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INVESTIGATING BEST PRACTICES FOR ONLINE HOMEWORK AND THE BEGINNING OF LESSONS FOR 9TH-GRADE ALGEBRA STUDENTS WITH VARIOUS ENGLISH LANGUAGE ABILITIES IN AN INTERNATIONAL SCHOOL SETTING

MA thesis

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Abstract

Investigating best practices for online homework and the beginning of lessons for 9th-grade algebra students with various english language abilities in an international school setting

This study investigates the scheduling of two different, individual, online tasks that students work on by themselves in an Algebra 1 math class, in an international high school based on the American Curriculum. It presents and compares two different scheduling strategies for using educational technology to deliver student homework and in-class activity to aid formative assessment and to better prepare students for end of unit assessments. Two different online tasks were considered over the period of one unit of instruction. Task1: Online Inquiry-based learning tasks. Task2: A series of assigned exercises on Khan Academy. Both classes completed both tasks, either as a homework task or in class. The study investigates which schedule is more effective as measured by student performance on an end of unit assessment. Furthermore, the study also investigates the impact of English as an Additional Language (EAL) in completing these tasks. The results from the experiment, suggest that the inquiry-based learning task is best done as a homework assignment, while Khan Academy assignments are preferably done in class where students have access to a teacher or peer knowledge to assist in correcting misconceptions or minor procedural errors. The paper indicates the importance of scaffolding EAL students academic language skills, so they have the confidence to discuss group work in class in English as that is the language of instruction and assessment.

Keywords: Homework, Inquiry-Based Learning, Khan Academy, Scaffolding, EAL, Algebra, Educational Technology, Scheduling

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1. Theoretical Background

1.1. Introduction

In “The Search for Methods of Group Instruction as Effective as One-to-One Tutoring”, the famous educational psychologist Benjamin Bloom discovered that compared to a typical student in a class of around 30 students, students who were taught using mastery would perform one standard deviation better, while students who received one to one education from a subject matter expert would perform on average 2 standard deviations higher than a student in a class of 30(Bloom, 1984). Over thirty years later as educational technology is moving into the Age of Conceptual Learning, which allows “greater flexibility, accessibility, immediacy, interaction and collaboration”, there is the opportunity for teachers to close this two standard deviations gap (Warren, Lee, & Najmi, 2013).

The students in this study are placed in heterogeneous groupings with previous data suggesting a wide variety of test performance and homework completion. Students in this study generally perform better in tests on questions that assess procedural skills versus conceptual knowledge.

The main goal of this study is to investigate homework and start of lesson strategies to allow all students including EAL students to be more successful on these conceptual questions as mandated by the Common Core standards for Mathematics. “Students must be able to access concepts from a number of perspectives in order to see math as more than a set of mnemonics or discrete procedures” (Key Shifts in Mathematics, 2016).

1.2. Student Orientated tasks and Teacher Directed Instruction

Teachers are the foundation of each lesson in how and why materials are chosen to present a topic. In Mathematical Mindsets by Dr Jo Boaler, several characteristics are listed for promoting an evolving, inquiry-based learning environment (Boaler, 2014). In a discussion of the philosophy of mathematics and how it should influence the teaching of the subject, Dr Reuben Hersh makes various arguments for teaching mathematics through the subject’s history, research, applications, intuition, economy, comprehensibility, precision, simplicity, and originality/novelty. There is no mention of completing procedural based problems, which are the primary skills assessed in a traditional math classroom (Hersh, 1997).

The Organization for Economic Co-operation and Development (OECD) runs a Programme for International Student Assessment (PISA). This test every three years samples

15-year-old students from around the world and measures their mathematical literacy. A report entitled “Ten Questions for Mathematics Teachers-And how Pisa can help answer them” breaks down the various ways that mathematics is taught and which strategies have been more successful (OECD,2016).

There is a strong correlation that shows that the more frequently teacher-directed instruction is used compared with student-oriented learning the more frequently students learn by memorising material (OECD, 2016, p.g 12,13).

The teacher checks for understanding, then the student is expected to apply this knowledge to mathematical problems using explicitly defined formulae or algorithms. Teacher-directed instruction is mainly operating at the bottom three levels of Bloom’s Taxonomy, illustrated below and is primarily assessing procedural knowledge (Bloom, 1956).

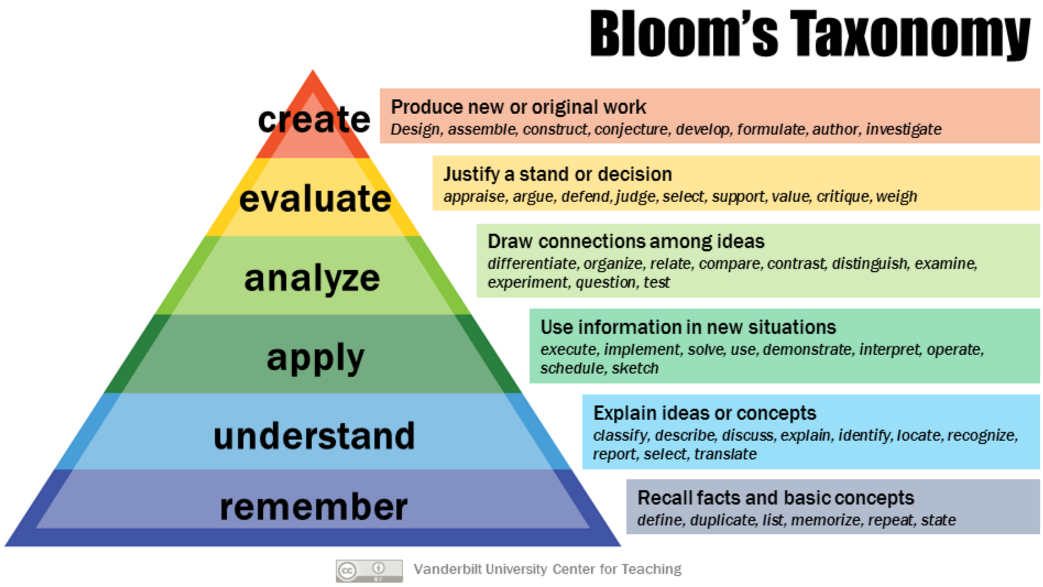

Figure 1.Bloom’s Taxonomy (Armstrong, n.d).

As Bloom demonstrated, the higher the level that students are learning at on his taxonomy, the deeper the learning connections that students make. One way to facilitate students learning at the higher levels of Bloom’s Taxonomy is orienting activities around the student.

It is clear that finding the right balance of scheduling learning time between student orientated and teacher-directed instruction is a classic mathematics problem of maximisation.

The less complicated the material in mathematics is the easier it is to generate an appropriate student orientated activity. As content becomes more difficult, there is an indication from the PISA report that more students benefit from teacher-directed strategies (OECD, 2016, p.g 11). The teacher used this guideline to schedule two online tasks, the first task was to complete inquiry based learning activities with a low entry to build confidence in students approach to conceptual questions.

The second online task assess students prior knowledge and knowledge from previous lesson by completing teacher assigned assignments on Khan academy, leaving the more difficult core curriculum and meaningful instruction through student-oriented activities to be completed within the remaining one hour of the lesson (Khan, 2013).

1.3. The Role of Technology in the Modern Classroom

The evolution of technology use in the classroom does not match that in most workplaces. A surgeon from the past may find himself lost in a modern theatre with it's associated technologies but would be at home in a modern classroom during his studies. Computers are often used to do things in classrooms that could be done as easily on pen and paper. The point of technology in the classroom is for students to enhance their learning. For example, instead of using document software to type a long essay, instead, it would be better to write an argument on a public blog, where the school community can comment. A student spends more time doing careful research, editing and clarifying posts in response to their peer's critiques (Thompson, 2014).

Teachers should employ educational technology to reduce tedious activities such as data collection, input and analysis. Computers can collate large amounts of data, which a teacher would struggle to do. By using a computer as a tool for efficiency, teachers can spend more time on planning, engaging, stimulating lessons, while in class quickly identify students who are struggling on specific tasks in order to provide them with targeted instruction. Adolescent students lack the executive functioning skills to organize and plan their work. When teachers use technology effectively, they can assist students with this problem (Gilbert, 2009). The Common Core State standards mandate that students in Algebra 1 develop procedural skills and fluency in calculation (Key Shifts in Mathematics, 2016), these standards state the importance of using tools strategically. This includes appropriate use of technology such as online graphing calculators, spreadsheets and accessing other digital content on websites to develop their understanding and fluency (Common Core State Standards Initiative, 2018).

Technology offers many opportunities for a teacher to improve student learning. However, the use of technology as a learning aid is not without its disadvantages. For example, time spent online amongst teenagers is correlated with higher obesity rates (Tsitsika et al, 2016), disrupted sleep patterns (Johnson, 2010) and risk taking in online chat rooms(McCarty et al, 2011).Time students spend working online should be carefully considered in order to maximize learning opportunities. As such both of these tasks in the study are limited to 15 minutes to allow for 1 hour of student-orientated, group, hands-on learning to be completed in class.

1.4. Mathematical Language

Approximately 70% of the students in both the classes are English as an Additional Language (EAL) learners. Although these students may quickly learn English for social purposes, learning academic math language is a more complex process. Fluent conversation skills do not necessarily indicate academic proficiency. Vocabulary such as chord, foot, volume may have different meanings in a math class than in a dictionary. Word problems are especially problemsome, with several lines of complex sentences filled with information, some of it useless to solving the problem itself (Barrow, 2014). The importance of building students formal mathematical language is mandated by the Common Core State standards, where the third standard states that mathematically proficient students “Construct viable arguments and critique the reasoning of others”, “communicate precisely” and "use clear definitions in discussion with others" (Common Core State Standards Initiative, 2018).

Students in Algebra 1 face difficulties when studying functions, as prior to this they were only solving equations with one variable, x. Now they have to consider different values for the variable x and how the value of the function is changing with respect to these different values of x, resulting in a lot of new vocabulary and unfamiliar concepts (Meyer, 2015). It is recommended that teachers “draw upon and formalize students informal language” (Meyer, 2015, p.g 44). Analysis of students language used in online Inquiry based learning tasks can be used to formalize their mathematical language.

1.5. High expectations may not lead to Mastery Learning

In a landmark study by Robert Rosentahl in 1965, it was demonstrated that teachers expectations of students indirectly influences, students self esteem and performance on later tests. Students who had been randomly designated as “growth spurters” after completing a fictional test to the teacher outperformed their undesignated peers who acted as a control

(Rosentahl, 1965). Students who believe their abilities in mathematics is a fixed trait, having a fixed mindset, are at a significant disadvantage compared to their peers who believe their abilities can develop, having a growth mindset. (Dweck, 2008) Dweck has found that when teachers have high expectations and when students have a growth mindset this effect is compounded (Dweck, 2008).

Students with a growth mindset react to failures by putting in more effort or by developing strategies to solve these problems. A key feature of having a growth Mindset is seeing effort as a path to Mastery. Mastery learning in the math classroom is defined as the strategy of using student progress data to plan personalized learning (Cargile & Harkness, 2013).

Khan Academy claims to automate Mastery learning by having students do diagnostic tests and based on their performance assigns them a pathway to achieve Mastery in a certain subject. The pathway involves a series of videos, assignments and quizzes which students can work on in the absence of a subject expert. A problem with the mastery approach through Khan Academy is that if students are following their own personalized content then it is in direct contrast to the common core curriculum for Algebra 1, which mandates what topics must be taught to all students.

Studies have shown that Khan Academy as an after-school program may be useful for creating a personalized learning path for students who are behind their peers for but only with an instructor present to ensure students are interacting with the material correctly (Cargile & Harkness, 2013). There has been no definite success outside of these highly controlled environments.

1.6. Khan Academy

The virtual tutor can aid in the students learning, by providing videos, worked examples, and practice quizzes (Cargile & Harkness, 2013). This study uses Khan Academy (KA) as the virtual tutor. In his book “The one world schoolhouse”, Salman Khan, the founder of KA expresses his goal for the site is to provide world-class education accessible to all students regardless of their wealth or background. He recommends that KA be used to personalise instruction to free up class time for student-orientated activities and meaningful instruction (Khan, 2012).

1.6.2. Scaffolding through Hints.

Khan Academy provides hints, similar to other computer based assistance programs such as the ASSIST system. The ASSIST system was developed by researchers in Maine in partnership with the U.S Department of education and the National Science Foundation. In a statewide program, teachers used this system to assign homework (Mendicino, 2014). The ASSIST system provides instantaneous feedback by delivering contextual hints to incorrect answers. In a small study, The ASSIST program was demonstrably better in improving students procedural mathematics skills in comparison to traditional paper and pen homework.

Traditional homework in this study is described only as pen and paper assignments. It does not suggest whether this homework was well designed, consistently completed by students, nor differentiated to meet students needs.

Wang illustrates a general machine learning approach to develop hints for computer based assistance systems (Wang, 2004, p.g10).

1. Knowledge retraction: What are appropriate questions to assess student knowledge in a specific domain?
2. Evaluate possible student responses: What incorrect answers may students give?
3. Diagnose students misconceptions: Why might students give these answers?
4. Suggest remediation processes: What resources should be suggested to students to correct their misunderstandings?

It is unclear how KA designs its hints, but given that it does use Machine learning to assist in accurate generation of streaks when students are following a Mastery of learning path, they probably do a method similar to what Wang suggests (Hu, 2011). The volume of users provides KA with an immense amount of data where the success rate of different hints for specific misconceptions can be quantified using Bayesian analysis. This ensures that hints are of sufficient quality, however it does not ensure that students use these hints in an appropriate manner without instruction.

KA assesses both procedural knowledge and conceptual knowledge. A key to translating a conceptual question to a procedural question is to look for and make repeated use of structure. Common Core State Standards Initiative. (2018). Standards for Mathematical Practice. Retrieved from http://www.corestandards.org/Math/Practice/On inspection of the hints that KA provides for conceptual questions, they merely point out the structure in rather than develop any general strategy

1.6.3. Scaffolding through Video.

KA provides videos to assist students in their learning. Yet by assigning these videos as a homework task here is no guarantee that students will watch supporting videos, or if they do, are they engaged and learning? There are numerous issues with providing a video to assist student learning.

- There is no convincing research, which indicates whether watching a video is any better than reading a piece of text.
- There is no guarantee a student will commit the time to watch a video.
- The videos may take a few minutes to explain a slight misunderstanding
- An experienced teacher may know a quick hint that will work for the student involved.

These videos are designed to teach isolated instructional topics. There is no context for these isolated instructional topics, instead it is assumed that students understand the purpose of learning this unit. Meyer also notes that the language used in KA is very similar to that which is used in math textbooks (Meyer, 2015).

Furthermore, a teacher assigning KA videos has no control over the quality of the instruction. The original narrator of the videos is not a certified math teacher, and there are numerous valid concerns about simplifications of certain topics (Ani, 2013). However, these videos are under constant review and given the investment involved will continue to be updated, the site actively encourages subject matter experts to enter contests by submitting videos that “explain academic concepts with clarity and depth, are friendly and conversational, and laser-focused on helping students when they most need guidance” (Khanacademyblog, 2017).

1.7. Inquiry Based Learning in a Mathematical Classroom

By not providing students with the required content material, students must use intuition to solve problems; an essential part of mathematical practice with real-life applications (Hersh, 1999). Generating knowledge about a specific problem prior to receiving explicit instruction, students gain a deeper knowledge, due to students viewing new information as tools to solve existing problems, rather than memorization (Schwartz & Bransford,1998). Inquiry-based learning happens through experimentation, critical thinking and reason (Kolloffel, Eysink, De Jong, 2011). Inquiry-based learning is described as a student-centered, self-directed and constructivist form of education (Maeots, Pedaste, 2014).

At college level mathematics courses, one class studying differential equations showed a much higher understanding of conceptual knowledge when they were assigned tasks related to inquiry-based learning on the topic versus traditional, teacher-directed instruction. Students procedural knowledge in both settings was equivalent (Rasmussen, 2007), while another study found the impact of Inquiry-based learning activities is sizeable and consistent, especially for decreasing performance gap related to gender in a mathematics classroom (Logan, Kausen 2013).

There is a lot of debate regarding Inquiry-based learning in a high school setting (Hattie & Yates, Visual Learning, 2014). In his meta-analysis, Hattie describes inquiry-based learning as having a minimal effect size of 0.31. Hattie states that if students are not provided with appropriate information, then there is little opportunity for deep learning.

1.8. Homework in the Mathematics Classroom

A wide variety of research shows differing results on the effectiveness of homework in the mathematics classroom. On an individual level, data suggests little correlation between time spent on homework and performance (Westerhof, K., Creemers, B., & Jong, R. D., 2000).

A typical math teacher in an American high school assigns homework that emphasizes skills, yet there is evidence to suggest that this homework does not maximize students learning potential. There is no standard length of time for homework in a math classroom. Students overall grade may be improved by homework completion, but this does not necessarily cause improvement in math performance (Maltese, 2012).

On the other hand, homework activities which is based on inquiry based learning may be more effective, but quite often there is a reluctance to take risks when faced with problems without teacher assistance. Students have been taught strategies for approaching complex problems but lack the executive function to work through these steps in a systematic manner (Gilbert, 2009).

Research has shown significant improvement on standardized tests when homework is assigned consistently and systematically, with the aim of building important independent study habits in self-regulated learners. (Fernández-Alonso, Javier Suárez-Álvarez, José Muñiz, 2015).

1.8.2. Recommended time to Complete.

For students in their early teens, Spanish researchers determined that reasonable and adequate time be one hour of homework per night, any extra homework time after that and the gains sharply decreases, and have an adverse effect after 90 minutes. How students spent their time on homework was shown to be more important than how long they studied as students who completed their homework assignments autonomously performing on average in the 70th percentile in standardised testing versus students who required external help to complete. (Fernández-Alonso et al, 2015)

1.8.3. Students' Value of Homework is Misunderstood.

The specific learning intentions in a homework assignment of the teacher and the student are not always aligned. Up to 65% of homework done by student across a range of Grade 11 classrooms in a North American study subverted the learning intentions of the teacher. This happens when students do not do their homework themselves but use classmates, tutors or the applications on the Internet to do the homework for them. From the teachers' point of view the student has learned, but in reality they have not. There is a strong correlation between cheating on a homework activity when it is marked for correctness. (Allan, 2013)

Teachers value of homework is also important, when they apply research-based strategies to students homework practice, they will create a classroom of learners who also believe in the importance of the work. (Carr, 2013)

1.9. Feedback on Homework

As defined by Hattie, there are four different types of feedback an instructor can provide for a learner. They are

1. Feedback on the task
2. Feedback on the process
3. Feedback on Self Regulation
4. Feedback that focuses on the self as a person

The most successful feedback builds effective strategies that work regardless of the task and develops self-regulative skills, such as going through a mental checklist of learning aids and heuristics. (Hattie, 2014)

Feedback should be formative to drive further instruction. Students should be given tips on how to improve without having to worry about scores, grades, or other types of formal judgments that may inhibit student learning. Formative feedback need not always come from the teacher, and students can learn a great deal from fellow students' observations and comments during discussions. To make informal assessment valuable for the students, teachers must talk over their observations and resulting insights with their students. (Erlaur, 2003, p.g 117)

There is debate surrounding the comparative benefits of immediate versus delayed feedback. (Shute, 2008, p.g 165, 166) In this study, the KA task offered immediate feedback on the task via the program itself, while further feedback on the task, the process and self-regulation was provided by the teacher to the entire class.

1.9.2. Feedback on the task.

This level of feedback focuses on whether a task is completed correctly, and if done incorrectly, advice to a student about how they might go about correcting it. This type of feedback has been demonstrated to have substantial effects on student performance if it addresses faulty interpretations as opposed to a lack of information.

If a teacher can minimise the time spent between completing an assignment and receiving feedback on the task can maximise the potential of feedback. (Kulik & Kulik, 1998)

When there is too much feedback on the task it can have a negative effect on student learning as the students are focusing on the immediate goal rather than the task itself. Feedback of this type, is focused on the task in hand and often does not generalize to other tasks contained in the same unit (Hattie, 2007).

In the mathematics classroom, the teacher can use educational technology to collate and analyze student work. Various online programs such as Khan Academy completely automate feedback on the task by checking for correctness, by suggesting relevant example videos or by providing hints, (step-by-step instructions on how to complete the problem). Khan Academy cannot identify students misconceptions and explain why the answer selected is incorrect, nor does it claim to do so.

1.9.3. Feedback on the Process.

Feedback at this level focuses on how the student processed information or instructions to complete the task. By focusing on the process, it helps students to develop effective strategies for error detection and providing feedback for themselves. By providing students with effective protocols for approaching mathematical problems, teachers can direct learners to the appropriate strategy to solve a particular problem, with the ultimate goal of learners autonomously deploying appropriate strategies (Hattie, 2007, p.g94).

1.9.4. Feedback on Self-Regulation.

When faced with difficult problems, effective learners create internal feedback and cognitive routines when they are performing difficult assignments.
Students at this age need to be instructed in developing these self-regulation tools.
Scaffolding student learning by explicitly referencing problem solving strategies can help build effective self regulation (Pedaste et al, 2012).

1.9.5. Feedback that Focuses on the Self as a Person.

By praising a students effort or intelligence has been demonstrated to have the least effect on student performance (Hattie, 1990, pg90).

1.10. Aims of the study and research questions

Although Khan Academy promotes Mastery of Learning, it has only been shown to be truly effective in formal intervention programs. It was not feasible for the teacher in the study to place students in these after-school programs. The teacher wanted to ensure that all students could access the material presented during the main lesson. To do this, the teacher needed to accurately assess student prior knowledge and knowledge gained from the previous lesson.

This study compares Khan Academy as a homework activity or as an in class activity. This study considers Inquiry-Based Learning activities as being an alternative homework activity allowing the Khan Academy to be completed in class with teacher guidance and peer assistance.

1. Does IBL activities help students performance on assessments that test conceptual knowledge?
2. Can previewing and prior exposure of the IBL activities and vocabulary involved, counteract Hattie's concerns about inquiry based learning?
3. Does KA activities help to build student procedural skills and fluency?
4. Which activity is best done as a Homework task?
5. Which activity is best done at the start of the lesson?
6. Which treatment can be more succesful for students who are not academically proficient in English?

2. Methods

2.1. Outline

This Experimental study investigated two online tasks
Task 1: Inquiry based learning (IBL)
Task 2: Khan Academy (KA)
It also investigates when each should be scheduled, as a homework assignment or as an in class assignment to be completed at the start of the lesson.
The experimental subjects are 2 classes of Algebra 1 students, from a diverse range of backgrounds in an international high school in Rome, Italy.
One Experimental class did IBL as homework and KA as classwork.
Another Experimental class did KA as homework and IBL as classwork.

Prior to the test, both classes followed the same learning curriculum; students experienced both types of tasks in both homework and classwork in order for them to be familiarized with the situation, but did not follow a consistent lesson to lesson schedule.

This pre-experiment test determined the control group for both experimental classes. A two sample t-test for independent means show that there is no statistical difference between the classes at this stage.

All students generally perform well on questions that test procedural knowledge, but there is a wide performance range on questions that test conceptual knowledge, despite students having answered similar questions in class discussions and in group based tasks.

When assessed as an individual they were unable to apply strategies that worked in a group. The goal of this study is to compare and contrast two tasks that can be assigned as homework or as a start of class activity with the implicit goal of improving their score on conceptual knowledge.

Improving students performance on conceptual knowledge is important not just for their better understanding of the topic but also to improve students performance as reflected in SAT math exam which all students in the study will take two years later (CollegeBoard, 2017).

2.2. Participants

The participants for this study are students in 9th grade studying Algebra 1 in a private, American style, international high school in Rome, Italy. Students in both classes are between

13 and 15 years old. All students have access to a laptop. Classes meet every second day and have the same teacher.

Experimental class 1 completed IBL as homework and KA in class.

Experimental class 2 completed KA as homework and IBL in class.

Class 1 has 24 students. Mean age is 14.25 with a Standard Deviation of 0.532

Class 2 has 19 students. Mean age is 14.37 with a Standard Deviation of 0.496

33 of the 43 students involved in the study completed a Measure of Academic Progress test at the end of year 8. This test showed that 76% of the students at or above grade level in math, and 70% at or above grade level in reading, language usage and writing.

Students were heterogeneously placed into these two classes to fit their schedule based on their elective subjects. As such there was a wide range of abilities in the classes. Both of these classes have a similar distribution of prior test scores.

Although the language of delivery is in English, around 70 % of the students are non-native speakers and are classified as English Additional Language (EAL) learners. All students are conversant in English. However, It was observed by the teacher that approximately 50% of students regularly discuss math problems in their first language despite being explicitly encouraged by the teacher to discuss their work in English, the language of instruction and assessment.

2.3. Experimental Time Frame

For the past seven months, both classes have followed the same schedule of class and homework material. The teacher has been demoing both inquiry-based learning activities and Khan Academy activities as homework and classwork, to familiarise students and to develop teacher skills in anticipation of the experiment.

The assigned time for both activities was 15 minutes. Students were encouraged to stick to this time frame, but the researcher is unaware of whether students adhered to it when completing the IBL homework task. The teacher informed the students that the quality of the homework done that is important, rather than the amount of time spent on homework.

The recommended time for each homework activity is 15 minutes, and each class takes place for 80 minutes. Each period of learning takes place over 95 minutes. The experiment took place over seven lessons, and the first six lessons followed the schedule outlined below. The end of unit assessment took place in the last lesson, and this was the post-test data. The students are studying exponential functions.

An explicit purpose of both the IBL and the KA tasks was to give students prior exposure to the material they will be completing during the main body of the lesson. The main body of the lesson follows a highly recommended Algebra 1 Math curriculum, the Mathematical Visions Project. (Mathematics Vision Project Integrated series, 2016).

Table 1. Class schedule

Task		Where	Time
Class1:IBL task	Class2:KA task	Homework	15 minutes
Class1:KA task	Class2:IBL task	In class-Start of the lesson	15 minutes
Homework Review		In class	5 minutes
Group Project Based Tasks, class discussion, explicit instruction and procedural skills		Majority of the Lesson	55 minutes
Homework Preview		End of Lesson	5 minutes

2.4. Proposed Tests and Hypothesis.

Prior to the start of the experiment, the teacher suspected and a 2 sample t-test for independent means on students previous units test confirmed that both classes scored similarly on procedural, conceptual knowledge, and their combined score. This is the control data.

These two classes will be compared in the same manner at the end of the experiment. The null hypothesis is that there is no significant difference between the two classes at the end of the experiment.The alternative hypothesis is that there is a significant difference between class one and class two.

The researcher believed that EAL issues affected student performance on the test as such both classes were split into two blocks, to investigate the effect of this confounding variable on the study. The teacher split both classes into two blocks, proficient and novice to investigate the effect of this confounding variable on the study.

Proficient: Native English speakers and EAL students who spoke exclusively in English.

Novice: EAL students who regularly discussed assignments in class in Italian or Spanish

2.5. Pre-Test and Post-Tests Assessment-

The end of unit assessment was similar to past unit assessments. The test consisted of two equally weighted parts. (See Appendix1)

Part 1: Procedural Assessment

There were 5 questions worth 10 marks each on the Quadratic Functions test,

There were 6 questions worth 6 marks and 2 questions worth 7 marks on the Exponential functions test similar to questions that students completed on KA and in class.

Note: The difference in the number of questions was due to the expected length of time to complete these questions.

Part 2-Conceptual Assessment

There were 5 problems on both tests that assessed students conceptual understanding of homework and material covered in class.

2.6. Materials

2.6.1. Task 1: Interactive Online Inquiry based Learning.

This study used technology to select existing inquiry-based learning (IBL) tasks, tinkering with them if necessary or designing appropriate IBL tasks from scratch.
Some of these assignments were posed as questions in Google Forms and posted on the Google classroom. Student responses were collated and available to the teacher. Other tasks took place on Desmos, an online graphing calculator with onsite activities designed to improve students inquiry and communication skills.
When IBL was assigned as a homework activity, new vocabulary was introduced and defined during the homework preview section at the end of the previous lesson. When IBL was assigned as an in class activity, this preview happened at the start of the lesson, immediately before students got started on the task.
Examples of Inquiry based tasks used in this unit. (See Appendix 2)

1. Comparing sizes of Data plans on the phone. Students were asked to estimate how much data they use on their phone. What is a GB,MB,KB? How are these abbreviations related to powers of 2?

2. Investigating how the graph of an exponential function changes as the variable within the function change, when given the following function.

$$f(x) = a\left(1 + \frac{r}{100}\right)^t$$

Students used the online graphing program Desmos, to graph this general form of an exponential function. Desmos allows the users to set up moveable sliders for the variables a and r. Students had to investigate, how does the graph change as the values of a and r change? What does a and r represent? Desmos records students answers to allow the teacher to develop their formal mathematical language from their informal language at this stage.

3. Finding real life examples of exponential decay functions, when given real life examples of exponential growth functions on Quora.

4. Using a teacher designed Google Sheet template to investigate simple versus compound interest.

5. Marble slides on Desmos. A game designed for students to learn how to transform the basic exponential function, and to develop their language for describing these transformations. (Desmos, 2018)

2.6.2. Task 2: Khan Academy Tasks.

The second activity is assigned exercises on Khan Academy. Assignments were selected by the teacher to assess students prior knowledge and understanding of material covered in the course curriculum. Hints and optional videos were available to the student. Students could retry the activity several times if they wanted to, but the expected completion time was 15 minutes.

A short survey amongst students in this study indicates a slight preference for instructional text over instructional video, although there was considerable difference. This study did not assign videos on KA for homework or in-class activity, although they were not discouraged from doing so.

Students were allowed to listen to music in class if they wanted, a playlist rule was implemented at the lend of the first lesson as students had spent too much time choosing music and some used this as an excuse to try and watch music videos.

The proportion of students who were listening to music and the length of were not measured as it was predicted to be inconsistent.

At the end of the activity, the teacher provided class feedback on the task, correcting common misconceptions.

2.6.3. Scaffolding Strategy: Problem Solving Toolbox

Throughout the course of the experiment students were encouraged to follow the following protocols when faced with a difficult problem. These were displayed in large print at the front of the classroom and all students had copies in their folders to use. When students asked questions in class they were directed to specific statements while the teacher elicited verbal responses.

Problem Solving Toolbox

Step 1: Evaluation

- Look at the problem.
- Have you seen a similar problem before?
- How is it similar? How is it different?
- What facts do you have?
- What do you know that is not stated in the problem?

Step 2: Select your Tool/Tools

- Compute or Simplify.
- Use a Formula
- Draw a Diagram or a model
- Make a table, Chart,list
- Make an Educated Guess, and check
- Ask a simpler question
- Eliminate
- Look for Patterns

Results and Discussion

Table 2. Descriptive statistics of groups in class 1 and class 2 and the results of a t-test for differences between groups in the two classes.

	Class 1			Class 2			t-Test Statistics					
	Group A	Group B	Group C	Group A	Group B	Group C	Group A		Group B		Group C	
Test	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	t	p	t	p	t	p
Pretest												
Procedural knowledge	39.46 (7.5)	39.92 (7.9)	38.91 (7.3)	36.63(5.9)	36.88(5.8)	36.4 (6.2)	1.35	.185	0.98	.337	-0.65	.5232
Conceptual knowledge	26.67 (13)	32.85(13.5)	19.36 (8.2)	29.21(11.1)	32.88(11.2)	25.9 (10.5)	-0.68	.502	-0.01	.994	-1.6	.1265
Total	66.13 (18)	72.77(18.6)	58.27(14.3)	65.84(14.5)	69.77 (14.8)	62.3 (14.1)	0.06	.956	0.40	.693	-1.93	.0692
Posttest												
Procedural knowledge	42.25 (2.9)	42.85 (2.4)	41.55 (3.4)	37.79(6.1)	34.55 (7.2)	36.2 (5.8)	3.17	.0029**	1.74	.097	2.61	.0171*
Conceptual knowledge	41.5 (5.2)	43.46 (4.6)	39.18 (5.1)	31.26(10.4)	36.4 (6.3)	28.3 (12.2)	4.22	.0001**	3.57	.0019**	2.71	.0138*
Total	83.75 (6.7)	86.37 (5)	80.73(7.35)	69.05(13.6)	74.1 (10.3)	64.5 (15.1)	4.65	.00004**	3.72	.0013**	3.2	.00049**

Note. *$p < 0.05$, **$p < 0.01$.
Group A = both high and low ability English speakers, Group B = high ability English speakers,
Group C = low ability English speakers.

Analysis of results

Results from the PreTest indicate that students from both classes have similar procedural scores in both classes, this is true for both proficient English speakers and novice EAL students.
However, the novice students in both classes performed significantly worse on conceptual questions compared to proficient students.
Referring to the questions posted at the end of the literature study, PostTest data indicates the following.

1. Does IBL activities help students performance on assessments that test conceptual knowledge? Possibly, Data suggests that if this is done as a homework activity, then students are more successful when completing conceptual tasks.
2. Can previewing and prior exposure of the IBL activities and vocabulary involved, counteract Hattie's concerns about inquiry based learning? Yes, when completed as a homework activity, students were more engaged in this prior exposure, possibly because of when this happened.
3. Does KA activities help to build student procedural skills? Possibly, but only when students interact with the material in the correct manner, by making notes of their mistakes, writing out calculations if appropriate. Procedural skills were worked on using pen and paper in previous units and students were moderately succesful, however they did not get the immediate feedback that KA provides.
4. Which activity is best done as a Homework task? Interpretation of these results indicates that the students involved are more likely to be successful on conceptual activities if they complete the inquiry-based tasks for homework.
5. Which activity is best done at the start of the lesson? The KA task is best done at the start of the lesson, for reasons outlined below.
6. Which treatment can be more succesful for students who are not academically proficient in English? The results from the PostTest shows significant improvement in both sections of the test for Class 1 in comparison with Class 2. The results also show little difference between the proficient and novice students in Class 1, while this difference is still present in Class B.

Below are possible reasons for these answers.

Better Opportunities for Feedback

Class feedback on the IBL tasks focused on students process and self-regulative skills. The teacher suggested and elicited strategies on how students may approach similar tasks.

Students who had struggled on the IBL task worked on the problems in a small group with a student who the teacher had identified as performing well on the task. These students completed their KA task outside of the class scheduled time.

Although KA can provide feedback on the task by instantly assessing the veracity of an answer, it is impossible for it to provide accurate feedback on the process as it cannot identify the causes of student error correctly, as it is merely operating in a limited if-then loop. Although the quality of hints on KA is continuously improving, this feedback is not efficient as it does not ask calibrating questions to identify student misconceptions nor does it understand students methods for solving a mathematical problem.

Building students self-regulative skills.

On the contrary, when students were working on KA tasks in class and got a question incorrect, in addition to the hints available to them, they also had the teacher or their student peers available to assist. The role of the teacher is quite nuanced at this point providing differentiated instruction in response to student's skills and needs. Students were referred to the problem-solving toolbox while the teacher was giving feedback on their process.
Some students working on KA in class were receptive to teacher suggestions to follow strategies in the problem-solving toolbox, as the unit progressed students learned to follow these strategies without intervention, while some students engaged with the hints on KA but as they knew that their time on KA was fixed, they did not rush through the hints to find the correct answer. Most students did a combination of both but because there was such a wide variance this was not recorded. Whether the strategies listed in the toolbox are more succesful than hints provided by KA is a proportion that could be studied.

The figue below indicates how KA provides hints to change a conceptual problem into a procedural problem. Had the student engaged with strategies from the problem solving toolbox, he could have used several methods to solve it, such as making a table, drawing a graph, using a formula. The Common Core standards state that mathematically proficient students "look for and make use of repeated stucture" (Common Core State Standards Initiative, 2018). By engaging with the hint, the student it is not clear what if anything the student has learned, if they had engaged with the Problem-solving toolbox could they have figured out the answer by themselves? This is a suggestion for further study.

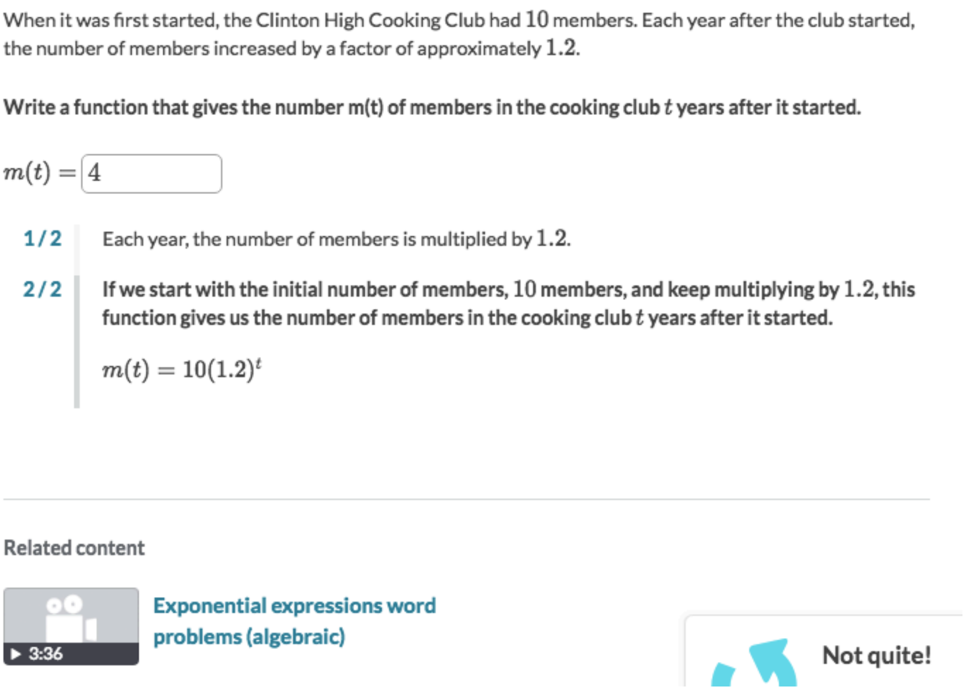

Figure 2: Example Conceptual problem in Khan Academy with hints

"Whether students engage in error correction strategies following error detection depends on their motivation to continue to pursue the goal or to reduce the gap between current knowledge and the goal" (Hattie, 2017, p.g 94). The teacher suspects that many students who attempted KA at home did not follow the strategies in the problem-solving toolbox nor did they engage with the hints correctly as they could have rushed through the hints so that they could complete the homework quickly.

Guaranteed time spent on KA, fixed length of time for IBL task.

Sal Khan suggests that Khan Academy should only consist of 15% instructional time (Sal Khan, 2013). Students do not arrive in class as one group, Some students come early, and others arrive slightly late. Students who completed KA tasks at the start of the lesson opened their laptop and got started with little direction from the teacher. The order imposed by the familiarity of the KA tasks was a more efficient use of time than in the IBL class.

A few students who worked on KA in class returned to their problems outside of class time. All students who were absent from class for vacation, sport and illness reasons from class completed assigned activities outside of class time. Students who arrived late also caught up to the minimum expected time. This may be because of familiarity with the completion of KA tasks and is a suggestion for further study.

Analysis of student time spent on KA for homework designed to be completed typically in 15 minutes showed a wide variety of time spent on these tasks.

For a minority of students in the KA class, the opposite is true. On inspection of their time spent on Khan Academy, they had spent more time than the rest of the class significantly. When questioned about this, they responded that they enjoyed watching the videos as they could pause it and rewind it if needed.

Providing students and parents with clear guidelines as to the expected length of time for homework may be useful in increasing completion rate (Carr, 2013). The IBL tasks where designed by the teacher to take a typical student 15 minutes to complete and students were informed of this time expectation. However, time spent on these tasks as homework was not controlled. Further study can determine how long students spent on these tasks.

When the students were working on the IBL problems in class, some students would wait until teacher intervention or peer assistance before beginning their inquiry, when faced with an unfamiliar situation students were reluctant to engage with the problem-solving toolbox to solve these IBL, again looking for peer or teacher assistance.

More signal less noise

The information-action ratio is a concept explored in the book "Amusing ourselves to death" by cultural and educational critic Neil Postman. In the distant past, humans received a low information-action ratio as time moves the amount of information has been increasing (Postman, 1986). To avoid being overwhelmed with information, it is essential that teachers are selective with the data they are using, when they are using it and how to use it.

When KA tasks happen as a homework task, it is, impossible to identify if somebody else completed the task for the student. The teacher was not convinced that all students had completed all activities independently based on student observation on assignments during the rest of the lessons, for example certain students claimed to have no idea on how to solve problems that they had "mastered" in KA for homework. Having unreliable data negates the purpose of its collection and analysis. On the contrary, by analysing student responses when the IBL task was completed for homework, it was more apparent whether students had completed these tasks by themselves. When KA happened in the classroom, it provided the teacher with a more controlled assessment of student learning and prior knowledge.

Supporting EAL students learning

Research has demonstrated that English language learners acquire social language skills before academic language (Barrow, 2014). The students who routinely use English to discuss word problems performed statistically better in the class who completed IBL for homework and KA in class. While the IBL task was being previewed, the homework paid more attention to new vocabulary and how to interact with Desmos versus the class who had this preview at the start of the lesson.

Limits of the study and Recommendations for Further study

Although the sample sizes of the two classes were too small to generalize to the population they are quite useful for the teacher who will teach Algebra 1 to new students, with a similar demographic next year. The results from the study suggest further investigation and direction for the teacher to further customize best practices for homework and time spent online.

It is important to note that overall better scores on the post test in comparison with the pre test may be indicative of an easier test, a more consistent schedule or students making more connections with previous units, and being more familiar with function terminology. The teacher may also have been more observant of students.

Although the study could not measure the effect of scheduling either task in isolation, further studies may randomly block students within each class to either treatment, it does measure the combined effect of placing these two tasks in a specific order.

The results re-affirmed the teacher's belief that students use of English, the language of instruction and assessment is vital for students to understand and use appropriate mathematical language. Expressing one's ideas in mathematics may be difficult for students learning an abstract topic, but more consideration of developing academic language needs to be taken into account by the teacher. Strategies for building this academic language are useful not only for EAL learners but for all students.

In the future, the teacher will plan groupings to minimise the proportion of students who are not speaking English. A suggested unit project for students is a personal text/image/video blog designed by directly adding answers from IBL tasks, building a personal dictionary by adding text, images or instructional video links from KA if appropriate to students learning style or interests. Students can also add notes on how to answer different questions. Students can use this as a reference guide throughout the unit and as a study guide before the end of unit and semester tests.

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Author's declaration

I hereby declare that I have written this thesis independently and that all contributions of other authors and supporters have been referenced. The thesis has been written in accordance with the requirements for graduation theses of the Institute of Education of the University of Tartu and is in compliance with good academic practices.

Signature: Date:

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Appendix 1.Pre and Post Test

PreTest

QuadraticFunctions Name____________________________________ ID: 3

ProceduralKnowledge-10 pts per question Date________________ Period____

Solve each equation by taking square roots.

1) $7v^2 + 1 = 8$

Solve each equation by factoring.. Sketch a graph, indicating the x-intercepts and the vertex.

2) $x^2 + 2x - 24 = 0$

3) $n^2 + 4n = 0$

Solve each equation by completing the square. Sketch a Graph, noting the vertex and all the intercepts.

4) $v^2 + 10v - 75 = 0$

Solve each equation with the quadratic formula. If necessary leave your answer in radical form,

5) $11n^2 - 10n - 17 = 0$

Part 2: Conceptual Understanding- 10 marks per question.

1.The Discriminant: Sketch a quadratic function when

$b^2-4ac>0$

$b^2-4ac=0$

$b^2-4ac<0$

Write a quadratic equation to solve the following questions.

2.A certain number added to its square is 20. Find the number.

3.The product of two consecutive even integers is 80. Find the integers

4.The ages of three family children can be expressed as consecutive integers. The square of the age of the youngest child is four less than five times the age of the oldest child. Find the ages of the three children.

5.The side of one square is 5 centimeters longer than the side of the second square. If the sum of their areas is $125cm^2$, find the length of the side of each square.

PostTest

ExponentsTestPt1 Name____________________________________ ID: 1

qn 1-6=6pts each, qn5-8=7 pts each. Period____

Simplify. Your answer should contain only positive exponents. Show all your work.

1) $2^3 \cdot 2^{-3}$

2) 3^{-2}

3) $\frac{3^4}{3^2}$

4) $(yx^{-1})^{-1} \cdot x^0 y^2$

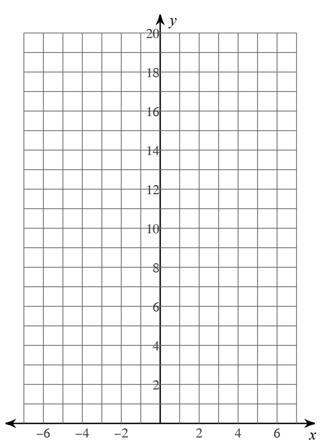
Simplify the following radicals.

5) $\sqrt{24}$

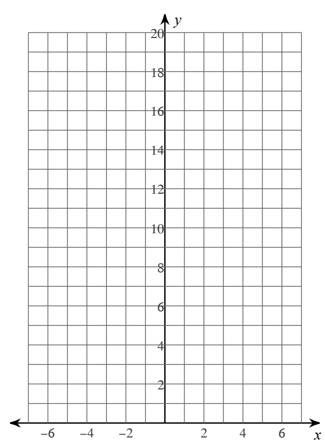
6) $\sqrt{200}$

Sketch the graph of each function. Create a table of values to help you.

7) $y = 4^x$



8) $f(x) = 3 \cdot \left(\frac{1}{2}\right)^x$



Part 2: Conceptual Understanding- 10 marks per question.

1.<u>Linear, Quadratic or Exponential</u>

Identify the Linear, Quadratic, and the Exponential function

Explain your selections.

Find the explicit equation, for each function.

x	0	1	2	3	4	5
f(x)	-5	-1	3	7	11	15
g(x)	0	1	4	9	16	25
h(x)	1	3	9	27	81	243

2. Which of the following functions show exponential growth and which shows exponential decay. Give a reason for your answer.

$$f(x) = 100(0.5)^x \qquad g(x) = 0.5(1.2)^x$$

3. A population of 800 rabbits on the island of Sicily is growing each month at a rate of 20%.

a) Write an equation that expresses the number of rabbits at time x.

b) About how many rabbits will there be in 3 months?

c) Can this growth rate increase forever? Why or why not?

4. 128 single tennis players are in a tournament.

Every round, half of the players are eliminated..

The tournament continues, until there is only 1 winner.

How many different rounds are there in the tournament?

Write an exponential function to model this situation.

How many different matches will be played?

5. The side of square A is 10 centimetres. Find its area.

Constuct this square on the provided graph paper.

Draw a square B that has an area of exactly 200 metres squared, on the same graph paper. Label the sides with the exact values.

Appendix 2. Sample Inquiry Based Learning Tasks

1.Mobile Data inquiry

Qn1: How much data per month do you need for your phone?

Your answer

Qn2: How many bytes of data are in 1 gigabyte of data?

Your answer

Qn3: Can you describe two different ways to answer the previous question?

Your answer

Qn4: How many bytes of data do you need for your phone?

Your answer

Send me a copy of my responses.

SUBMIT

2.Real life examples of exponential decay inquiry

ExponentialFunctionsHW2 Form

Here are some examples of exponential growth

https://www.quora.com/What-are-some-real-world-examples-of-exponential-growth?utm_medium=organic&utm_source=google_rich_qa&utm_campaign=google_rich_qa

Your task is to find 5 examples of exponential decay, that you think no-one else in the class will think of.

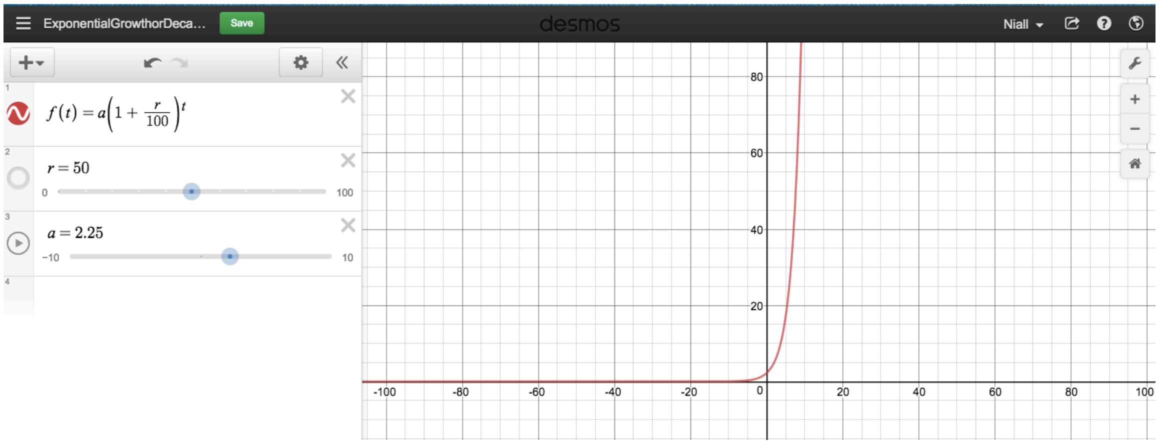
What is your name?

Your answer

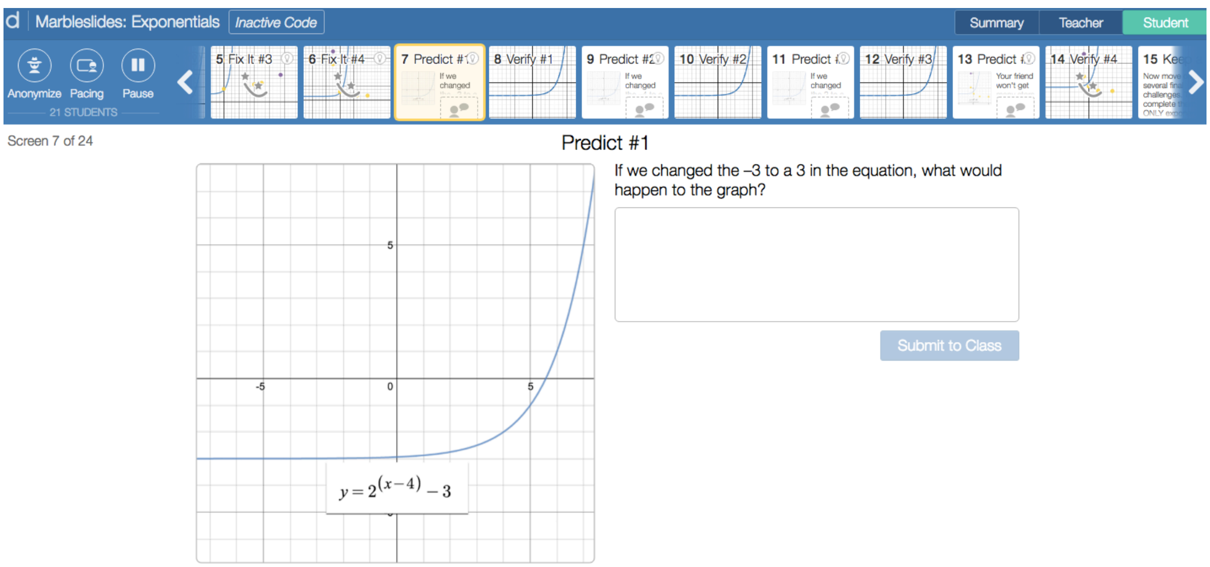
Post your answer here.

Your answer

3. Format of the exponential function.What happens when a and r change?



4.MarbleSlide inquiry. How can we transform exponential functions at will?



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