

GraphMaster Final Report

Katarina Gram, Teresa Lo and Aiping Xiao

Word Count: 2488

Permissions:

Publicly release the code - No

Publish video and report - Yes



Introduction

GraphMaster is an educational app which teaches students how to line graph.

As a science teacher and department head Katarina has taught graphing as a skill to students and designed integration across grades and subject areas for it. She has seen how in the traditional classroom students struggle significantly with learning to graph. Many students never fully master or even understand the basics of graphing, getting by with only a superficial understanding, despite a deep need for students to be able to understand graphs in today's data driven society.

This difficulty with teaching and learning to graph is due to a number of reasons:

- Graphing is not a single skill, but a multi-step process which requires a variety of skills, such as determining the independent variable or calculating an axis' interval. Students must be able to do each skill effectively and in sequence to create a single graph.
- In a single classroom there will be significant diversity in students' graphing ability, but a teacher still has to meet the individual needs of each student. Differentiating instruction is both challenging and time intensive.
- Teachers often only provide feedback to students after an entire graph has been created and may take days to mark a graph and tell students where they struggle. Because each step in graphing is a site for error there is a need for timely feedback on each step, but this volume of feedback is simply not possible for already overworked teachers.

GraphMaster aims to create a more effective graphing learning process by eliminating these challenges.

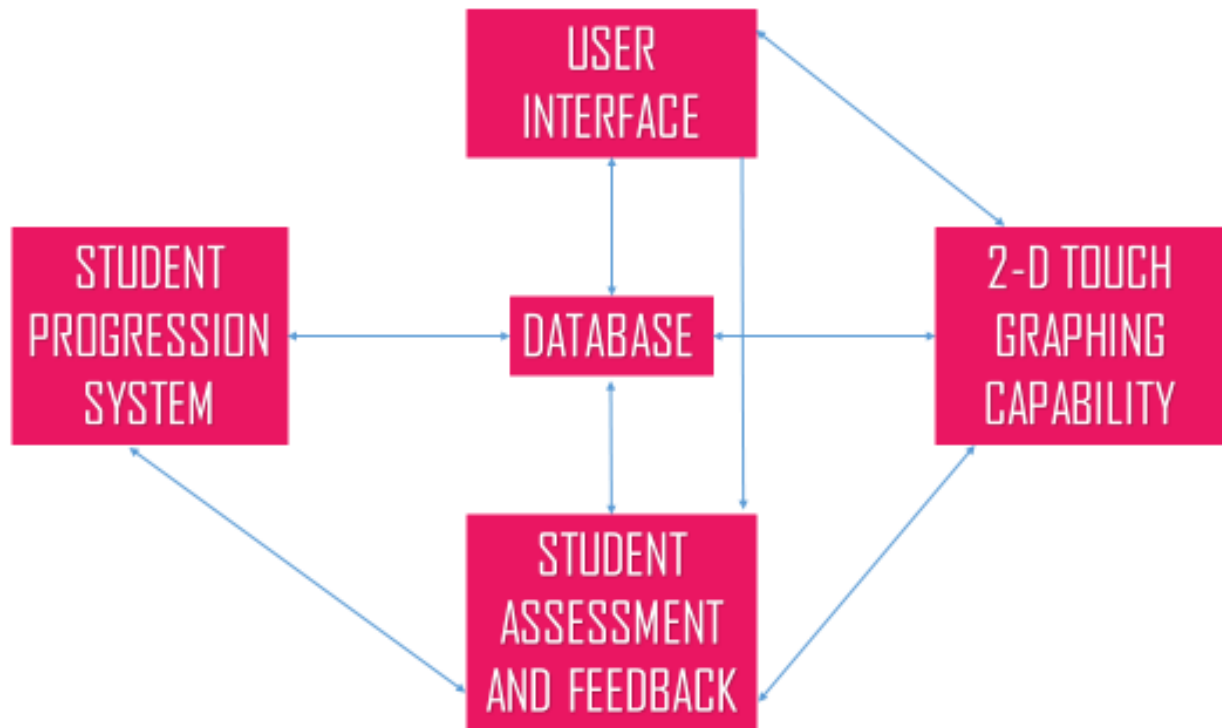
With GraphMaster learning is individualized. Students begin at a level appropriate to their background. The app measures a student's performance and determines their needs, moving students to more challenging questions when they have mastered a certain level of difficulty or to easier questions if the student is struggling significantly. Learning occurs at the fine line between challenge and attainability where students learn best.¹

With GraphMaster feedback is given on each step of the graphing process. The app assesses students on each individual skill, such as the ability to plot a point or calculate the interval. If incorrect students can learn how to complete the step correctly through video, image and text lessons specific for that individual step and question. Before proceeding to the next step, students correct their answer using their new found understanding of how to do the step.

¹ McLeod, S. (2012). Zone of Proximal Development. Retrieved April 07, 2016, from <http://www.simplypsychology.org/Zone-of-Proximal-Development.html>.

With this built in support, as well as a separate Learn to Graph video library which teaches the graphing process from start to finish, GraphMaster can be used as a stand-alone replacement for classroom instruction, or as part of regular classroom activities.

Design



Database: Contains practice questions, answers, links to videos and teaching content. The database communicates with all other parts of the app, which communicate back.

2-D Touch Graphing Capability: Allowing students to plot points on a graph requires control of graphical input and output with a deep connection to the graphics underlying the touch interface. Information on what is an appropriate graphical input for the user comes from the database, and the user's input is validated against it.

Student Assessment and Feedback: As students answer a question the system (drawing from the database) responds to the input, providing feedback on their progress. For certain types of questions students must self-assess their answers. At times more than one response is appropriate and the database adjusts based on which answer is given.

Student Progression System: Based on a student's progress on a question a simple algorithm calculates and moves students to a new question of appropriate difficulty level for their learning needs.

User Interface: Child friendly interface which displays the main question and each graphing sub-step, while providing feedback as students answer. Generates dynamically different types of answer selection (ex. radio button or textbox) based on the type of question.

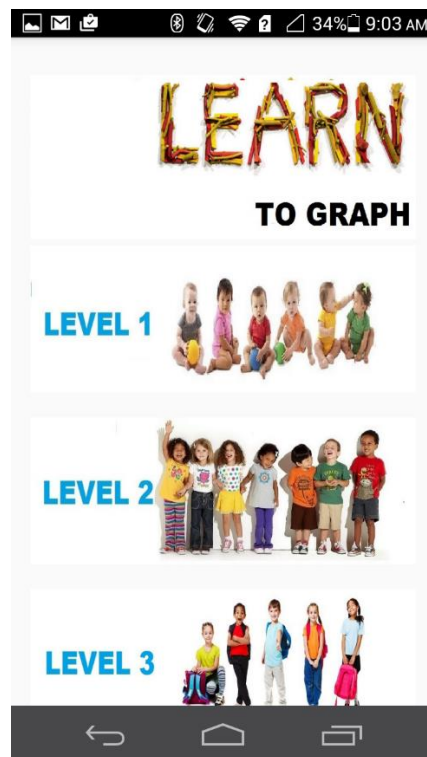
Statement of Functionality

Entering GraphMaster:

Students open GraphMaster because they are looking for more support on learning to graph.

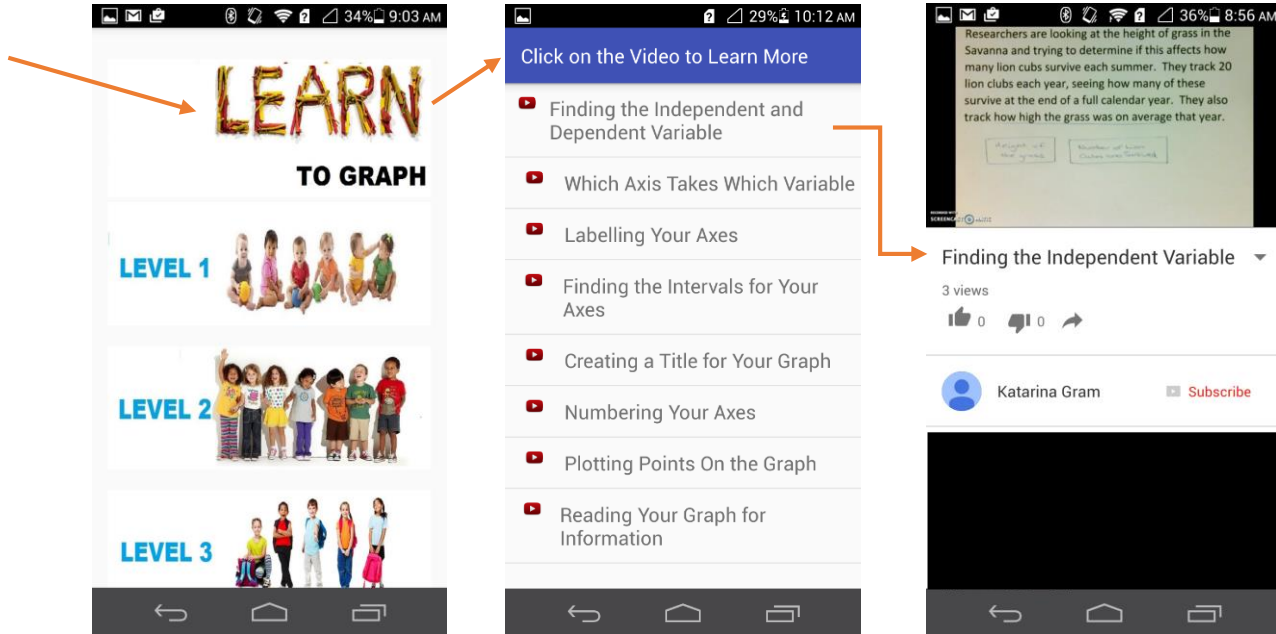


The app opens to the main menu.



Supporting the Learning of Graphing:

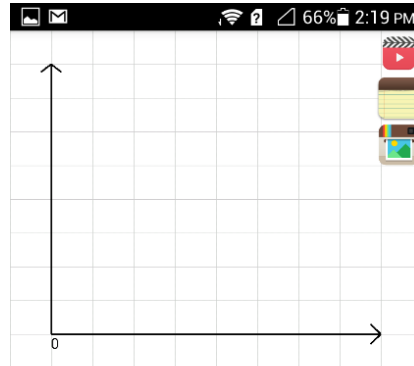
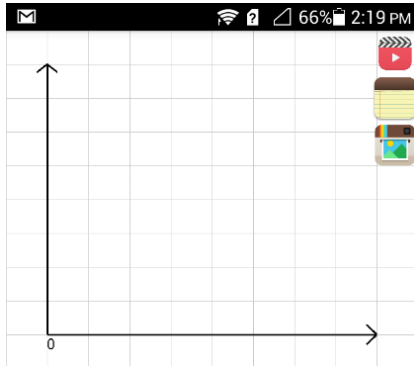
If students are struggling with the core concepts of graphing, or have no prior knowledge, they can open the *Learn to Graph* video library on the main page and from there learn the individual steps through a video lesson.



Practicing Graphing

The core function of the app is to allow students to practice graphing. When they enter the app students choose their level of difficulty based on their prior knowledge and work through the steps of graphing sequentially to create a final graph.

The same main question (with its accompanying data table) and a grid where the graph will be created appear at the top of every step in the graphing process.



A group of students are testing how many snails can cross the finish line in one minute, depending on how many snails actually compete in the race. They hypothesize that if there are more snails at the starting line of the race, then there will be less snails that finish by the end of a minute; they think the snails will bump into each other and get off track and the more snails there are the more likely they are to bump into each other

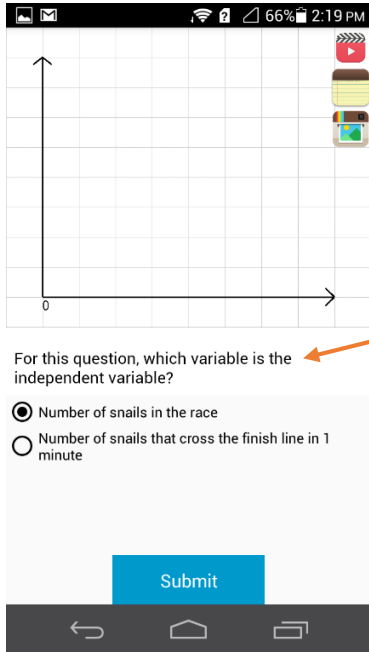
Number of snails in the race	Number of snails that cross the finish line in 1 minute
1	1
2	1
3	2
4	4
5	3
6	6

Number of snails in the race	Number of snails that cross the finish line in 1 minute
1	1
2	1
3	2
4	4
5	3
6	6

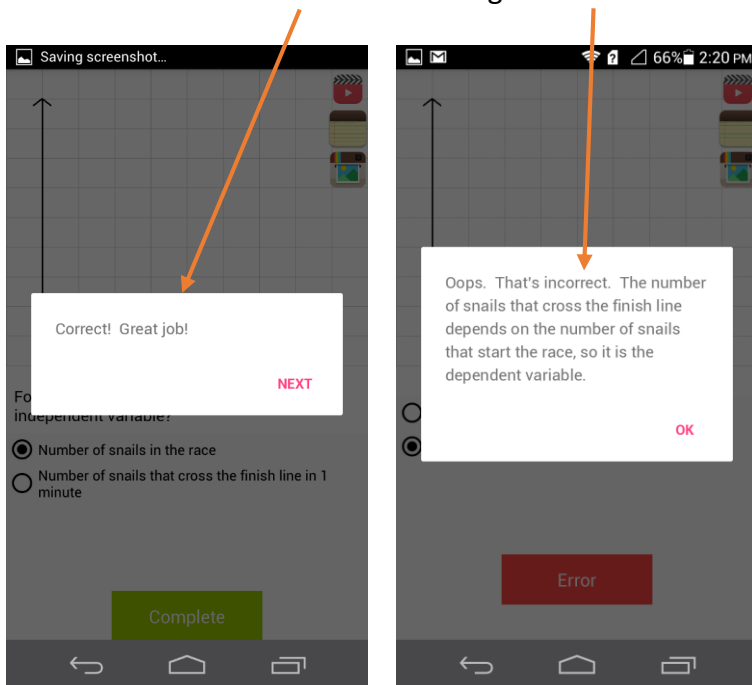
For this question, which variable is the independent variable?

Students work through each of the steps of graphing in sequence.

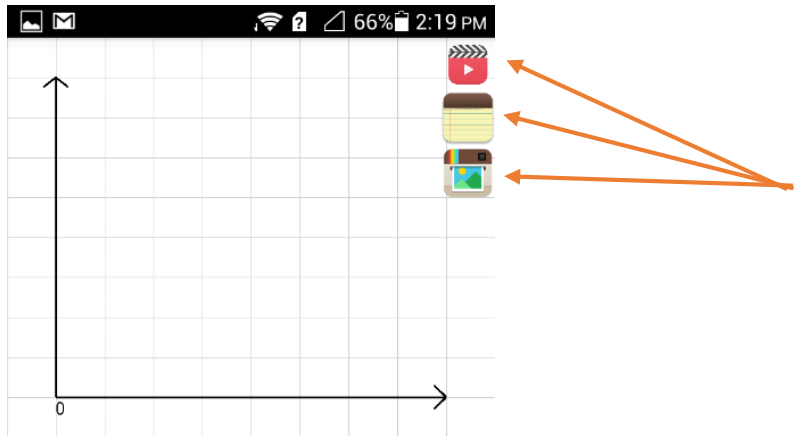
Finding the Independent Variable:



For each step (except writing axes labels and the title) the app will let students know if they have achieved the correct answer or guides them in finding the correct answer.



If students don't understand how to complete the step they can use the teaching tools in the top right corner: videos, text lessons or PDF images of the graph and calculations. This content is specific for each individual step and question.



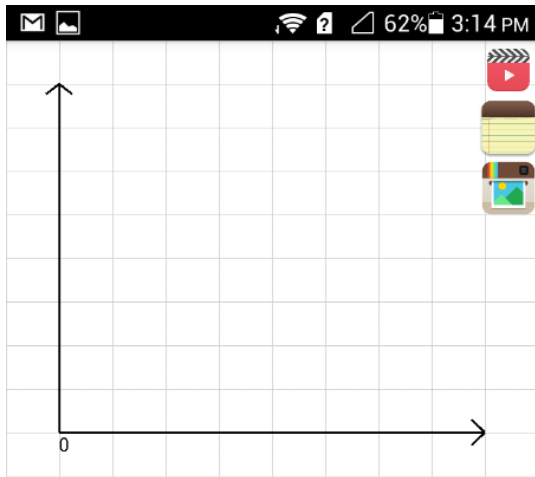
For this question, which variable is the independent variable?

- Number of snails in the race
- Number of snails that cross the finish line in 1 minute

Submit



Knowing Which Axis to Put Which Variable On:



Which axis does the dependent variable go on?

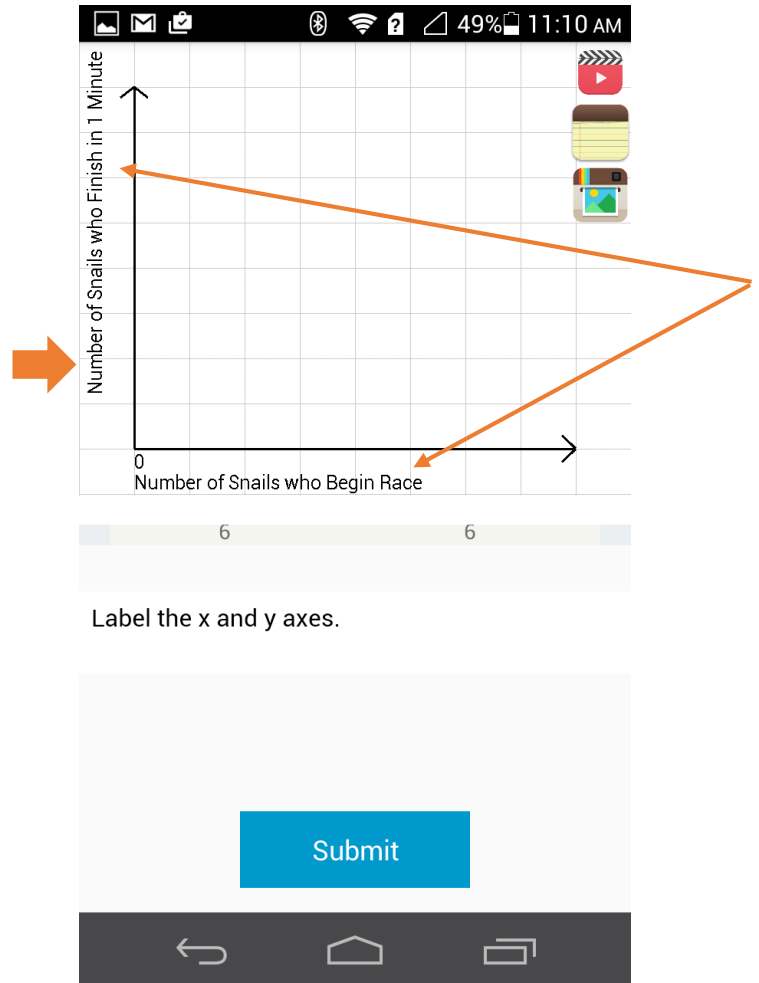
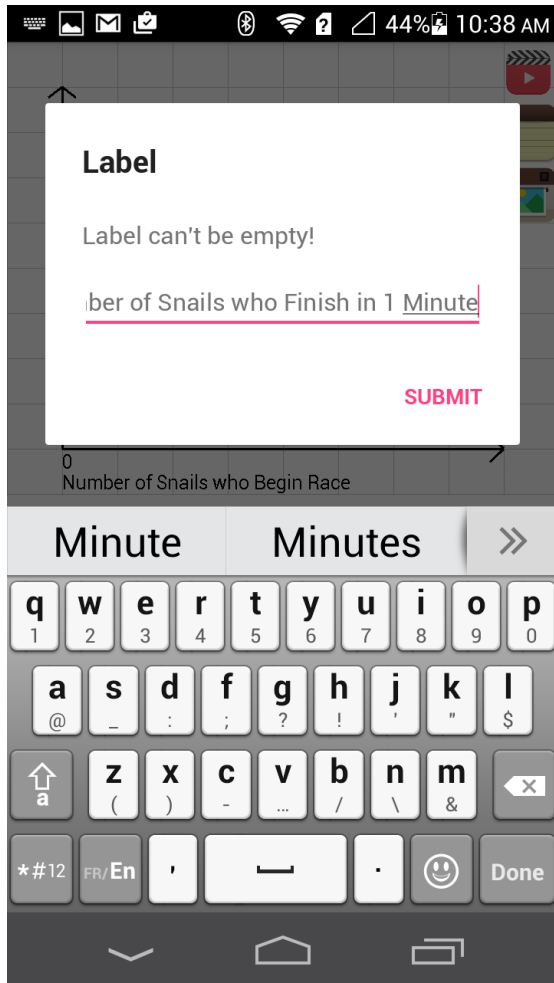
- The x-axis
- The y-axis

Submit

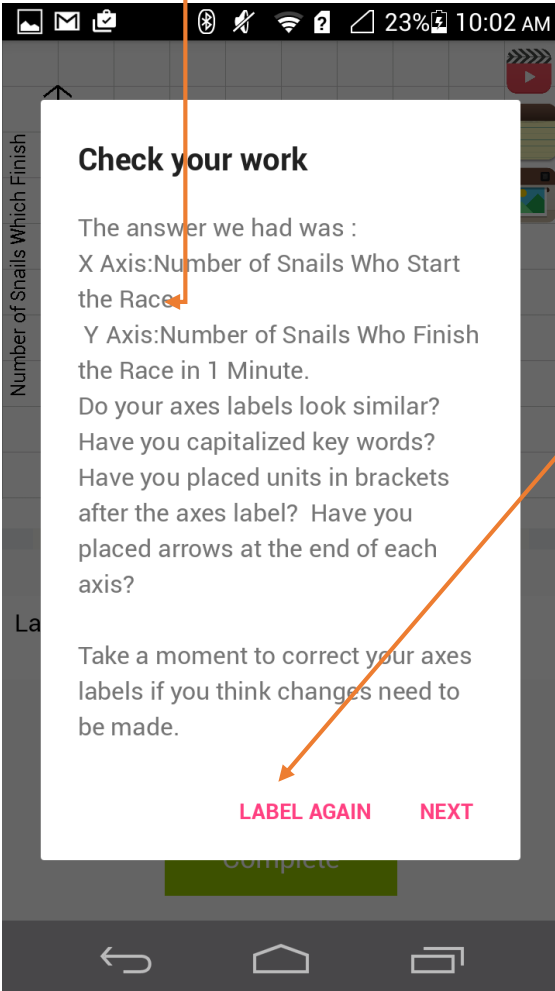


Writing Labels for the X and Y Axes:

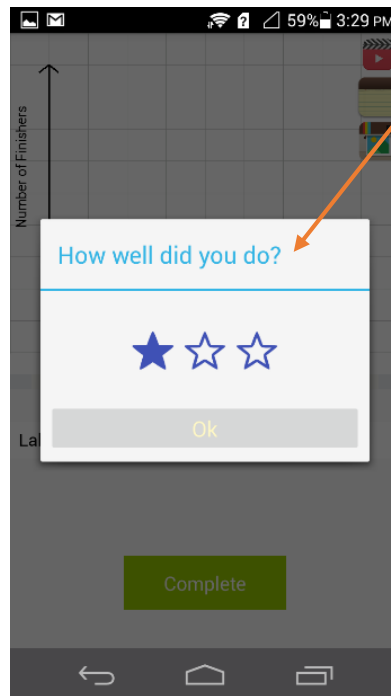
Students tap where the axis label is supposed to go on the graph and are able to enter the label, which appears on the graph



When writing axes labels (and later the title) there is no 100% correct answer the app can verify against. The app therefore asks students to self-verify their answer. The student sees an exemplar answer and guiding questions, and based on these can go and make changes to their answer if they feel they need to.



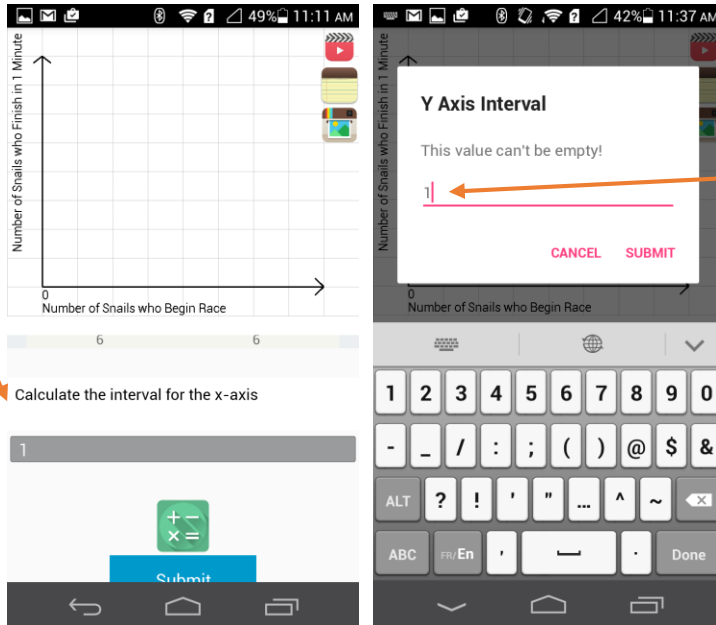
Students are then asked to mark themselves on how they did, which the app uses in determining their progress. This type of self-assessment, known as assessment as learning, is a very effective way to learn and a key skill for students to develop.²



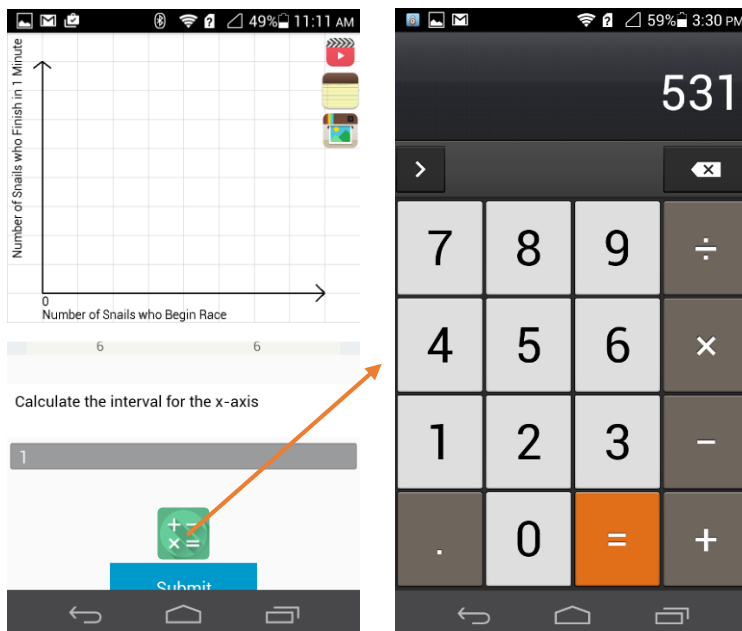
² Ontario Ministry of Education. (2010). Growing Success: Assessment, Evaluation, and Reporting in Ontario's Schools. Retrieved April 07, 2016, from <https://www.edu.gov.on.ca/eng/policyfunding/growSuccess.pdf>

Calculating the Intervals for the Axes:

Students determine what interval is appropriate for each axis. At times there is more than one correct answer that a student could calculate. The app will accept all correct answers and use the answer given as the basis for grading in later steps.

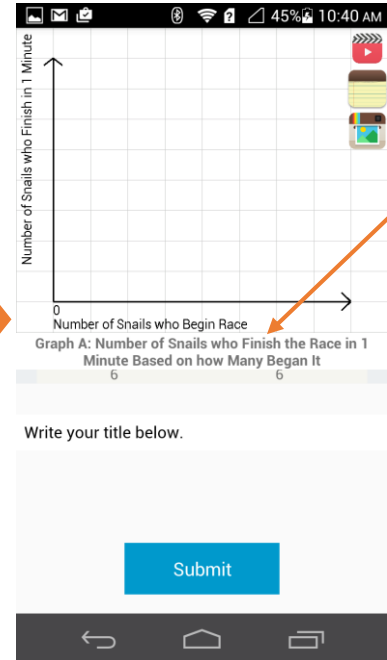
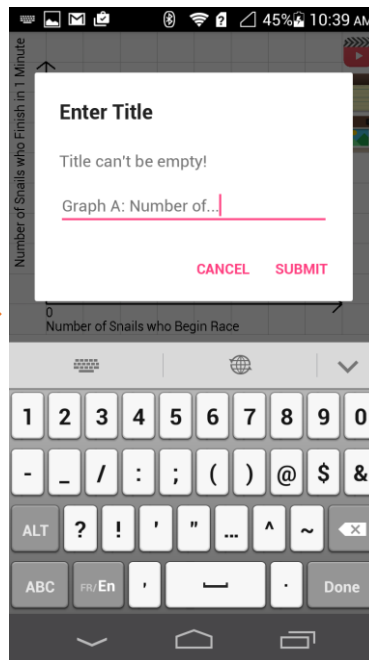
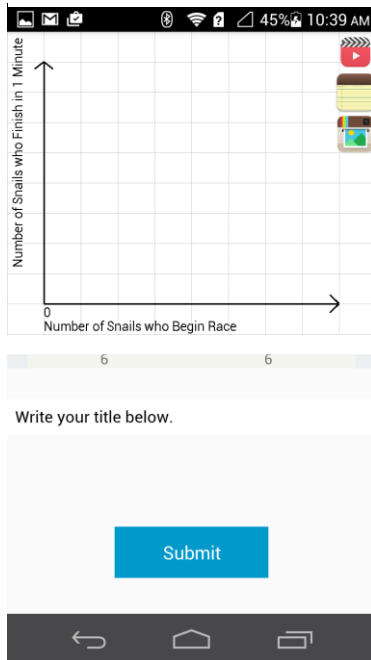


If students are struggling with the calculations needed to find the interval they can open the phone's built in calculator.



Writing a Title

Students tap on where the title is supposed to be and enter the title, which then appears below the graph.



Plotting the Intervals on the Axes

Students touch each gridline on the axis to enter the intervals one at a time.

Number of Snails who Finish in 1 Minute

Number of Snails who Begin Race

Graph A: Number of Snails who Finish the Race in 1 Minute Based on how Many Began It

Begin by numbering your axes and then place your points on the graph.

Submit

Please touch on the x axis to type in the interval value!

OK

Number of Snails who Finish in 1 Minute

Number of Snails who Begin Race

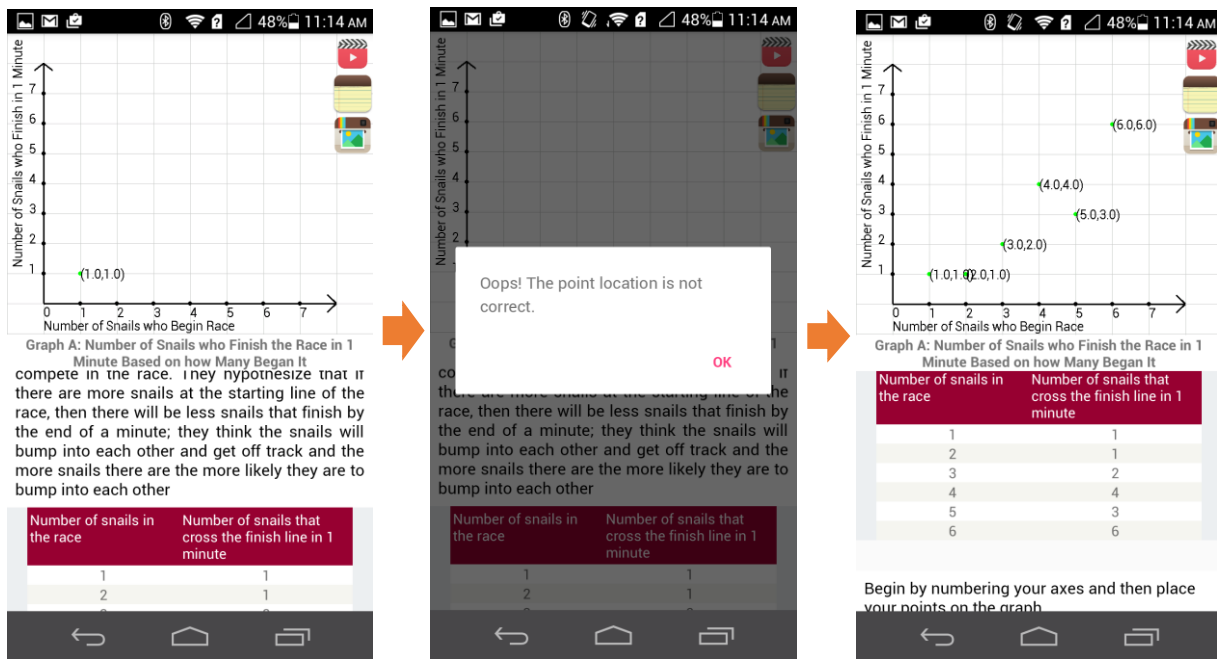
Graph A: Number of Snails who Finish the Race in 1 Minute Based on how Many Began It

Begin by numbering your axes and then place your points on the graph.

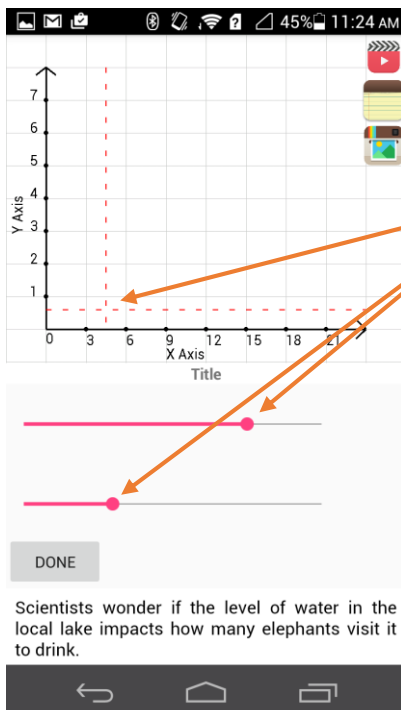
Submit

Plotting a Point on the Graph

At lower levels students can tap directly on the intersection of the gridlines where their point is located to plot a point. At these levels they are only plotting points that appear at the intersection of gridlines, such as (1,2) or (5,3).

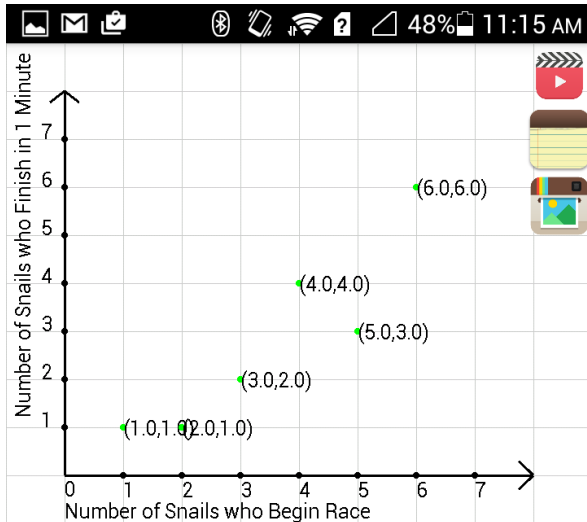


As graphing becomes more complex in levels 3 and 4 students have to plot between the gridlines (for example, if their intervals are 1,2,3, they may need to point [2.7, 5.2]). In order to graph between the grid lines students click on the region where the point should be and then scroll back and forth on the axes to move the point into position.



Answering Questions Based on the Graph

Students are asked to use the graph they created to answer questions about the relationship between the independent and dependent variable.



Graph A: Number of Snails who Finish the Race in 1 Minute Based on how Many Began It

Based on the graph, choose which statement is correct

- a. The number of snails that start the race determines how many snails finish the race.
- b. The number of snails that start the race does not seem to have an impact on how many snails finish the race.

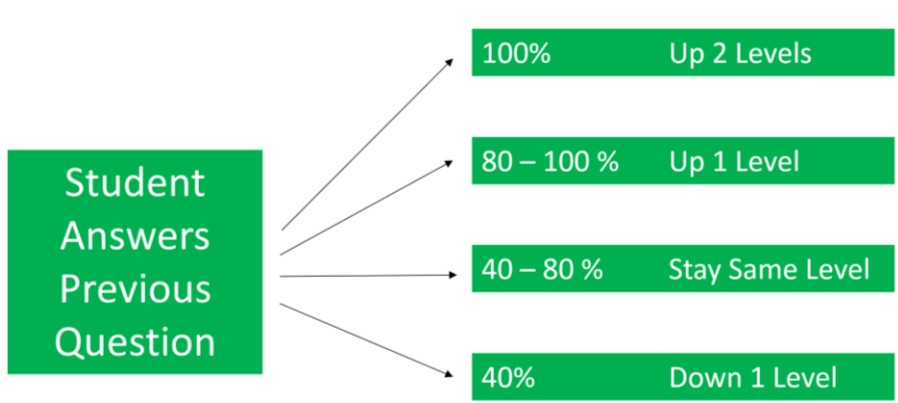
Student Progression Through the App:

Students enter the app and choose a level to begin practicing based on either their prior knowledge or a teacher recommendation. The levels become sequentially harder.

Level 1	The intervals for the axes are 0, 1, 2, 3, 4... only.
Level 2	Axes intervals are whole number multiples of 2, 5 or 10. No rounding is done when finding the interval.
Level 3	Axes intervals are whole or decimal numbers (but not multiples of 1, 2, 5 or 10), for example 8, 16, 24. Students are required to round to the nearest appropriate

	interval. More than one interval could be appropriate. Scrolling between gridlines in order to plot points is required.
Level 4	Challenging whole or decimal number intervals are required. Rounding is required to determine more than one appropriate interval. Students have to place points between the intervals. Titles become more difficult. Students have to write their own independent variables.

At the end of each question the app makes a decision about which level the next question should be in based on how the student scored in the previous question (N.B. this score includes the student’s self-assessments). The student is moved to a new question in either the same level or shifted up or down based on their score. This ensures that the question remains challenging, but also attainable, which is important to ensure learning happens.



What We Learnt

A great deal of our learning involved how to create effective teams. We quickly went from working in isolation with infrequent communication to working as a cohesive unit which met and communicated frequently. It became particularly important for us to work together in the same room, as the code we were developing became cleaner and problems were solved quickly and more effectively. We focussed on building spirit and morale through activities like team breakfasts. We also learnt a great deal about communication, taking time to develop a clear, common language after problems arose from talking at cross purposes. We came to see how often our problems resulted from not taking time to communicate clearly.

As a specialist Katarina quickly became cognizant of how significant even small changes were in terms of coding.

With no teaching experience, Teresa and Yolanda developed a much deeper understanding of how complicated it is to take a skill that seems easy to them, like graphing, and make it accessible to someone who knows nothing about it.

As a team we really came to appreciate the idea of a spiral. Planning very specifically beyond the next spiral only created frustration when our plans inevitably had to change. We came to understand that fluidity and change are part of the process and to only think long term in a general sense.



Contribution by Group Members

Katarina:

Katarina developed the concept of the app. She wrote its curriculum and created the teaching tools built into it (for example, the video lessons). She was involved in testing and feedback at each stage of development. A significant part of her role was also as the team's project manager; she coordinated all team contact, ensured there was on-going, constant communication, and kept everyone motivated, fed and watered. She also worked to build a team dynamic, organizing activities like meals and social events which allowed the team to develop a morale that made them more effective. She took the lead in writing the report.

Teresa:

Teresa was responsible for the design of the database, pulling questions from it and displaying them in the UI. She also created the student self-assessment function, grading system and student progression system that moves students to the appropriate level based on prior progress. She created the graph and the ability to input points on the graph. She helped Yolanda with the scrolling ability when plotting points, particularly the fine tuning of it. She was also involved in building parts of the UI and in testing for bugs.

Yolanda:

Yolanda was also responsible for the initial database setup, as well as inputting data into the database. She created the functionality for validation of students' answers. She was significantly involved in creating the graph and the ability to input points on the graph, as well as scrolling between points. She designed the dialogue boxes that provide student feedback. She took the lead in developing the UI, and refining it based on specialist feedback.

Specialist Context

In her experience as a teacher Katarina has seen how greatly students struggle with graphs. These observations are supported by large amounts of anecdotal evidence from teachers.³ Some students quickly master graphing, while many simply squeak by a pass and never fully understand the concept. Katarina has witnessed first-hand how hard learning to graph is without significant teacher feedback on each of the skills in graphing, the crushing teacher workload this type of feedback requires, and how differentiating instruction to meet each individual student's needs, with so many steps in graphing, is an overwhelming and very likely impossible task.

Further, Katarina has seen how students struggle with how to read a graph for information and to understand how numerical data can be manipulated in the graphing process, which comes from a fundamental understanding of how graphs are constructed. This makes the need for students to be able to create graphs even more compelling. In today's data driven society,

³ Tierney, John. "Can Your Kid Read Graphs and Charts?" The Atlantic. October 30, 2012. Accessed March 23, 2016. <http://www.theatlantic.com/national/archive/2012/10/can-your-kid-read-graphs-and-charts/263689/>.

awash with statistics on everything from shopping to cancer treatment, students must be able to both create and read graphical data. These skills are not only a necessity for a wide variety of careers (well beyond math and science), but also to be able to take in information and be an informed citizen. Unfortunately graphing and the wider field of information and data literacy is often only covered superficially and only at lower grade levels, despite the fact that it is something every child will need.^{4,5,6}

GraphMaster aims to begin to fill this void and to provide a better quality and more effective learning experience through individualized instruction, and significant and timely feedback to students in the area of line graphing. It begins to make learning to graph more effective in a time when graphing is an overlooked skill, preparing students for their future lives, both professionally and as informed citizens.

Future Work

Features we'd like to add to the existing app:

- A teacher server, which tracks student progress and allows teachers and students to communicate.
- Student-to-student communication: Students chat to request help and learn from their peers.
- Timed, individualized quizzes completed and marked in the app.
- The ability to create more complicated graphs, with multiple lines on one graph, the ability to extrapolate the graph, draw a line of best fit or break the x and y axes.

New functionalities we'd like to create:

- Instruction and practice on how to read graphs for information.
- Instruction and practice for bar and pie graphing.

Finally, we hope to create this app for iPhones, Android tablets and iPads, to ensure all students can learn to graph. Tablets would allow different sized grids to be used, as a small grid size is a current limitation of phones.

⁴ Manyika, James, and Michael Chui. "MBAs Can't Afford To End Their Math Education With Calculus." Business Insider. March 12, 2013. Accessed March 25, 2016. <http://www.businessinsider.com/why-statistics-is-worth-more-than-calc-2013-3>.

⁵ Benjamin, Arthur. "TED: Teach Statistics Before Calculus!" TED. February 2009. Accessed March 25, 2016. https://www.ted.com/talks/arthur_benjamin_s_formula_for_changing_math_education?language=en#t-80261.

⁶ Salzberg, Steven. "Should We Stop Teaching Calculus in High School?" Forbes. July 17, 2014. Accessed March 25, 2016. <http://www.forbes.com/sites/stevensalzberg/2014/07/17/should-we-stop-teaching-calculus-in-high-school/#506fd0a13afd>.