SURVIVING ON MARS WITH GEOGEBRA

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Abstract: In this paper, the authors describe an interdisciplinary lesson focused on determining how long an astronaut can survive on Mars. The lesson utilizes resources provided by NASA within an inquiry-based context and is aligned to the Common Core modeling standard. The authors detail the use of a GeoGebra applet that encourages students to explore their own questions.[1]

Keywords: problem solving, inquiry-based learning, modeling, GeoGebra

Introduction

With the increased popularity of technology in school classrooms, there has been a corresponding call for inquiry-based learning (IBL). Edelson (1999) and others define IBL as an instructional approach in which students are presented with problems that are challenging and unfamiliar. Within an IBL classroom, students are encouraged to ask questions, discuss ideas and possible solution strategies with peers, and apply newfound knowledge while solidifying their answers. IBL aligns well with Standards for Mathematical Practices advocated within Common Core State Standards[2].

When attempting to create a problem that is centered around IBL, Common Core State Standards, and Standards for Mathematical Practices, teachers must consider how much information, time and resources to provide their students. These concerns will be addressed through the exploration of the following problem:

How long can an astronaut survive on Mars with a stockpile of 8,000 potatoes?

The task is inspired by the popular film, *The Martian*. Lead actor, Matt Damon, is stranded on Mars until his team is able to rescue him. Damon's character keeps a video diary documenting the passing days. Students will be shown a short clip of *The Martian* depicting the first video diary entry once the astronaut is aware of his situation. After this clip has been shown, students will be asked how long they think the astronaut can survive on Mars.

The original problem is ill-defined by design. To successfully answer the problem, students must formulate and explore many secondary questions such as the following:

[1]Originally developed as part of a NASA Space Consortium Grant.

[2]HSF.LE.A.1.A: Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals; HSF.LE.B.5: Interpret the parameters in a linear or exponential function in terms of a context.

1. How many calories does the average male/female need in a day to survive?
2. How many calories does a potato provide?
3. What is the distance between Earth and Mars?
4. How long does it take to get to Mars?
5. Are there factors in daily life that would reduce calorie intake (for example, exercising)?

Note that students are not required to answer all of these questions. As part of the IBL process, students are encouraged to work in groups to formulate their own researchable questions and determine solutions to the original problem. Such an approach supports a view of inquiry promoted by the National Academy of Sciences—one in which students (a) question, (b) investigate, (c) use evidence to describe, explain, and predict, (d) connect evidence to knowledge, and (e) share findings (Shavelson and Towne, 2002). These five steps are addressed in the lesson to ensure that students are working on critical thinking skills and developing a deeper understanding.

Students work in small groups to explore questions and visualize the problem scenario with the applet. Once students have generated estimates of the maximum survival time, the teacher plays a clip from the popular movie, *The Martian*, that reveals an answer to the initial problem scenario. This viewing leads to yet more student questions including queries regarding accuracy and precision, model parameters, and the plausibility of the movie's findings. Such questions reveal that quantitative findings, particularly those generated with mathematical models, are subject to argument, change, and interpretation.

Student Exploration

Surviving on Mars is envisioned as part of a three-day interdisciplinary lesson developed to expose students to NASA materials and linear relationships in an inquiry-based manner using a GeoGebra sketch. The three-day lesson is structured in the following manner.

Day 1 A clip from *The Martian* will serve as an engaging hook, resulting in curious and intrigued students. Then students will move between four different "space" stations in small groups. The stations are set up to foster student engagement and deeper student understanding of the problem by targeting four different styles.

1. Visual learning: Students at this station will watch a short clip from NASA discussing the importance of space food to astronauts. After viewing the video, all members of the group will work together to complete a comprehensive worksheet.
2. Auditory learning: Students at this station will take verbal directions to complete a collaborative task. Students will calculate the distance between Earth and Mars on a specific day and time given by the teacher, and then use the solution to determine how long it takes a space station to reach Mars.
3. Reading/Writing learning: Students will be presented with a NASA article explaining the concept of growing plants and vegetables. After reading the article, the group will work together to complete a reflective assignment showcasing the new information. Students will write a paragraph summary and come up with a short oral presentation or a multimedia project.
4. Kinesthetic learning. Group members will weigh an actual potato and estimate its caloric content.

Day 2 The second day of the lesson will consist of applied mathematical concepts and the collaborative journey toward a solution to *Surviving on Mars*. Students will rejoin their group members to discuss the data they collected and to discover relationships between calories needed and the time a human can survive. A Geogebra applet (see Appendix) will be provided to help students model the newly uncovered relationship. Students will be given this applet after completing several fundamental calculations to determine that the relationship between potatoes eaten and number of calories is, in fact, linear. The applet will allow students to formulate observations and questions regarding *Surviving on Mars*.

Target observations for students

1. When the variable 'workout' is factored into the problem the relationship remains linear.
2. There is a range of calories that the astronaut must stay within to survive. This range is the same range that students discovered during station work with NASA materials on day 1 of the lesson.
3. The point P represents the linear relationship between the number of calories in a potato and the number of potatoes eaten.
4. When workout time is considered, the point P moves with respect to workout time as well.

Target questions for students

1. Are there other factors that may affect the astronaut remaining in the optimal range on the graph?
2. Are there any additional factors that could be added to the graph to create a nonlinear relationship?
3. Is there any way to incorporate the concept of days survived into the applet?

Students will continue working with their groups to determine concrete answers to more direct questions. Specifically, students are asked to examine the following questions.

4. As the number of potatoes increases, what happens to the number of calories?
5. As the amount of workout time changes, what happens to the point P?
6. Upon examination of the point P, what relationships are causing the point to move?
7. What is the minimum number of calories the astronaut can consume in a day to survive?

Classroom time will be dedicated to applet exploration so students can better understand mathematical concepts behind the linear relationship. The main purpose of the applet is to provide students with a visual way to calculate the number of potatoes that can be eaten in a given day. Once students determine that number, they can use the result along with information provided in *Surviving on Mars* to find a solution. Students are then challenged to modify the applet in a way that produces a solution to *Surviving on Mars*. This task introduces various new elements of consideration. First, students must discover how to effectively manipulate the existing applet to ensure that it depicts the desired result. Second, the students will have to present a new condition to be considered in the existing relationship (number of calories burned while sleeping or number of calories burned when not exercising). By adding additional obstacles to the homework, students are required to utilize the problem solving techniques discovered during class to work through the homework alone.

Day 3 At the beginning of class, a final clip from *The Martian* will show students how long filmmakers expected the astronaut to survive. This information will allow students to compare their answers to the film while exploring the plausibility of various results. In addition, students will be able to contemplate what could have skewed their results or the results in the movie. Further analysis of results and supporting mathematics solidifies the applicability of linear relationships in everyday life.

Purpose of Technology

The implementation of technology within this lesson offers multiple benefits that allow more comprehensive understanding to students. The sketch allows students to work at their own pace as they uncover linear relationships in an interactive manner. Sliders in the sketch afford students the opportunity to interact with variables in a way that makes them come alive. As students drag sliders within the sketch, they discover that workout time effects the caloric intake but does not affect the number of potatoes eaten per day. Moreover, the applet provides students with visual representations of the problem scenario while automating many of the arithmetic calculations that otherwise distract students from conceptual understanding—specifically the linear relationship between potatoes consumed and calorie intake. By automating the repeated calculation of the y-value for point P, the students will be able to focus on the path that point P takes—a line with positive slope. The applet effectively eliminates discrepancies in results caused by student error. Given that there is a range of acceptable potato consumption, not all students will arrive at the same answer. However, all students should reach the understanding that an increase in potato consumption causes a direct increase in calories. In contrast, an increase in time spent exercising causes a decrease in calories and no change in potato consumption. This will result in students having a variety of answers, all of which are plausible. An additional benefit is the speed with which the students will be able to manipulate variables. Sliders allow students to quickly see how changes in variables affect the linear relationship in various instances. Sliders are not the only dynamic features of GeoGebra aiding students. Tracing the point on the graph to clearly show students the linear relationship between potatoes and calories per potato is another dynamic feature. The ability to factor in, or not factor in, calories burnt while working out by the use of a checkbox also adds to the benefits of the applet. Overall, students' use of technology will allow a fuller comprehension of linear relationships.

Conclusion

To implement this lesson successfully, students need to be familiar with the use of technology and inquiry in the mathematics classroom. When students are accustomed to both of these areas, the focus of the lesson can remain on the mathematics. As a result, throughout this Mars-themed lesson, students are encouraged to gain a deeper understanding of mathematical concepts, specifically linear relationships. Additionally, students reflect on their results by providing evidence for their conclusions. By the end of the lesson, students utilize their knowledge of modelling, prove linear functions grow by equal differences over equal intervals, and interpret the parameters in a linear or exponential function in terms of a context. This lesson challenges students, but, through the use of scaffolding and engaging activities, the goals of the lesson can be achieved. The addition of the GeoGebra applet allows students to visualize the relationship among variables. By asking students to produce a modified applet as a homework assignment, they are also given the opportunity to improve their critical thinking and problem solving skills.

REFERENCES

1. D. C. Edelson, D. N. Gordin, and R. D. Pea, *Addressing the challenges of inquiry-based learning through technology and curriculum design*, Journal of the learning sciences, 8 (1999), no. 3-4, pp. 391-450.
2. R. J. Shavelson, and L. Towne, *Scientific research in education*, National Academy Press, 2002.

Appendix—Steps for Creating the *Surviving on Mars* Applet

We begin by specifying parameters of the graphics window. The axes of the graph need to be modified to take into account caloric values of the problem scenario. Because there can not be a negative number of potatoes consumed or minutes working out, the axes need to be set to only show positive values. Furthermore, we decided to place the maximum number of potatoes consumed to be 30 and the maximum calorie amount to be 3500. These settings are illustrated in Figure 6.2. Figure 6.3 shows the completed graph with axes scaled. Additionally, we added text boxes to label the x-axis as potatoes and y-axis as kcals.

In keeping with realistic expectations of survival rates, we determined what level of kcals consumed per day for an average male would correspond to obese and malnourished levels. We determined that 2500 kcal and 1500 kcal, respectively, would fit this requirement. We then inserted a line a, corresponding to $y = 2500$, and line b, corresponding to $y = 1500$, by entering these equations into the input box. From there, we decided to alter the properties of the line for aesthetic purposes. In Figures 6.4 and 6.5, we illustrate how to modify object properties. Figure 6.6 shows both lines red and dotted

Next, we began to add the manipulated elements. First, we created a checkbox with the caption 'Workout' and corresponding Boolean value C. A slider was created with the same caption and values ranging from 0-15, incremented by one unit. A similar process was done to create the checkbox and slider associated with 'Potatoes' and Boolean value D. Figure 6.7 shows how to create the 'Workout' check box.

The final step included adding the point P, representing the relationship between potatoes consumed and calories available. The equation for this point shows that the x-value will be the number of potatoes consumed. The y-value

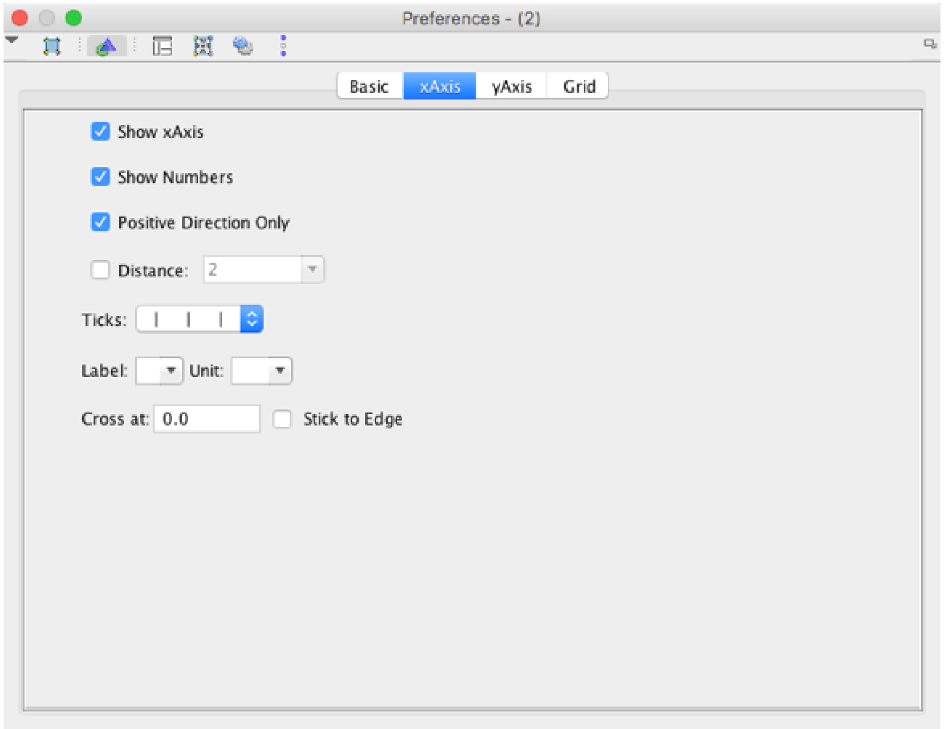

Figure 6.1: Window settings in GeoGebra.

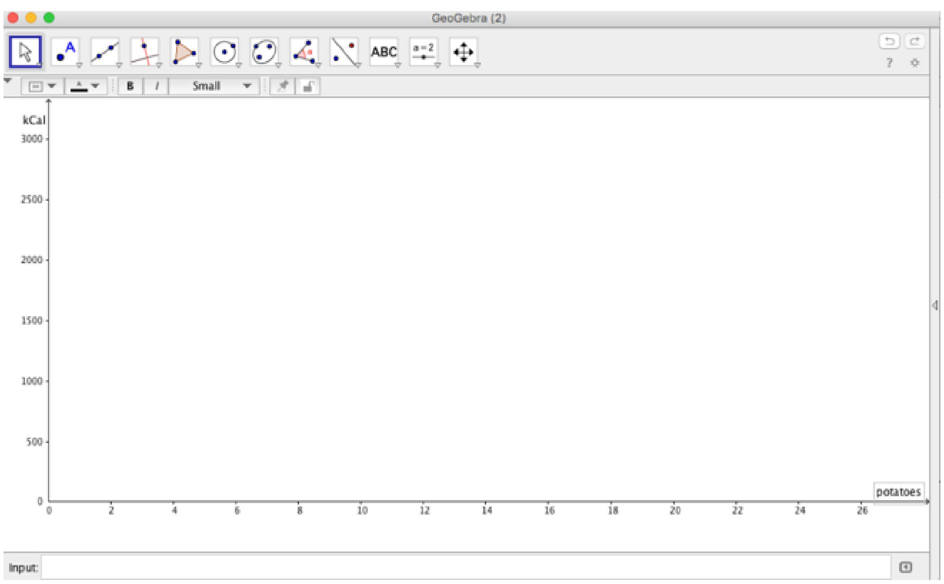

Figure 6.2: New window.

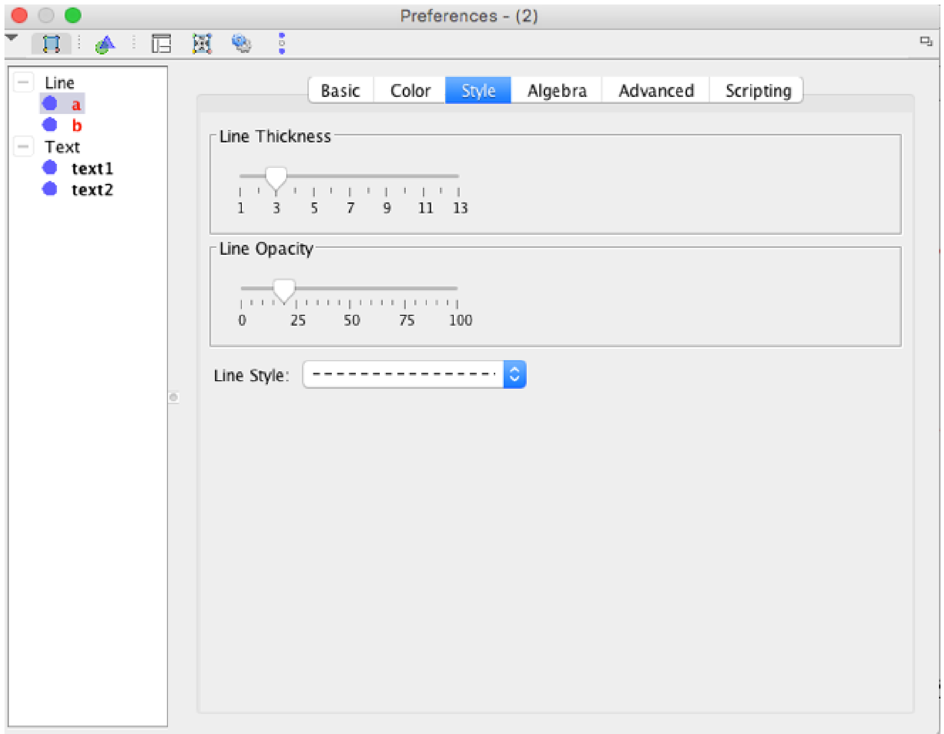

Figure 6.3: Line Style.

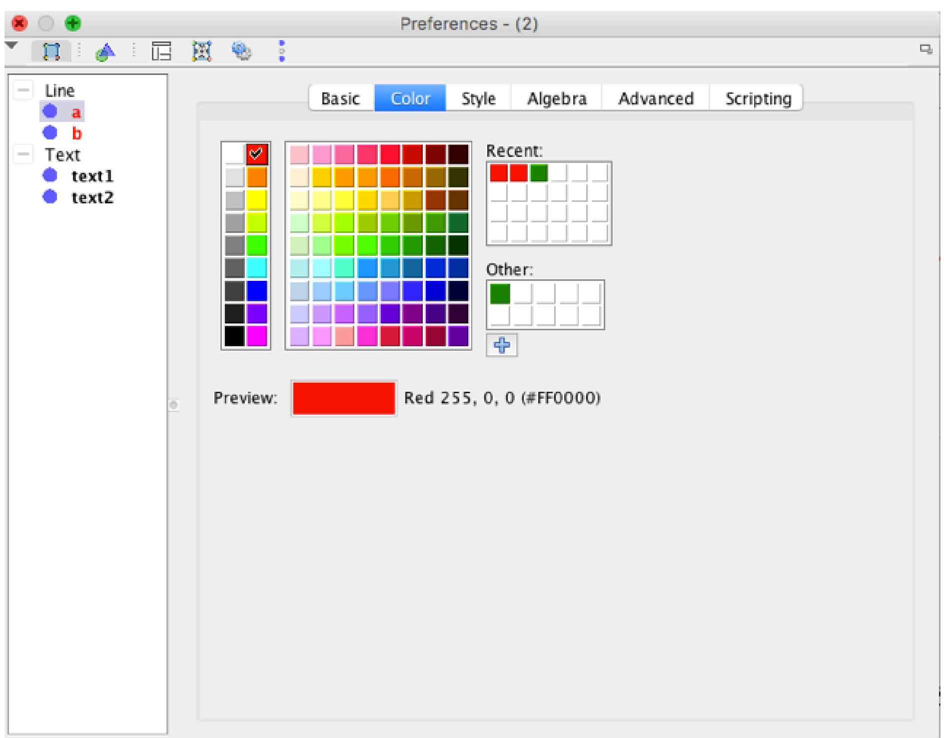

Figure 6.4: Line color.

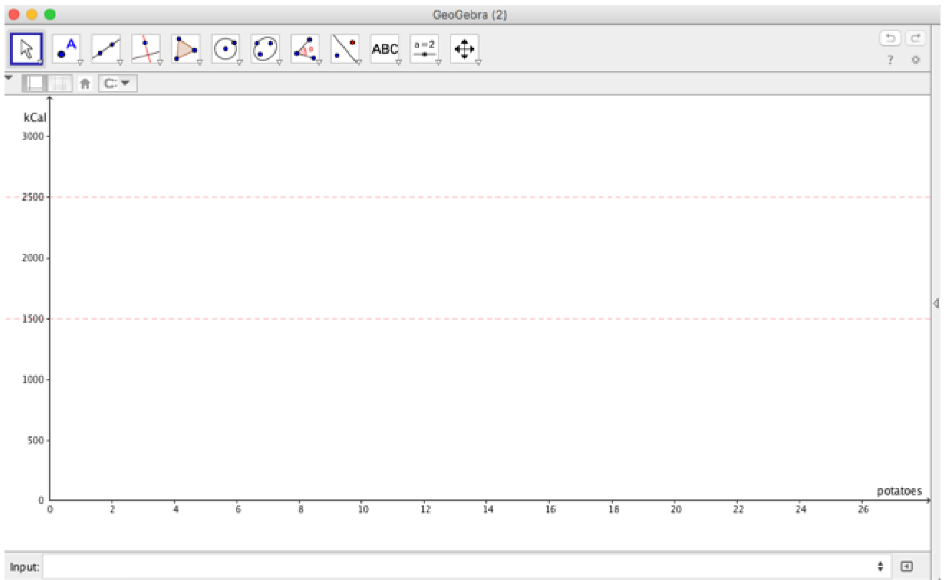

Figure 6.5: Completed lines.

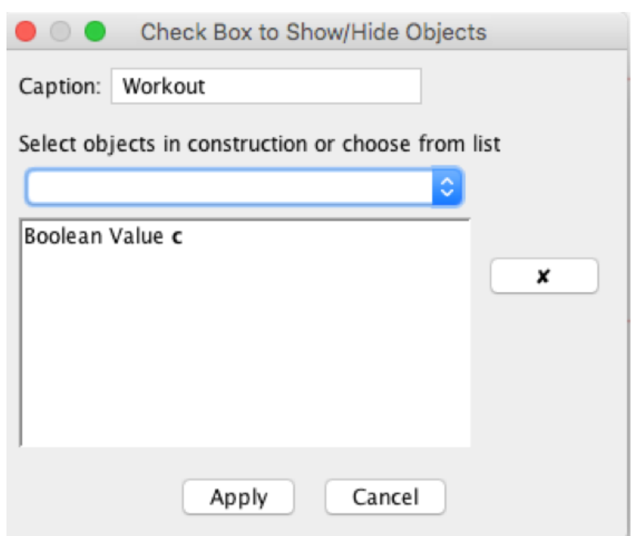

Figure 6.6: Workout checkbox.

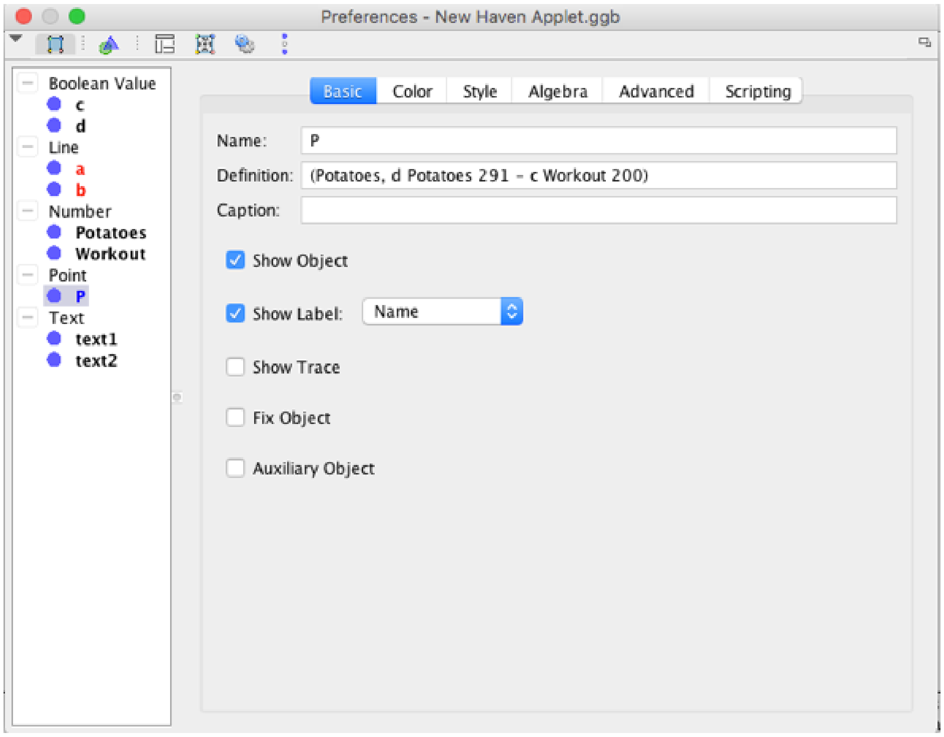

Figure 6.7: Workout checkbox.

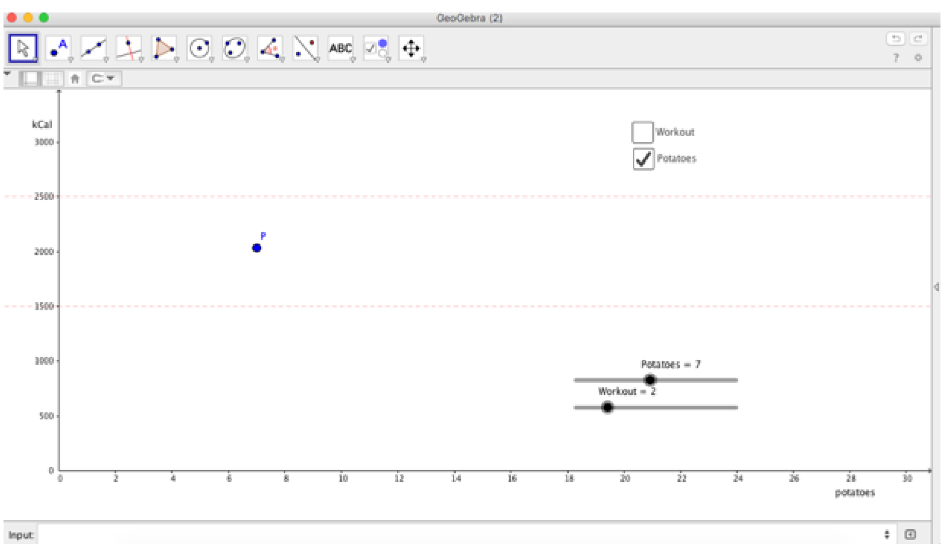

Figure 6.8: Completed initial sketch.

reflects the idea that calories available will be calories consumed. For calories consumed, we determined that an average potato has 291 calories. For calories burned, the teacher determined that an average male will burn 200 calories per hour of working out. Therefore, the calories available is the number of hours spent working out multiplied by 200 subtracted from the number of potatoes consumed multiplied by 291. Figure 6.8 shows where the equation should be entered. Figure 6.8 shows the final product.