student 43	3	3	3	2	2	1	2	4	3	2	3	2	3	3	2
Student 44	5	2	3	3	1	2	2	4	3	3	2	2	1	3	3
Student 45	4	5	3	3	2	2	2	4	4	4	3	5	3	4	5

	#16	#17	#18	#19	#20	#21	#22	#23
Student 1	3	1	4	5	3	4	5	4
Student 2	4	4	4	3	4	3	4	4
Student 3	1	5	1	1	2	2	3	3
Student 4	3	3	2	3	3	4	4	4
Student 5	2	3	1	3	3	3	3	3
Student 6	3	4	4	2	4	1	5	5
Student 7	3	2	5	5	4	3	5	4
Student 8	5	4	4	2	4	1	3	5
Student 9	4	4	4	3	5	2	5	5
Student 10	3	4	4	2	4	2	1	1
Student 11	3	3	5	4	3	3	2	2
Student 12	5	3	4	3	5	3	5	4
Student 13	4	3	5	5	4	3	4	4
Student 14	3	1	3	5	4	4	3	2
Student 15	3	3	4	3	4	2	4	4
Student 16	5	3	4	3	3	4	4	4
Student 17	3	2	4	5	4	5	5	4
Student 18	3	4	4	2	4	2	5	5
Student 19	2	1	1	4	2	3	3	3
Student 20	4	3	4	3	5	3	5	5
Student 21	3	5	4	1	5	2	4	4
Student 22	4	4	5	3	4	3	4	4
Student 23	3	3	4	2	4	3	5	3

Table Continued

	#16	#17	#18	#19	#20	#21	#22	#23
Student 24	5	5	4	3	3	2	3	2
Student 25	2	3	4	4	5	3	4	4
Student 26	4	2	4	5	3	2	5	5
Student 27	3	3	3	3	3	3	3	3
Student 28	2	4	3	3	1	3	5	4
Student 29	2	2	4	3	3	3	4	3
Student 30	1	5	3	3	3	5	4	3
Student 31	2	3	3	3	4	2	4	4
Student 32	4	4	5	2	3	2	4	5
Student 33	4	3	4	3	4	3	4	4
Student 34	3	4	5	3	4	4	4	3
Student 35	3	3	4	3	3	2	5	5
Student 36	2	2	4	4	4	4	4	4
Student 37	5	5	5	1	4	2	4	4
Student 38	3	3	4	3	3	1	4	3
Student 39	4	3	4	2	3	2	4	3
Student 40	3	3	4	3	2	3	3	3
Student 41	3	3	4	3	4	2	5	4
Student 42	5	4	5	3	5	3	5	5
Student 43	2	4	4	3	3	3	5	3
Student 44	3	3	2	2	3	4	5	5
Student 45	3	3	3	3	5	2	4	5

APPENDIX E

Level Tests

Level 2 Test
Level 2 retest
Level 3 Test
Level 3 retest
Level 4 Test
Level 4 retest
Level 5 Test
Level 5 retest
Level 6 Test
Level 7 Test
Level 7 retest
Level 8 Test
Level 8 retest
Level 9 Test
Level 9 retest
Level 10 Test
Level 10 retest
Level 11 Test
Level 12 Test
Level 12 retest
Level 14 Test
Level 14 retest

Level 2 Test: Function Notation

Learning Targets:

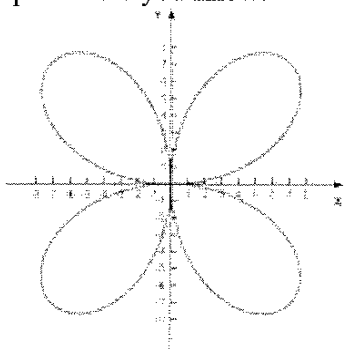
Understand and correctly interpret function notation & Find inputs and outputs of functions.

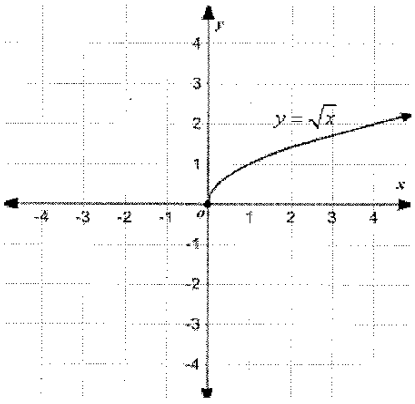
Knowledge

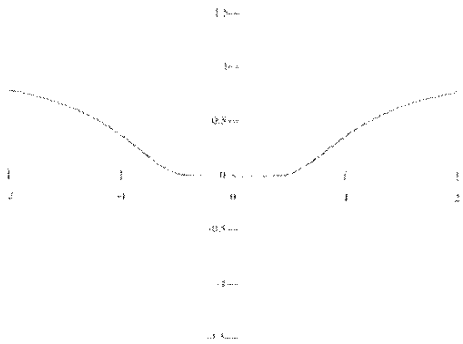
1. Given the function machine below what is the value of $x = 3$ $\downarrow$ $f(x) = x^2 - 2x$ $\downarrow$ $f(3) = ?$	2. $f(x) = \lvert x - 10 \rvert$ If 2 is the input of the function above, what is the output?

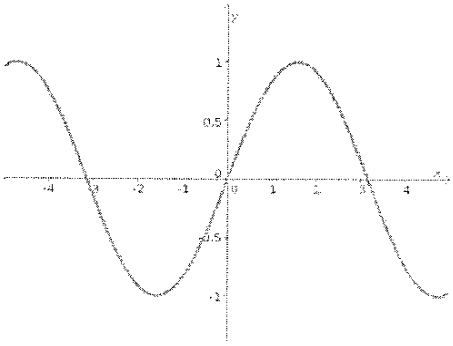
Comprehension

3. Examine each graph below. State whether the graph is or is not a function. If it is not a function explain how you know.









Application

4. If $x = 3$ create a function that produces an output of -8.

5. The area for any square is given by the function $f(x) = x^2$, where x is the length of a side of the square. Use function notation to find the area of a square with a side length of 3.5 inches. (Include units in your answer).

Analysis/Synthesis/Evaluation

6. Completely fill out the table below so that the data DOES NOT represent a function.

x	y

7. Sketch a graph that fits each description.

a. A graph that passes through all four quadrants and represents a function.

b. A graph that passes through all four quadrants and does not represent a function.

c. A graph that passes through Quadrants 1, 2, & 3 only and represents a function.

d. A graph that passes through Quadrants 1, 2, & 3 only and does not represent a function.

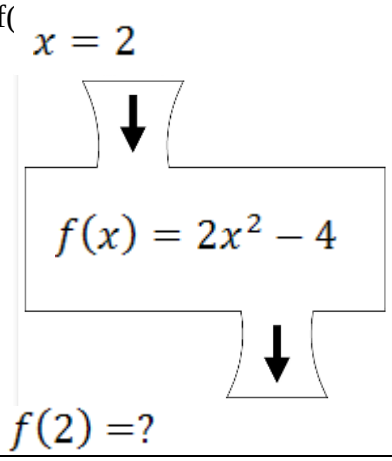
Level 2 Re-Test: Function Notation

Learning Targets:

Understand and correctly interpret function notation & Find inputs and outputs of functions.

Knowledge

1. Given the function machine below what is the value of f(

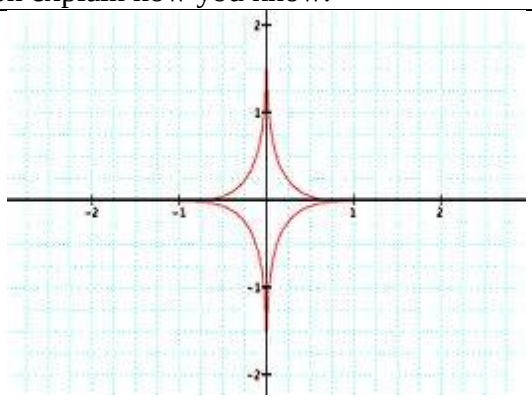


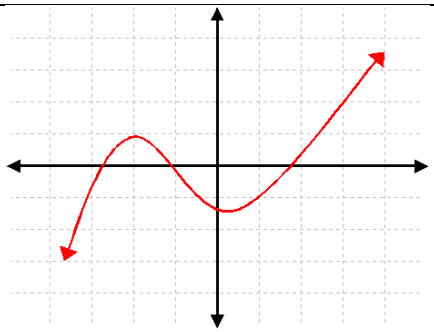
2. $f(x) = |x - 15|$

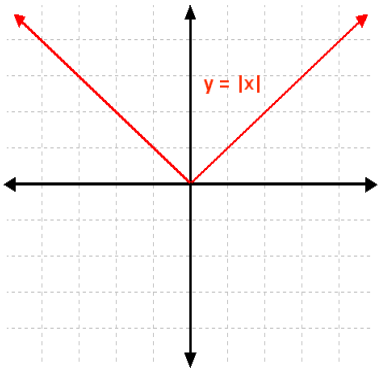
If 7 is the input of the function above, what is the output?

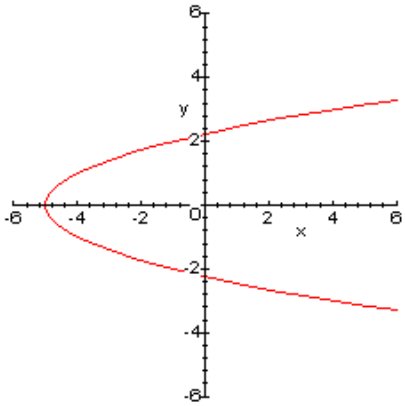
Comprehension

3. Examine each graph below. State whether the graph is or is not a function. If it is not a function explain how you know.









Application

4. If $x = 5$ create a function that produces an output of -4.

5. The area for any square is given by the function $y = x^2$, where x is the length of the side of the square. Write the equation in function notation. Find the area of a square when the side is 4 ft.

Analysis/Synthesis/Evaluation

6. Completely fill out the table below so that the data DOES represent a function.

x	y

7. Sketch a graph that fits each description.

a. A graph that passes through all four quadrants and does represents a function.

b. A graph that passes through all four quadrants and does not represent a function.

c. A graph that passes through Quadrants 1, 2, & 4 only and represents a function.

d. A graph that passes through Quadrants 1, 2, & 4 only and does not represent a function.

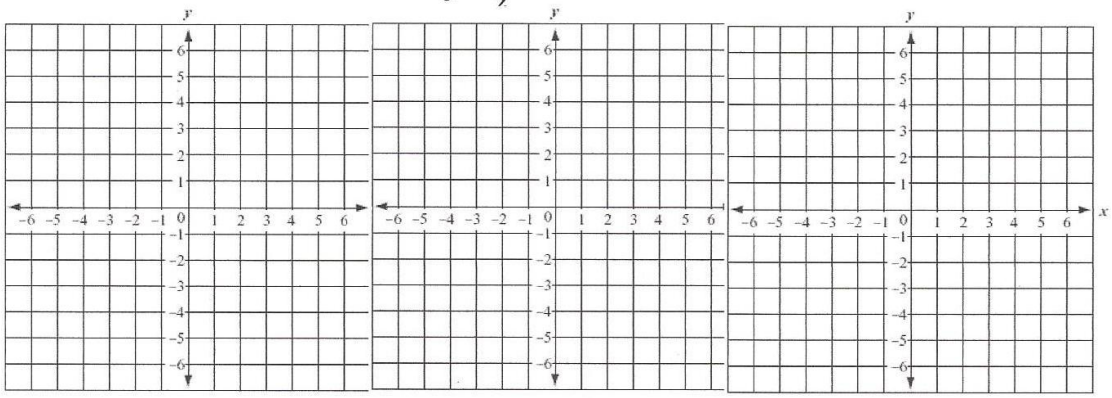
Level 3 Test

Learning Targets: **Use m and b to graph a linear equation without making a table**
Interpret Slope and y-intercept from an equation

Knowledge

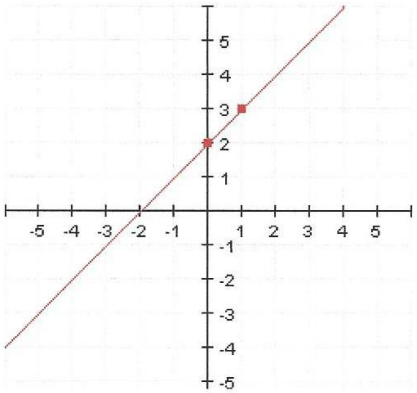
1. Graph the equation AND describe the slope and y-intercept.

a. $y = 2x - 3$ **b.** $y = \frac{1}{2}x + 2$ **c.** $y = -4x$

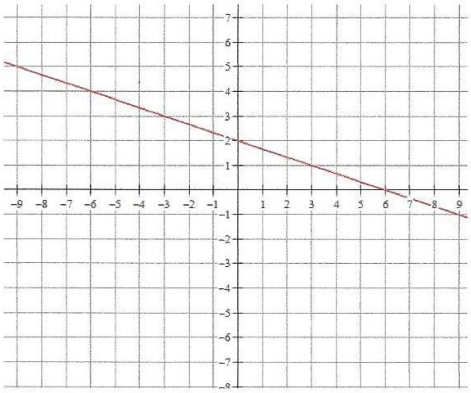


2. Write the equation of the line in slope intercept form

a.



b.



Comprehension

3. Write the equation of the line using the table below:

x	0	1	2	3	4	5
y	-3	2	7	12	17	22

Application

4. Write an equation for a line that is decreasing, crosses the x-axis at the point (3,0) and crosses the y-axis at the point (0,4).

5. Find the slope of the line containing the two points: (2,3) and (4,7)

Analysis/Synthesis/Evaluation

6. Fill out the table and write an equation for the number of tiles in this pattern. Predict how many tiles will the 8th figure will have.

Fig #	# Of Tiles
0	
1	
2	
3	
4	
…	
8	

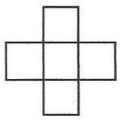


Figure 1

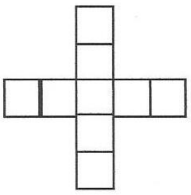


Figure 2

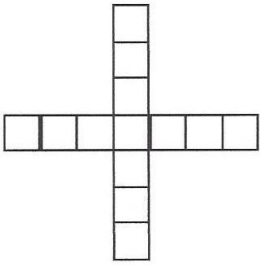


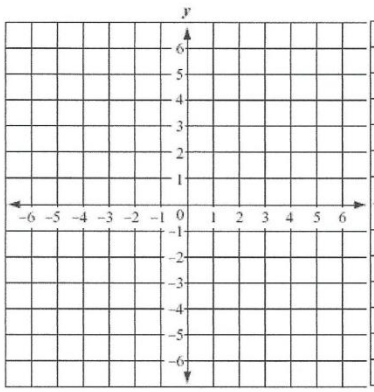
Figure 3

Level 3 Test Retest
Learning Targets: **Use m and b to graph a linear equation without making a table**
Interpret Slope and y-intercept from an equation

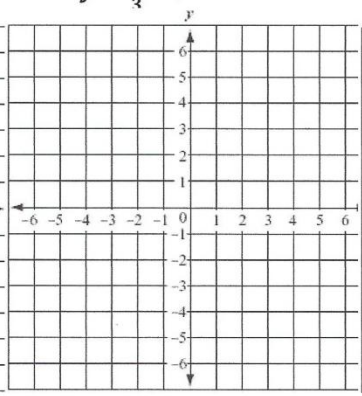
Knowledge

7. Graph the equation AND describe the slope and y-intercept.

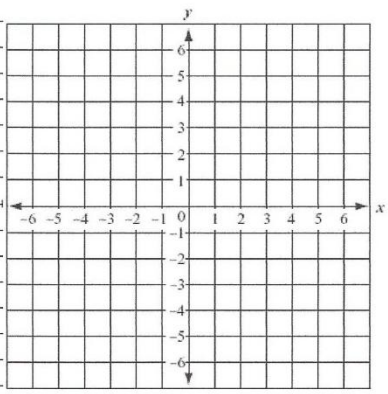
d. $y = -2x - 3$



e. $y = \frac{2}{3}x + 1$

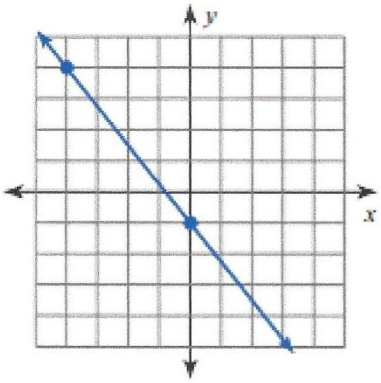


f. $y = 2x$

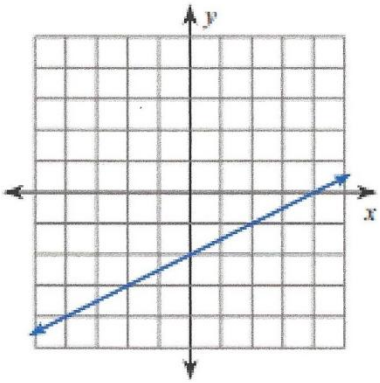


8. Write the equation of the line in slope intercept form

c.



d.



Comprehension

9. Write the equation of the line using the table below:

x	0	1	2	3	4	5
y	15	12	9	6	3	0

Application

10. Write an equation for a line that is increasing, crosses the x-axis at the point $(-3,0)$ and crosses the y-axis at the point $(0,7)$.

11. Find the slope of the line containing the two points: $(19,-2)$ and $(-11,10)$

Analysis/Synthesis/Evaluation

12. Fill out the table and write an equation for the number of tiles in this pattern. Predict how many tiles will the 14th figure will have.

Fig #	# Of Tiles
0	
1	
2	
3	
4	
…	
14	

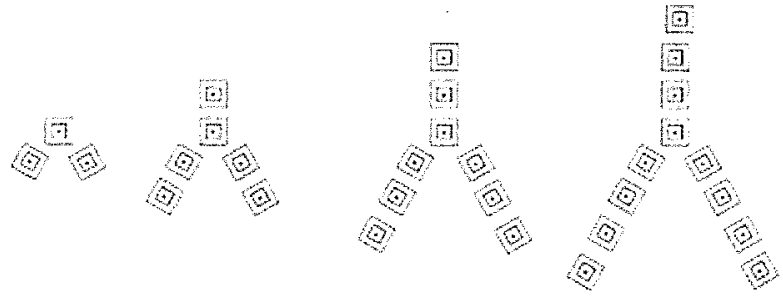


Figure 0 Figure 1 Figure 2 Figure 3

Level 4 Test

Objective: Write the equation (and/or interpret slope and y-intercept) from:

a) Tile pattern
b) Situation

Find the slope from a table without a y- intercept
Understand the slope as a rate

Knowledge

1. What is the rule (equation) that makes the table

$\boldsymbol{x}$	2	3	4	5	6	7
$\boldsymbol{y}$	-1	-4	-7	-10	-13	-16

2. Write a rule for the given tile pattern. How many tiles will be in figure 20?

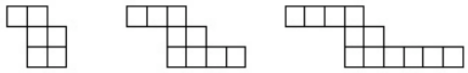


Figure 1 Figure 2 Figure 3

Comprehension

3. Find the equation of the line passing through the two points:

$$3, 4 \quad and \ (6, -8)$$

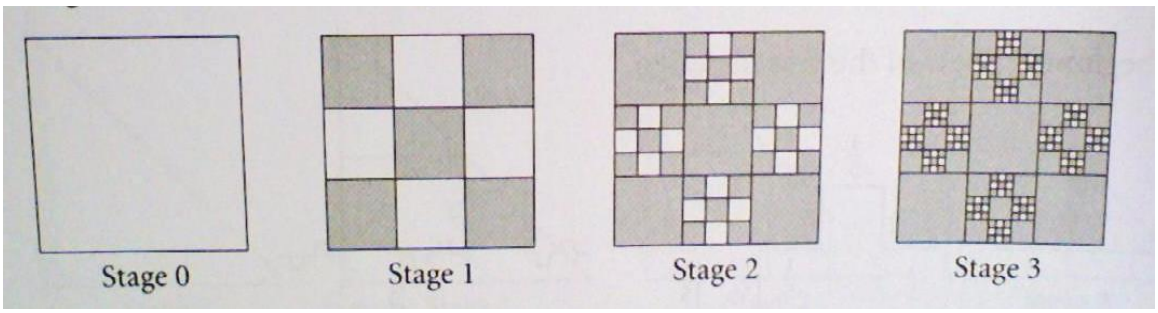
Application

4. Eric starts with $30 in his bank account and saves $15 every month. Write an equation for the amount of money in his bank account. State what x and y represent.

5. Create a tile pattern that grows by 4 tiles for every new figure. Draw figures 0, 1, 2, and 3 of your pattern. Make an $x \rightarrow y$ table to match your drawings and write an equation (rule) for the table.

Analysis/Synthesis/Evaluation

6. Examine the fractal pattern below



a. Make a table of values where x= stage # and y= # of dark squares
b. Plot the points on a coordinate plane
c. Describe the graph

Level 4 Test RETAKE
Objective: Write the equation (and/or interpret slope and y-intercept) from:

c) Tile pattern
d) Situation

Find the slope from a table without a y- intercept
Understand the slope as a rate

Knowledge

7. What is the rule (equation) that makes the table

$\boldsymbol{x}$	2	3	4	5	6	7
$\boldsymbol{y}$	-5	-7	-9	-11	-13	-15

8. Write a rule for the given tile pattern. How many tiles will be in figure 20?

Figure 1 Figure 2 Figure 3

Comprehension

9. Find the equation of the line passing through the two points:

$$2, 4 \quad and \ (6, -4)$$

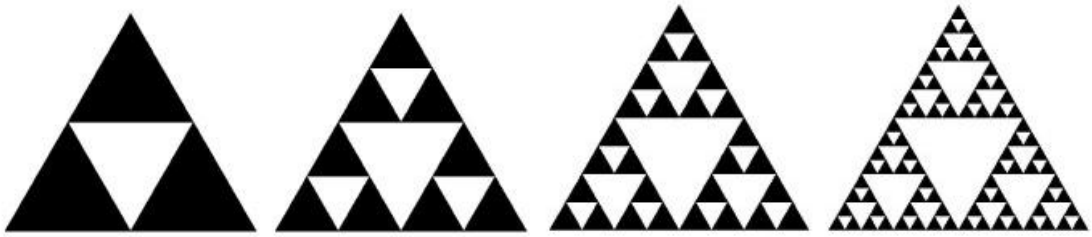
Application

10. Eric starts with $75 in his bank account and spends $8 every month. Write an equation for the amount of money in his bank account. State what x and y represent.

11. Create a tile pattern that grows by 3 tiles for every new figure. Draw figures 0, 1, 2, and 3 of your pattern. Make an $x \rightarrow y$ table to match your drawings and write an equation (rule) for the table.

Analysis/Synthesis/Evaluation

12. Examine the fractal pattern below



d. Make a table of values where x= stage # and y= # of dark triangles
e. Plot the points on a coordinate plane
f. Describe the graph

Level 5 Test

Objective: Simplify expressions with positive exponents & Simplify expressions with zero and negative exponents

Knowledge/Comprehension:

1. Use properties of exponents to rewrite each expression:

a. $3x^2 \cdot 2x^4$	b. $\frac{14a^5b^3}{-2b^5}$	c. $2y^{2\ \ 4}$
d. $x^0 \cdot y^3$	e. $\frac{1}{7^{-3}}$	f. $\frac{y^{-4}}{x^{-4}}$

Application:

2. Identify which of the following expressions below are equivalent and re write them so they are in groups using the boxes below.

$\frac{x^5}{x^3}$ $\quad x^{4\ \ 2}$ $\quad x^{-1\ \ 8}$ $\quad \frac{1}{x^{-2}}$ $\quad x^{-2}x^{10}$ $\quad x^{-2\ \ 4}$ $\quad x^5x^3$ $\quad \frac{1}{x^8}$ $\quad \frac{x^9}{x}$

3. Alan thinks that $4a^{2\ \ 3} = 64a^5$. Do you agree or disagree? If you agree explain and show why you are both right. If you disagree explain to Alan where he went wrong.

Synthesis/Analysis:

4. Consider the equation $y = 2^x$. Use this equation to fill out the table below.

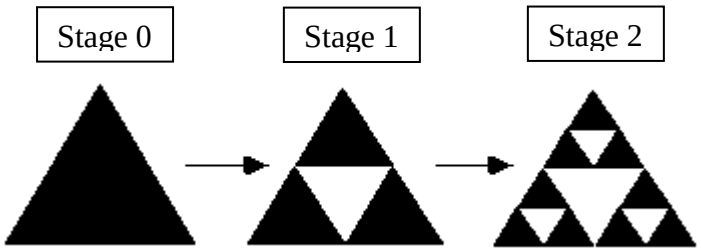
x	y

-2	
-1	
0	
1	
2	
3	

EXPLAIN why 2^{-1} is $\frac{1}{}$

5. The pattern below looks at the black triangles in each stages:

Stage # x	Number of Black Triangles y
0	1
1	3
2	9
3	
4	



Fill out the rest of the table and EXPLAIN how exponents relate to this problem.

Level 5 Test RETEST

Objective: Simplify expressions with positive exponents & Simplify expressions with zero and negative exponents

Knowledge/Comprehension:

6. Use properties of exponents to rewrite each expression:

g. $4x^3 \cdot 3x^6$	h. $\frac{20a^4b^2}{-5b^8}$	i. $2g^{5\ \ 3}$
j. $b^2 \cdot a^0$	k. $\frac{1}{6^{-2}}$	l. $\frac{a^{-3}}{b^{-5}}$

Application:

7. Identify which of the following expressions below are equivalent and re write them so they are in groups using the boxes below.

$\frac{x^7}{x^2}$ $\quad x^{6\ \ -1}$ $\quad x^{2\ \ -3}$ $\quad \frac{1}{x^6}$ $\quad x^9x^{-2}$ $\quad x^{-1\ \ 6}$ $\quad x^4x^3$ $\quad \frac{1}{x^{-5}}$ $\quad \frac{x^{10}}{x^3}$

8. Eric thinks that $\frac{12x^5}{2x^2} = 10x^3$. Do you agree or disagree? If you agree explain and show why you are both right. If you disagree explain to Alan where he went wrong.

Synthesis/Analysis:

9. Consider the equation $y = 3^x$. Use this equation to fill out the table below.

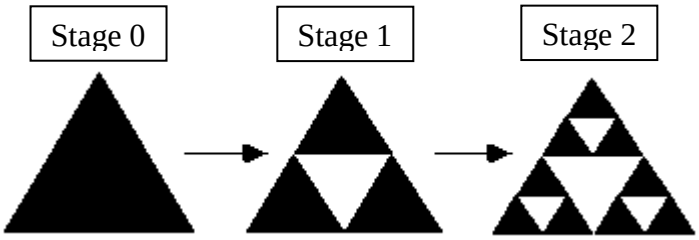
x	y

-2	
-1	
0	
1	
2	
3	

EXPLAIN why
2^{-1} is $\frac{1}{}$

10. The pattern below looks at the black triangles in each stages:

Stage # x	Number of Black Triangles y
0	1
1	3
2	9
3	
4	



Fill out the rest of the table and EXPLAIN how exponents relate to this problem.

Level 6 Test

Objectives: Compute areas and dimensions on generic rectangles
Use the distributive property to simply and solve equations
Multiply binomials and polynomials

Knowledge

1. What is the area as a product AND as a sum:

	5	–3
1		

2. *F*ind the area of each part and the find the area of the whole.

	12	5
6		
4		

Comprehension

3. Use the distributive property to simplify the following expressions:

a. $3x(-2x^2+4)$

b. $-2(-3x+2)$

Application:

4. Refer to the generic rectangle at the right
   a. Use what you know about generic rectangles to fill in the blanks.

		?
?	$2x^2$	?
3	?	-12

   b. Write the area as a product and as a sum.

5. Multiply and simplify the following expression by using either a generic rectangle or the distributive property: $(2x-4)(3x+2)$

6. Create your own generic rectangle and find the area as a product and as a sum.

Synthesis/Analysis:

7. Dan thinks that $x^2+9=(x+3)(x+3)$. Is he correct, why or why not?

8. Use what you know about multiplying binomials and exponents to expand and then simplify

$$(2x+3)^2-5$$

Level 7 Test

Objectives:

Solve simple absolute value equations in the form $ax + b = c$

Solve multivariable equations for one of its variables

Knowledge

1. Evaluate:

4 $\qquad$ -4 $\qquad$ -4

Comprehension

2. Solve the absolute value equation:

$2x - 4 = 8$

Solve the equation for the given variable:

3. Solve for x: $y = 2x + 3$

4. Solve for F: $W = Fd$

5. Solve for C: $F = \frac{9C}{5} + 32$

6. Solve for m: $2m - 6 = 4n + 4$

Application:

7. Use this formula to answer the following question:

$W = Fd.$

You and your friends are pushing a piano. The combined Force is 500 Newtons. The amount of work done is 1800 Joules. How far did they travel moving the piano?

8. If the absolute value of the equation $4x + 4$ equals 60, what are the values of x?

Synthesis/Analysis

9. Consider the equation $2y = 12 - 4x$. Eric thinks that completely solving for y results in the equation $y = 12 - 2x$. Is Eric correct? Why or why not?

10. Renee is in a race. She is running at a pace of 7 miles per hour and gets a half of a mile head start. The equation representing this situation is $y = 7x + 0.5$

Solve the equation for x and answer the following question: At what time was she 2 miles from the starting point?

Level 7 Retest

Objectives:

Solve simple absolute value equations in the form $ax + b = c$

Solve multivariable equations for one of its variables

Knowledge

1. Evaluate:

-7 $\qquad$ -7 $\qquad$ 7

Comprehension

2. Solve the absolute value equation:

$3x - 6 = 9$

Solve the equation for the given variable:

3. Solve for x: $y = 5x - 10$

4. Solve form: $\rho = \frac{m}{V}$

5. Solve for n: $2m = 14 + \frac{7n}{2}$

6. Solve for k: $8j + 6 = 4k - 2$

Application:

7. Use this formula to answer the following question:

$\rho = \frac{m}{V}$, where ρ represents density, v is volume, and m is mass.

If the density of turquoise is 2.6 grams/cm^3. Using a cylinder full of water you found the volume is 5 ml. What is the mass?

8. If the absolute value of the equation $2x + 2$ equals 16, what are the values of x?

Synthesis/Analysis

9. Consider the equation $3y = 21 - 9x$. Eric thinks that completely solving for y results in the equation $y = 12 - 3x$. Is Eric correct? Why or why not?

10. Fahrenheit can be found by using the equation $F = \frac{9C}{5} + 32$, where C represents Celsius.

Solve the equation for C and answer the following question: If the temperature outside is 50 degrees F what is the temperature in Celsius?

Level 8 Test: Systems of Equations

Objectives:

- Solve simple systems of equations, when one equation is given in $y = mx + b$ form, and the other is in standard $ax + by = c$ form.
- Understand that the solution to a system of equations is the point that makes both equations true
- Use graphing to estimate a solution to a system of equations

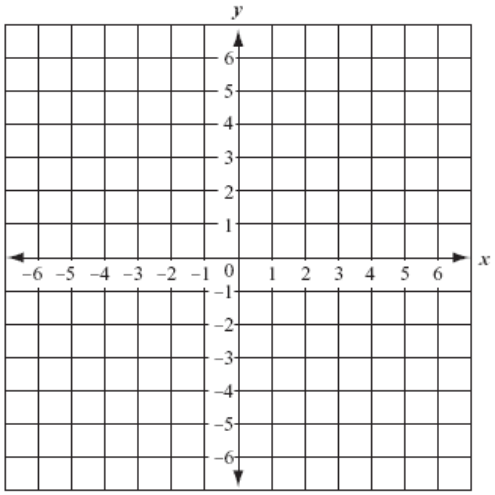
Knowledge/Comprehension

1. Solve each system of equations and check your answers.

$y = x - 4$ $y = -4x + 26$	$y = 9 - 2x$ $5x - 2y = 18$
Check:	Check:

2. Solve the system of equations by graphing.

$$y = -\frac{1}{2}x - 1$$
$$y = \frac{1}{4}x - 4$$



Application

3. Tickets for students to see White Christmas costs $10 and tickets for the public cost $15. Currently 370 tickets have been sold and $4,700 has been collected in ticket sales. How many student and public tickets have been sold?

Analysis/Synthesis/Evaluation

4. A door is on one side of the classroom, and a set of windows is on the opposite wall.
   Emily starts at the windows, which are 6 feet from the door, and walks towards the door at 3 feet per second. Allison starts at the door and walks towards the windows at the same pace as Emily.

   a) Sketch a graph to represent the situation, with the x-axis representing time and the y-axis representing distance from the door.
   b) Where will Allison and Emily cross paths? Use a system of equations.

Level 8 RE-Test: Systems of Equations

Objectives:

- Solve simple systems of equations, when one equation is given in $y = mx + b$ form, and the other is in standard $ax + by = c$ form.
- Understand that the solution to a system of equations is the point that makes both equations true
- Use graphing to estimate a solution to a system of equations

Knowledge/Comprehension

5. Solve each system of equations and check your answers. YOU MUST SHOW YOUR WORK!

$y = 6x - 11$
$-2x - 3y = -7$

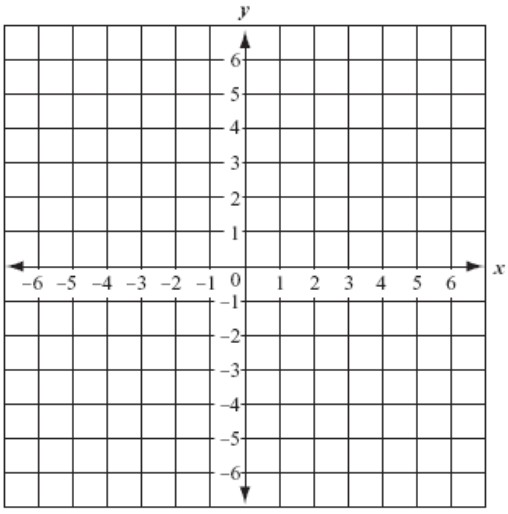
Check:

$y = 4x + 6$
$y = -5x - 21$

Check:

6. Solve the system of equations by graphing. What is the solution to the system?

$y = -\frac{1}{2}x + 3$
$y = 3x - 4$



Application

7. Inspire Algebra Students are raising money for a charity. They are hosting a bake sale and selling brownies for $3 each and peanut butter cookies for $2 each. At the end of the sale they know they have sold a total of 200 treats and made $510. How many brownies and how many cookies did the Students sell?

Analysis/Synthesis/Evaluation

8. You are at school walking to Celestino's for some delicious Oscar's Spicy Luau Pizza. Mrs. Reynolds is walking back to school from Celestino's already having had her Oscar's Spicy Luau Pizza for lunch.
   Celestino's is 5 miles away from school. You are walking at a speed 2 miles per hour and Mrs. Reynolds is walking at a speed of 3 miles per hour.

   c) Sketch a graph to represent the situation, with the x-axis representing time and the y-axis representing **distance from school.**
   d) Where will you and Mrs. Reynolds cross paths? Use a system of equations. Show or explain how you got your answer.

Level 9 Test

• Identify systems with infinite number solutions • Identify systems with no solutions	• Solve systems of equations, when both equations given are in standard ax+by=c form. • Write a system of equations from word problems (difficult)

Knowledge

1. What is the solution to each system of equations below? Use whatever method you would like. Be sure to show your work and circle your answer.

a)
$$y - x = 4$$
$$2y + x = 8$$

b)
$$5x - 5y = 10$$
$$3x - 2y = 2$$

c)
$$-4x + 5y = 0$$
$$-6x + 5y = -10$$

d)
$$4x + 2y = 6$$
$$2x + y = 3$$

Comprehension

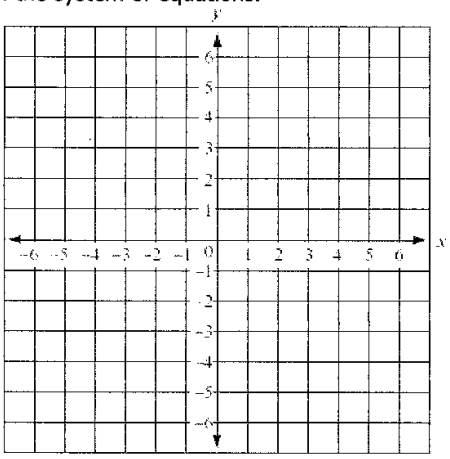
2. Solve the system of equations with elimination or substitution.

a) Solve the system with elimination or substitution.

$$2x + y = 3$$
$$4x + 2y = 8$$

b) Describe what happened when you tried to solve the system.

c) Graph the system of equations.



d) How does the graph of the system explain what happened with the equations?

Application

1. Mr. Kauffman is starting a farm. He will start out with a total of 63 animals, only Pigs and Chickens. Altogether the pig and chicken legs add up to 210 Note that each pig has all 4 legs and each chicken has both their legs. Use this information to **set up a system of equations** and tell us how many pigs and how many chickens Mr. Kauffman is starting his farm with.

Analysis/Synthesis/Evaluation

2. Write a system of two equations that satisfies each condition. Then solve the system of equations.

    a. The graphs of the equations do not intersect.

    b. The solution to the system of equations is (0,0)

b) Describe what happened when you tried to solve the system.

d) How does the graph of the system explain what happened with the equations?

Level 9 Retest

Knowledge

5. What is the solution to each system of equations below? Use whatever method you would like. Be sure to show your work and circle your answer.

e)
$$-4x - 2y = -12$$
$$4x + 8y = 24$$

f)
$$8x + y = -16$$
$$-3x + y = -5$$

g)
$$-4x + 9y = 9$$
$$x - 3y = -6$$

h)
$$2x + 8y = 6$$
$$-5x - 20y = -15$$

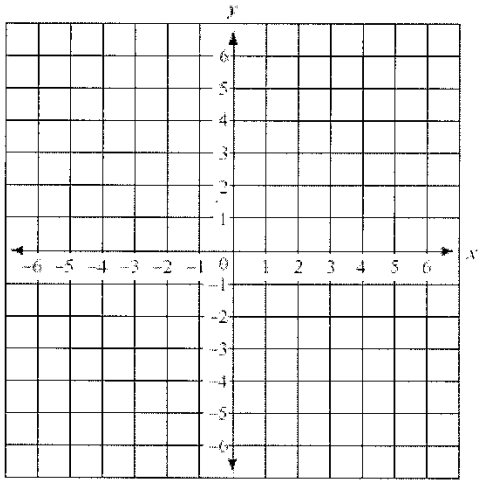
Comprehension

6. Solve the system of equations with elimination or substitution.

b) Solve the system with elimination or substitution.

$$-6x + 2y = -8$$
$$x + 2y = 6$$

d) Graph the system of equations.



c) Describe what happened when you tried to solve the system.

e) How does the graph of the system explain what happened with the equations?

Application

7. The difference of two numbers is 3. The sum of the same two numbers is 13. What are the two numbers?

8. Katie and Danielle are selling fruit for a school fundraiser. You can buy a small box of oranges or a large box of oranges. Katie sold 3 small boxes of oranges and 14 large boxes of oranges for a total of $203. Danielle sold 11 small boxes of oranges and 11 large boxes of oranges for a total of $220. What is the cost of a bag of small oranges? What is the cost of a bag of large oranges?

Analysis/Synthesis/Evaluation

9. Write a system of two equations that satisfies each condition. **Then solve the system of equations**.

    c. The graphs of the equations do not intersect.

    d. The solution to the system of equations is (1, 4)

Level 10 Test

Objectives:

- Recognize whether a sequence, table, or graph is linear (arithmetic), exponential (geometric), or something else.
- Identify the sequence generator from a sequence, table, or graph of arithmetic and geometric sequences and extend the pattern

Knowledge (part 1) /Comprehension (Part 2) (30%)

1. Describe how the sequence is generated and give the next three terms.

   a) $-\frac{1}{4}, \frac{1}{2}, -1, 2, -4, \ldots$

   b) $-4,\ -1,\ 2,\ 5,\ 8, \ldots$

   c) $4,\ 6,\ 10,\ 16,\ 24, \ldots$

Application (40%)

Complete this problem on a separate sheet of graph paper.
Investigate the three scenarios below. You may find it helpful to make a diagram or draw a picture to help you investigate the scenario BEFORE you make the table.

For each scenario:

- Create a sequence and put it in a table.
- Identify the sequence generator and extend the pattern in your table to include at least 6 data points
- Create a graph
- Fully describe the growth pattern and everything you can about the sequence/scenario. Use proper vocabulary from class in your description for full credit.

Scenario 1:
Lisa begins with 2 rabbits. Every month each pair of rabbits has 6 babies.

Scenario 2:
Mrs. Reynolds cactus is a height of 18 inches and will grow 3 inches each month.

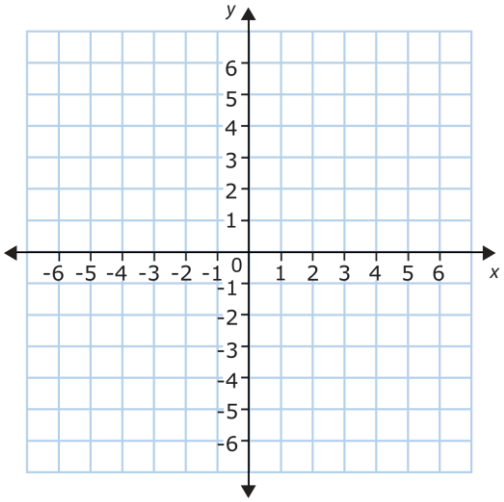
Scenario 3:

A tennis ball is dropped from a height of 100 cm and bounces to a height of 50 cm.

Analysis/Synthesis/Evaluation 30%

Consider the sequence:

$-3,\ -1,\ 1,\ 3,\ 5,\ 7,\ 9,\ \ldots$



a) What is the sequence generator?

b) Put the sequence into a table.

c) Graph the sequence.

d) Completely describe the graph taking into consideration the following
- Is the graph linear, exponential or something else?
- Identify any $x-$ and $y-$ intercepts (if any).
- Does the graph increase, decrease, or something else?

e) What is the equation for your graph in terms of x and y.

f) What new conclusions/connections can you form about this type of sequence and the type of equation you discovered?

Level 10 RETest

Objectives:

- Recognize whether a sequence, table, or graph is linear (arithmetic), exponential (geometric), or something else.
- Identify the sequence generator from a sequence, table, or graph of arithmetic and geometric sequences and extend the pattern

Knowledge (part 1) /Comprehension(part 2)

2. Describe how the sequence is generated and give the next three terms.

   d) $2,\ 6,\ 8,\ 14,\ 26, \ldots$
   e) $107, 98,\ 89,\ 80, \ldots$
   f) $4,\ 8,\ 16,\ 32, \ldots$

Application

Complete this problem on a separate sheet of graph paper.
Investigate the three scenarios below. You may find it helpful to make a diagram or draw a picture to help you investigate the scenario BEFORE you make the table.

For each scenario:

- Create a sequence and put it in a table.
- Identify the sequence generator and extend the pattern in your table to include at least 6 data points
- Create a graph
- Fully describe the growth pattern and everything you can about the sequence/scenario. Use proper vocabulary from class in your description for full credit.

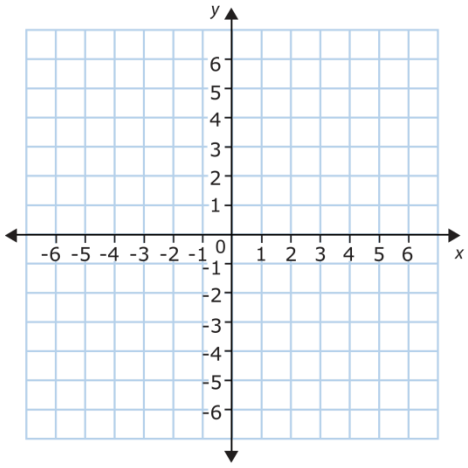
Scenario 1:
Lisa begins 4 baseball cards. Every month she buys 10 more.

Scenario 2:
Mrs. Reynolds started with 4 rabbits. Every month each pair of rabbits has 3 rabbits.

Scenario 3:
A tennis ball is dropped from a height of 120 cm and bounces to a height of 30 cm.

Analysis/Synthesis/Evaluation

Consider the sequence:
$-9, -3,\ 3,\ 9,\ 15, \ldots$



g) What is the sequence generator?

h) Put the sequence into a table.

i) Graph the sequence.

j) Completely describe the graph taking into consideration the following
- Is the graph linear, exponential or something else?
- Identify any $x-$ and $y-$ intercepts (if any).
- Does the graph increase, decrease, or something else?

k) What is the equation for your graph in terms of x and y.

l) What new conclusions/connections can you form about this type of sequence and the type of equation you discovered?

Level 11 Test

Objectives:
Write a recursive equation for an arithmetic sequence
Use multiple representations for arithmetic sequences

Knowledge

1. Consider the sequence: $-7, -4, -1, 2, 5, \ldots$.
   a) Identify the sequence generator and the first term.
   b) Write an explicit equation from the sequence.
   c) Write a recursive equation from the sequence.
   d) What is the 10th term of the sequence?

2. Write the 1st five terms of the sequence:

   a. $t(1) = 3$
   $t(n+1) = t(n) - 4$

   b. $t(1) = -2$
   $t(n+1) = 3 \cdot t(n)$

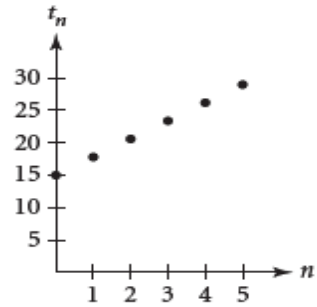
Comprehension

3. Consider the sequence 12, 14, 16, 18, 20, …
   a. Find the EXPLICIT equation for this sequence.
   b. Show how to find the 27th term using the equation from a.

Application

4. Determine whether 323 is a term of the sequences below. If so which term?
   $t(n) = 6n - 1$

5. Consider the graph at the right.
   a. Which recursive equation goes with the graph?
      i. $t\ 0\ = 15$
         $t\ n+1\ = t\ n\ + 5$
      ii. $t\ 1\ = 15$
         $t\ n+1\ = t\ n\ + 2.5$
      iii. $t\ 0\ = 15$
         $t\ n+1\ = t\ n\ + 2.5$
   b. Is the sequence represented by the graph Aritl something else? **How can you tell?**



Synthesis/Analysis/Evaluation

6. Consider the pattern:

Please do this problem on a separate piece of graph paper.

a. If you only look at the number of black triangles, at each stage in the pattern, what sequence can you find? Write the sequence for us.
b. Sketch a graph of this sequence
c. What type of sequence is this?
d. What is the recursive equation for this sequence?
e. Find another sequence in this pattern?

Level 12 Test
Learning Targets
Write a recursive equation and explicit equation for geometric sequences
Use multiple representations for geometric sequences
Determine a sequence generator from a percent increase/decrease word problem
Identify percent increase and/or decrease from a sequence

Knowledge

Consider the sequence: 50, 70, 98, 137.2, 192.08 ...

1. What is the sequence generator and what do we call it for **geometric** sequences?

2. Put this sequence in a table.

3. Graph your sequence
4. Describe your graph.

Comprehension

5. What is the RECURSIVE equation for the sequence?

6. What is the EXPLICIT equation for the sequence?

Application

Consider the function $f(x) = 240{,}000(.7)^x$.

7. Fill out the table to represent *the* sequence contained by this function.

x						
$f(x)$						

8. If this sequence represents the value of a house over time, what was the initial value of the house?

9. Does the price of the house increase or decrease as time increases **and** by what percentage rate?

10. How much will the house be worth after 10 years?

Synthesis, Analysis, Evaluation

1. Consider the following scenario. Jake and Jenny close their savings accounts at the same time. Jake had a total of $25,000 and Jenny had a total of $17,500. Jake is a wild gambler and spends 10% each month at the casino. Jenny decided to reinvest her savings and is now earning 5% interest of her total savings each month in her new savings account.

Use the tables provided to represent the two situations above.

n	0								
$t(n)$	25,000								

n	0								
$t(n)$	17,500								

Approximately which month will Jenny have more money than Jake?

Level 12 Retest

Learning Targets

Write a recursive equation and explicit equation for geometric sequences

Use multiple representations for geometric sequences

Determine a sequence generator from a percent increase/decrease word problem

Identify percent increase and/or decrease from a sequence

Knowledge

Consider the sequence: 50, 70, 98, 137.2, 192.08 …

1. What is the sequence generator and what do we call it for **geometric** sequences?

2. Put this sequence in a table.

3. Graph your sequence
4. Describe your graph.

Comprehension

5. What is the RECURSIVE equation for the sequence?

6. What is the EXPLICIT equation for the sequence?

Application

Consider the function $f\ x\ = 240{,}000(.7)^x$.

7. Fill out the table to represent *the* sequence contained by this function.

x						
$f(x)$						

8. If this sequence represents the value of a house over time, what was the initial value of the house?

9. Does the price of the house increase or decrease as time increases **and** by what percentage rate?

10. How much will the house be worth after 10 years?

Synthesis, Analysis, Evaluation

11. Consider the following scenario. Jake and Jenny close their savings accounts at the same time. Jake had a total of $25,000 and Jenny had a total of $17,500. Jake is a wild gambler and spends 10% each month at the casino. Jenny decided to reinvest her savings and is now earning 5% interest of her total savings each month in her new savings account.

Use the tables provided to represent the two situations above.

n	0								
$t(n)$	25,000								

n	0								
$t(n)$	17,500								

Approximately which month will Jenny have more money than Jake?

Level 15 Test

Objectives:

- Identify the x intercepts from a table and a graph for a quadratic
- Find the y intercepts of a quadratic from a table, graph, and/or equation
- Find the x intercepts from an equation by factoring and applying the Zero Product Property
- Find the vertex of a parabola using the x intercepts and equation
- Sketch a parabola once you have found the x intercepts and the vertex
- Sketch a parabola from vertex form of a quadratic

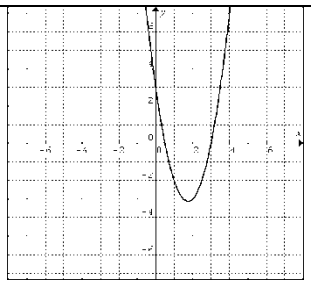
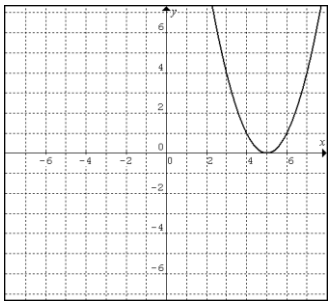
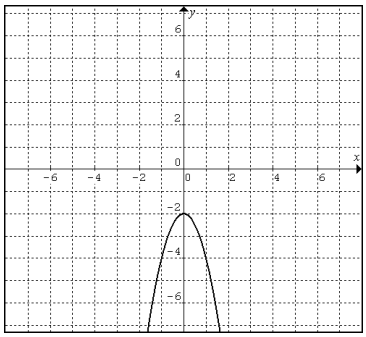
(1) <u>Knowledge (2) Comprehension:</u>

1. Factor the quadratic: $y = 2x^2 - 11x + 12$	*2. Find the x- and y-intercept(s) for the quadratic* $y = \ 2x + 144 \quad x - 133$ ***without*** *making a table or graphing. How are you able to do this?* ***Explain completely.***

<u>Application:</u>

3. Match each parabola below with its rule. Write the correct rule under its graph. Justify how you know the rule goes with each parabola. ***Note: Not all rules will be matched with a parabola.***

1. $y = \ x - 5\ ^2$ 2. $y = x^2 - x - 2$ 3. $y = -2x^2 - 2$ 4. $y = 2x^2 - 7x + 3$
5. $y = -5x^2 - x + 5$

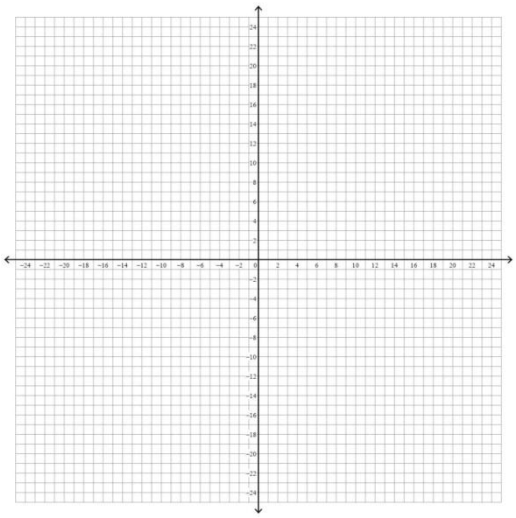
		
Justify:	*Justify:*	*Justify:*

<u>Synthesis/Evaluation/Analysis</u>

4. Consider the equation:

$2x^2 + 4x = 16$

a. *Solve this equation for x,* ***neatly show all work****.*



b. *Find the x intercepts for the graph of* $y = 2x^2 + 4x - 16$

c. *Find the vertex of the graph, using the line of symmetry.*

d. *Find the y intercept.*

e. *Carefully sketch the graph of* $= 2x^2 + 4x - 16$ *. Label all intercepts and vertex. Include the line of symmetry in your drawing to show that it goes through the vertex.*

f. *Is there a connection between your answer to part (a) and your graph? Explain completely.*

Level 15 ReTest

Objectives:

- Identify the x intercepts from a table and a graph for a quadratic
- Find the y intercepts of a quadratic from a table, graph, and/or equation
- Find the x intercepts from an equation by factoring and applying the Zero Product Property
- Find the vertex of a parabola using the x intercepts and equation
- Sketch a parabola once you have found the x intercepts and the vertex
- Sketch a parabola from vertex form of a quadratic

(1) <u>Knowledge (2) Comprehension:</u>

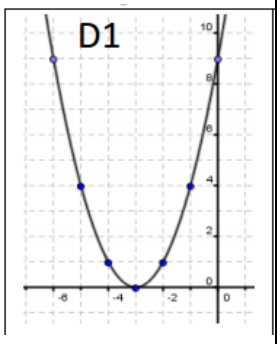
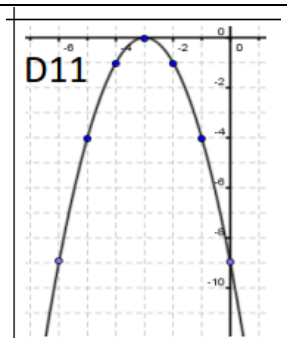
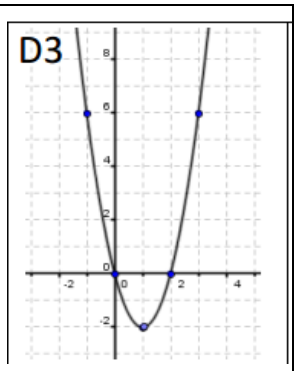
3. Factor the quadratic: $y = 3x^2 - 20x - 7$	*4. Find the x- and y-intercept(s) for the quadratic* $y = \ x + 52 \quad 3x - 27$ ***without*** *making a table or graphing. How are you able to do this?* ***Explain completely.***

<u>Application:</u>

3. Match each parabola below with its rule. Write the correct rule under its graph. Justify how you know the rule goes with each parabola. ***Note: Not all rules will be matched with a parabola.***

1. $y = -x^2 - 6x - 9$ 2. $y = (x + 3)^2$ 3. $y = x^2 + x - 2$ 4. $y = 2x^2 - 4x$
5. $y = -5x^2 - x + 7$

<u>Synthesis/Evaluation/Analysis</u>

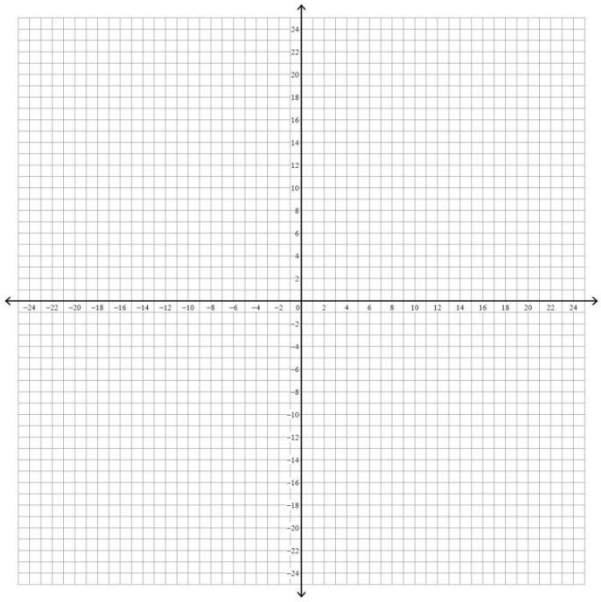
a.  *Justify:*	*b.*  *Justify:*	*c.*  *Justify:*

4. Consider the equation:

$$4x^2 = 16$$

g. Solve this equation for x, ***neatly show all work****.*

h. Find the x intercepts for the graph of $y = 4x^2 - 16$



i. Find the vertex of the graph, using the line of symmetry.

j. Find the y intercept.

k. Carefully sketch the graph of $= 4x^2 - 16$ *. Label all intercepts and vertex. Include the line of symmetry in your drawing to show that it goes through the vertex.*

l. Is there a connection between your answer to part (a) and your graph? Explain completely.