Ki-Bot

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ABSTRACT

UPDATED—29 April 2018. This paper explores the development of a robotic toy that will be helping students in kinematic physics. Physics has always been a hard class and it is very difficult for students to understand the concepts behind each topic in physics. Ki-bot will help students not only solve kinematic word problems, but also understand the concept of kinematic word problems by testing their answers to word problems on the bot. Ki-bot will essentially bring kinematic word problems to life to help the student understand kinematic physics. The paper will explore the advantages and disadvantages of using interactive toys for learning and will also discuss the other products in the market that help students in kinematic physics. I will also discuss the design decisions, coding decisions, and some of the testing I did in the process of building and developing Ki-Bot. Ki-bot has been successful in showing the proof of concept that this will work in helping students test their answer to word problems and understand them. Additionally, I will discuss the future work that could be done to improve Ki-bot.

Author Keywords

Physics; Kinematic Equations; Kinematic physics; kinematic word problems; robotics; android development; Arduino development

INTRODUCTION

Many students tend to struggle in physics, as it is one of the more challenging classes in school and in college. According to Charlie Schofield's blog on "Teachers' Tech Tools for Physics", teaching physics is not an easy topic to teach because of the overwhelming formulas, symbols, and concepts [7]. He states that with new technology coming out, teachers can make teaching easier, fun, and more interactive for students. Keeping difficult topics fun and interactive will keep students motivated and engaged to learn them. Also, as the semester goes, the topics will get harder with fluids, dynamics, forces, motion, et cetera. It is important for

students to get an understanding on the basic concepts early in the semester before going on to harder topics. Clinton Sprott made a book, "Physics Demonstration", entirely of demonstrations in physics to help engage students to learn different concepts in physics [8]. Clinton states that teaching physics is enhanced by use of demonstrations. Visual examples of abstract concepts will help students master different topics in physics. Also, he stated that the use of demonstrations and interactivity makes the process of learning physics easier and enjoyable for students.

CRITICISM ON DEMONSTRATIONS IN PHYSICS

There is evidence that show that demonstrations are not always effective. Students could watch a demonstration and assume from they see, without reinforcing relevant concepts. According to NSTA WebNews digest's journal, "Can Students Learn from Lecture Demonstration", there was an experiment where a professor demonstrated a pendulum demonstration and then then tested the demonstration during the midterm exam [4]. According to the scores, 25% of the students that saw the demonstration got the answers right. Despite the professor demonstrating a difficult concept, it failed the students to understand the physics behind it. The problem was students were assuming it was for a different reason instead of what the real reason why it was happening. In later years, there was another experiment where the students were seeing the demonstrations and then having interactive activities to help students understand the concept. The students would watch the demonstration done by the professor and then have experiments based on the demonstration where the students would collect data and analyze them. In the experiments they were then asked to solve problems they see through their observations and analysis. The students were then asked the same pendulum question on the midterm and more than half of the students that participated got the questions correct compared to the 25% from a demonstration alone. It is important to have interactive learning when it comes to explaining difficult concepts in physics.

EXISTING TOOLS

Currently in the market for physics there are several phone applications to help teach physics such as Gravity Lab and Vernier Video Physics. Gravity Lab is an application that allows students to create your universe and simulate collisions in space [2]. Simulating collisions will explain how momentum is conserved and how planetary motion works. The users can create many particles with different masses and different initial velocities by drawing velocity

vectors on the screen. The application is to help students understand gravitational forces.
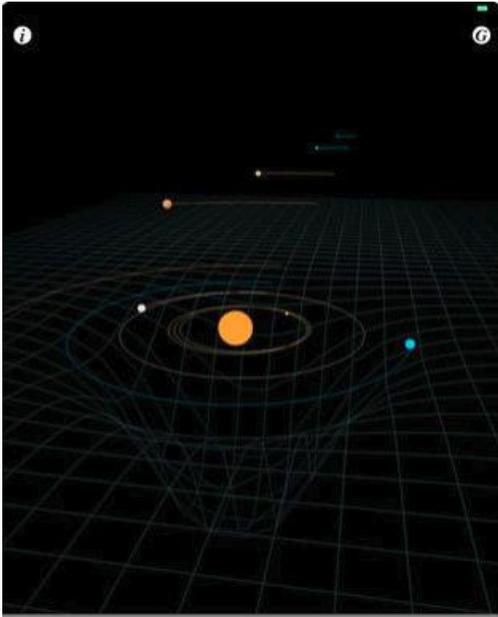

Figure 1. A screen shot from Gravity Lab Application

Another application that is used to help in physics is "Vernier Video Physics", made by Vernier Software and Technology [9]. The application allows the user to capture video of an object in motion and the app will start to track the object and create a trajectory, position, and velocity graph for the object. For example, a user can take a video of a basketball free throw shot and see the application will display the path of the ball and provide graphs of x vs y with their positions and velocities as a function of time. The graphs will give you in real time graphs of objects in motion to help students understand force, velocities, accelerations, motion, etc.
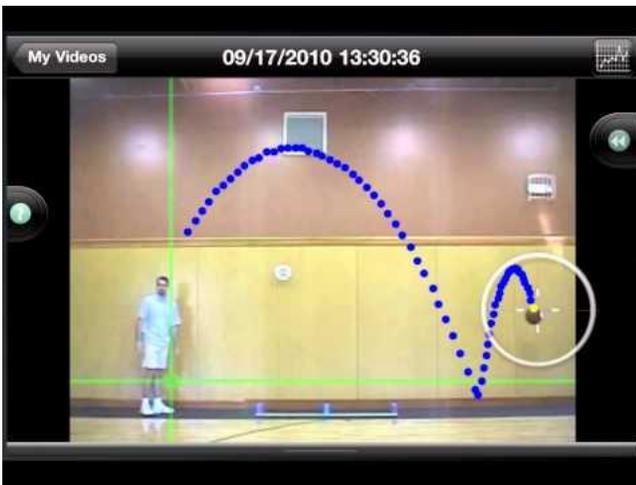
Figure 2. A screenshot of Vernier video physics application showing a graph of a ball in motion.

DISADVANTAGES OF PHONE APPS

While there are many educational applications out in the market, not all of them are indeed educational. According to the paper "Putting Education in "Educational" Apps: Lessons from the Science of Learning", information is best absorbed and processed at a deeper level when it relates to past knowledge or personally relevant [3]. Applications that encourage children to collect new information in their daily lives will be more effective than seeing what they see on an application. For example, if an application was helping a child learn about triangles, it would be more effective for them to take pictures of triangles in their house than picking triangles in an application. Interactivity with the real world will have a deeper learning experience than what they see on an application. Furthermore, there are more than 80,000 Apple Store apps that are labelled as "educational", and there are no scientific standards that will determine that the apps are educational. There are "educational" applications that can have a negative effect in kids. The applications could have distractions, such as noise, movement or side games that are unrelated to the topic, and distract students from learning.

BENEFITS OF INTERACTIVE TOYS

There are many interactive toys out in the market that help students understand a concept. According to Miniland's article, "Understanding the Role and Importance of Interactive Learning Toys in Kids' Development", interactive toys such as puzzles, building blocks, and other games encourage cognitive development in children at a young age [5]. The article later states that their logic and problem-solving skills will also improve with the use of toys that encourage users to complete patterns, count, and solve other problems. One interactive toy that helps students learn are Lego Mindstorms. Lego Mindstorms comes with a kit that includes a microcontroller, sensors, encoders, Lego blocks, etc. The user would have to build and code their robot for robot to work. This product introduces a fun and interactive way to bring students to the STEM field. There is no better way to inspire children and introduce them to several concepts in programming than Lego Mindstorms [1]. Lego Mindstorms also comes with a graphical programming language called LabView. LabView is like Scratch, where kids would use coding blocks to code their robot. If kids put the effort in, the possibilities available with the base set is incredible.

WHAT IS KI-BOT?

Ki-Bot is the name of the robotic toy I developed for my project in "Educational Technology". Ki-bot is a toy that students will use to solve kinematic word problems by bringing them to life through an interactive robot, hence the name Ki-Bot. The student would read a word problem and answer it, and input the values through a cell phone application to send to Ki-bot to observe and test if they got the answers correct.

KI-BOT VS THE OTHER TOOLS

There are other tools out in the market that help students learn and understand physics concepts. Gravity Lab and Vernier Video Physics are both great tools to observe and analyze results. Ki-Bot will essentially introduce another aspect that these applications don't have and it is to test the student's knowledge. Students can observe and analyze the results from the experiments but not test their knowledge which I believe is important to know if the student understands the concept. With Ki-Bot the student will be able to observe, analyze, and test their knowledge. Imagine a bot where a student can input values for different variables in the kinematic equation to solve for distance. The student can predict where the bot will end up when the robot stops.

1. $v = v_0 + at$

2. $\Delta x = (\frac{v + v_0}{2})t$

3. $\Delta x = v_0 t + \frac{1}{2}at^2$

4. $v^2 = v_0^2 + 2a\Delta x$

Figure 3. The kinematic equations

Using these equations, a student can play around with different values to measure the distance the bot will travel in the amount of time. The student will solve the word problem and predict the distance the bot will travel using the values provided by the word problem. Then the student will send the values via an application to the bot via Bluetooth and watch bot act out the kinematic word problem. If Ki-Bot stops where the student predicted, then the student solved the problem correct, if not the student will try again.

DEVELOPMENT

Robot

After some research looking for a robotic car, I found Elegoo selling a robotic toy with tires called the "Elegoo Uno R12". This is a "Do it Yourself" kit that includes an Arduino Uno microcontroller, HC-08 Bluetooth sensor, tires, motors for the tires, cables, batteries, and a L298N board to control the motors. This kit was all I needed for the project since it includes the tires, motors, tires, and an Arduino board. The kit also comes with instructions on how to build the bot and connect all the wires and a great tutorial on how to control it using Arduino.

Figure 4. Picture of Ki-bot

From figure 4, Ki-bot has two plates holding the boards and motors. On the top plate, the Arduino Uno is on the bottom of the top plate and an expansion board is connected on top of it. The Bluetooth sensor connects on the expansion board. The Batteries and its case are on the back of the top plate and connects to the expansion board. There are cables that go from the expansion board to the bottom plate which is where the L298N board is. The L298N board have the four motors connected to it to move the tires. Ki-Bot does not have a distance sensor, so there is no way for the bot to track the distance travelled. The user would have to measure the distance they predict or the distance provided by the word problem using a ruler.

Application

Being that this project has a lot going on with hardware, Arduino development, and phone application, I wanted to find a way where I can develop a phone application as easy as possible. I found a tool where I can develop a phone application with Bluetooth communication using MIT's App Inventor. The phone application I developed has three pages: Main, guide, and sending page.
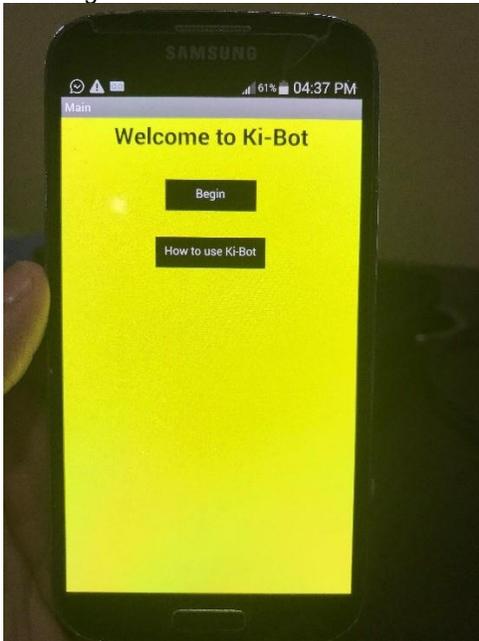
Figure 5. Main page

In the main page I have a "Welcome to Ki-Bot" title screen to welcome the user to the application. The page also has two buttons, "Begin" and "How to use Ki-Bot". When the user clicks "How to use Ki-Bot", it will take them to the guide page where it will guide the user on how to use Ki-bot and to use application. The "Begin" button will send the user to the "Sending" page where the user can send the values to the bot and see the bot in action.

Guide page
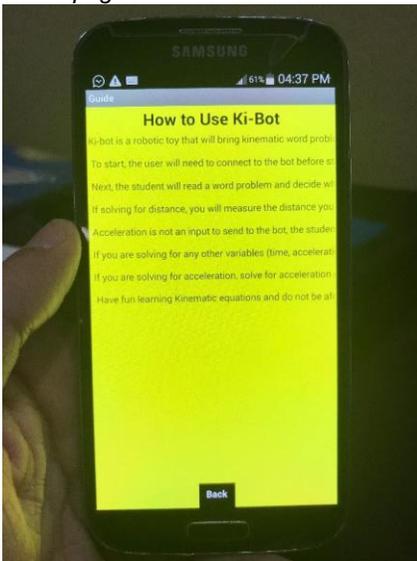
Figure 6. Guide page

I wanted to include a guide page to help users how to use Ki-bot and the application. The guide contains how to connect

via Bluetooth to Ki-bot and how to solve a problem and send the values to Ki-bot.

Sending Page
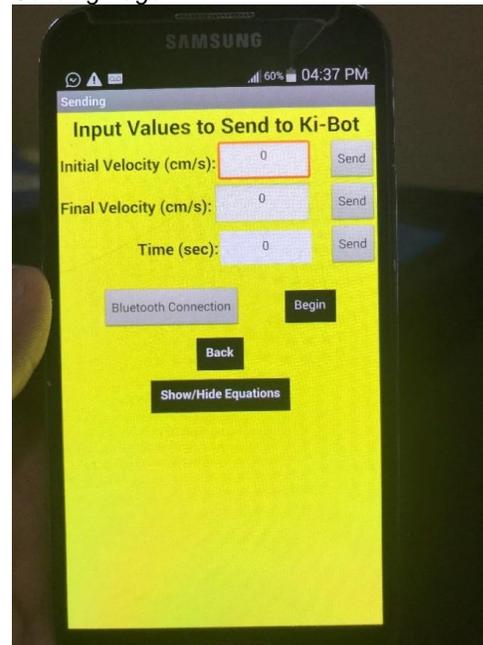
Figure 7. Sending page

In the sending page is where the user where spend most of their time using Ki-bot and how you can control the bot. There are only three values you can send which are initial velocity in cm/s, final velocity in cm/s, and time in seconds. Distance is not a value to send to the bot because the bot does not have a distance sensor to track how much distance it travelled. There is a button titled "Bluetooth Connection", the user where click this button and select the Bluetooth device on the bot to connect to the bot. Once connected, the title of the button will change to "Connected". The user will plug the values in each text box and send each individually to the bot. I included a button to send for each value because it was the easiest for the bot to receive without loss of data. Once all values are sent, the user will click "Begin" and the bot will move and the timer will start. I also included a button called "Show/Hide Equations", where the user can show and hide the kinematic equations for help.

Arduino
On the Arduino side, is where we must know how to receive data from the application and assign speeds and the timer. When the bot starts up it initializes the values and tells which pins will be set up as output. IN1, IN2, IN3, IN4, ENA, ENB are all assigned as output pins. ENA and ENB control the speed of the motors. ENA controls the left side while the ENB control the right side. IN1, IN2, IN3, and IN4 are all controlling what motors will be used. IN1 and IN2 control the left motors, while IN3 and IN4 control the right motors. For the bot to go forward you must have IN1 and IN4 HIGH and IN2 and IN3 LOW.

To determine the speed of the bot, I applied a certain value for each motor and let it run for a second and stop. When the bot stopped, I looked at how far the bot travelled in centimeters and determined that is the velocity per second. Once the motor speed is set it will run at constant speed which made it easy for me to determine what was the speed in cm/s after the bot stopped.

Receiving data was a bit tricky. Since Bluetooth communications are serial, the bot will data bit by bit and not all at once. I included a delay for it to work and gather all the characters in the value received. I had to make a count variable where it can keep track which value it was received. If count is 0 and the user sent initial velocity, the Arduino would know that it was initial velocity sent and count would increment by 1. If count is 1 and the user sent final velocity, the Arduino would know that it was final velocity sent. And if count is three, the Arduino would know it was timer received. For the velocities I had to convert from "cm/s" to a speed where the motor can apply which is from 0-255. I tried to find a multiplier where it can do the conversion. Once all three values are assigned and the user clicked "begin", the Arduino would read that the message received was "begin" and depending on what the values are determine whether to use constant velocity or use acceleration. If initial and final velocity is the same, then it will apply the speed to the motor and have a delay with the timer the user sent before the motors stop. If initial velocity is less than final velocity, the bot will accelerate with a delay with each velocity increment until the timer elapses. If final velocity is less than initial velocity, the bot will start from high speed and decelerate with a delay with each velocity decrement until the timer elapses. The delays are uniform with each increment/decrement which will equal the total time the user

sent. After the bot stops, all values are reinitialized to 0 where the user can start over.

CHALLENGES
When I started working on testing speeds on Ki-bot, I noticed there was a hardware issue with the bot. When I applied a certain amount of speed on the motors and started Ki-bot, the bot goes forward but does not goes straight. This was a difficult to troubleshoot to figure out why the bot wasn't going straight. I ended up getting a Volt-meter to measure how many volts was being applied to the tires. The volt-meter showed that the right tires were getting more voltage than the left tires. Because the right tires were getting more power, the bot was going left as it goes forward. What I did to solve this issue was to apply a higher speed on the left motors in the code to balance it out. Doing this caused the bot to go straight.

Another challenge I had was related to Bluetooth technology. The kit came with a HC-08 Bluetooth device to send/receive information. HC-08 Bluetooth is a Bluetooth device that comes with the new Bluetooth Light Energy protocol (BLE). The key difference with BLE and regular Bluetooth is that BLE uses low power consumption [6]. This is a positive

because regular Bluetooth uses a lot of power. A lot of devices are using BLE technologies such as blood pressure monitors, Fitbit-like devices, public transportation apps, etc. The challenge I had with the BLE device is that in order to send data to the device was requiring a service ID and characteristic ID. You cannot pair a phone to a BLE device. Because it cannot be paired, I could connect to it via the application I developed. I had to change my application to use BLE technology instead of Bluetooth. On the application side it wasn't hard creating a Bluetooth BLE object to send data, but the problem was on the Android side to receive it. I needed to download the library to be able to create a BLE object and set the Characteristic and Service ID. The code was not building even after I installed the CurieBLE library and was not working. After some research in the Arduino community it appears that the CurieBLE library is intended to work with the 101 board and would not work with the Arduino UNO. I did some more research in the Arduino community, and they recommend using the regular Bluetooth with either HC-05 or HC-06 and not the BLE devices. I went ahead and ordered a HC-05 device and some female to female jumper cables to connect to the board. I modified my application and Arduino code to use regular Bluetooth. After, I did some initial testing to see if Ki-bot receives data from the app to see if the bot can move and it did.

RESULTS
The results were very successful. First, I wanted to test if the concept would work with easy kinematic word problems using constant velocity. I made a word problem using a certain speed and have it going at that speed for certain amount of time and to solve for distance. The word problem I made was as follows:

If a toy car is going at 69.5 cm/s at constant speed for 3 seconds and stops, how in cm did the car travel?

The answer to the word problem is 208.5. Next, I need to test if Ki-bot would travel 208.5 cm if I cent a constant velocity of 69.5 cm/s and 3 seconds. The bot travelled 208.5 cm, showing that the concept works with easy kinematic word problems of constant velocity.

Next, I wanted to test if acceleration would be successful. I made another kinematic word problem that would have initial and final velocity be different values. The word problem I solved was:

If Ki-bot is driving at 53 cm/s and accelerates uniformly to 73 cm/s in 4 seconds and stops, how much distance travelled in cm did Ki-bot travel?

A student can solve this problem in two different ways. The student can solve it using the third and fourth kinematic equation from Figure 3.

The answer to the word problem is 252 cm. Next, I sent the values to Ki-bot and observed if Ki-bot goes 252 cm. After this experiment the bot could travel 252 cm, even though it

does not go straight. These successful experiments prove that Ki-bot brings kinematic word problems to life to help students understand kinematic physics.

FUTURE WORK

Ki-bot has the potential to help students understand physics early and have them engaged and motivated to keep learning as the concepts get harder in physics. There are a lot of improvements for Ki-bot to have for it to have a stronger impact for students to learn.

One-way Ki-bot could improve is on the phone application. It would be nice for a way for Ki-bot to use other unit of measurements other than cm such as inches, feet, yards, meters, etc. This way word problems are not limited to only centimeters.

Another way Ki-bot could improve with the application is by adding a bank of word problems and assign them to the students and have a reward system. The application could provide the student a random word problem and the student would need to solve and test their answer using Ki-bot. If the student got it correct, the application could reward them with points. The hardware side would also need to be improved by tracking distance with a distance sensor. The bot could also have a display to show the distance travelled for the user to know the exact distance the bot travelled. The distance sensor would get the exact distance travelled and Ki-bot would send the distance travelled back to the application for the application to determine if it matches the correct answer. If the answer matches, the application would tell the user it is correct and reward them points.

As of now, Ki-bot is limited to Kinematic word problems. Another way to improve Ki-bot is by adding different concepts in physics. Another concept of physics that could be added are forces. Adding forces such as gravitational force would open more possibilities of concepts that Ki-bot could help students. Word problems could include inclined plane problems, where it would make word problems more complicated for students to solve and determine where the bot would stop. If Ki-bot would start at the of top of an inclined plane from rest and once reaching the bottom and stays at a constant velocity for an amount of time, how much distance did the bot travel. These kinds of word problems would add another layer of difficulty and add a difficult concept in physics.

CONCLUSION

Ki-bot provides students an opportunity to learn the basic concepts of physics with kinematic word problems. Ki-bot will help students understand physics by bringing word problems to life and demonstrating kinematic word problems. Ki-bot will also test the student's knowledge in kinematic physics by observing if the values inputted would would match their answers. Ki-bot would provide a fun, engaging, and motivating students to learn the fundamental basics in physics. Based on the experiments I did, Ki-bot could demonstrate that applying kinematics to robotic toys is possible.

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