Learning Roomba: Teacher’s Guide

Introduction

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1 Welcome

Welcome to the Learning Roomba educational toolkit. The Learning Roomba educational toolkit is a collection of resources and tools to facilitate teaching robotics to pre-college students. Through these resources, students can learn about science, math, and engineering topics in a fun and exciting way. This introductory teacher’s guide will discuss the program, how to use the materials provided, and how to setup the tools provided. I hope you find this easy to use and valuable in the classroom.

- - Drew Housten (dhousten@gmail.com)

2 Learning Roomba Purpose

The number of students in the United States enrolling in engineering, science, and computer science fields is declining. Today’s American students are becoming less interested in those fields, and there are no signs of this improving in the foreseeable future. However, while the desire to become an engineer or scientist is on the decline, the demand for engineering and science professionals is expected to rise. Engineers and scientists are necessary for worldwide technical growth and to improve many of the current worldwide problems. Educators, engineers and scientists should take actions now to encourage today’s youth to follow rewarding careers in engineering and science.

Robotics education in pre-college curriculums is one area where this problem can be addressed. Not only does robotics encourage students to go into robotics-related fields, it also encourages general problem solving skills, math abilities, engineering principles, creativity, and teamwork. Robotics education introduces students to the more exciting aspects of any engineering or science career. Making a robot move for the first time is something that few students forget. And, the best part is that frequently robotics programs provide an education that students want to participate in and will do so voluntarily outside of school.

There are two major problems with using robotics in education. The first is cost. Many robot kits are very expensive and out of reach of many school budgets. The second problem is making resources accessible to people like you, the educators. The Learning Roomba educational toolkit attempts to address those issues by keeping total costs down while keeping the tools as easy to use as possible. To help with those goals, these resources are entirely free and any changes or improvements are encouraged.

These resources and tools were assembled as part of my Master’s Thesis work at Drexel University.
3 Educational Materials Provided

There are two types of materials provided: teaching resources and tools to enable education. The teaching resources are broken into Modules (or Chapters) that cover a small number of topics. Each Module includes a Teacher’s Guide, Student’s Guide, and Presentation Slides. The Teacher’s Guide discusses the purpose, educational merit, topics covered, any problem solutions (if needed), any necessary background information, and other related resources for the Module. The Student’s Guide is intended to be a hand-out to the students and will cover the topics in detail as well as include sample programs. The tools include iRobot Roombas and software to work with the Roombas. How to use the tools is described later in this guide.

These resources are not meant to be a full curriculum. They are provided as a base from which to build a curriculum. The recommended approach is to teach the students the topics in an interactive lecture setting followed by an open lab session where the students can experiment with the robot and with the concepts learned during the lecture. The students should work in small groups (3 or 4 students) so the students can learn from each other.

The work is targeted at pre-college students. This is a wide age group, so some of the resources may need to be varied and tailored depending on the particular students that the material is being taught to. The primary group of students considered is Grade 6 through 9.

The Modules include:

- **Module 1 - Robotics Introduction**: This Module introduces the topic of robotics and forms the base for all the other Modules. The topics include defining a robot, setting up the robot network, an explanation of programming, and how to build simple programs for a robot.

- **Module 2 - Robot Configurations**: This Module discusses the different types of robot platform configurations including differential drive, tricycle drive, Ackerman steer, synchro-drive, skid steer, roller wheeled, legged robots, and non-ground robot configurations.

- **Module 3 - Controlling Movement**: Controlling Movement teaches concepts related to moving a differential drive robot in its environment. The tasks include controlling the robot’s motors to have the robot drive forward, turn, and get to a location. The module also discusses why a robot does not always travel to the same location even with the same commands.

- **Module 4 - Sensors and Actuators**: The Sensors and Actuators module addresses the topic of a robot’s components in a Sense-Plan-Act (SPA) architecture. Different types of sensors and actuators are introduced along with potential uses of the sensors and actuators.
Module 5 - Localization: The problem of figuring out where a robot is located in the environment is discussed. The problem of mapping an environment is also addressed. General solutions to the problem are provided along with an explanation of an external camera based approach.

The materials should be presented in a way that accounts for visual, audio, and kinesthetic learning styles. Visual is provided through the student’s guides and the presentation slides. Audio is provided through classroom instruction and presentation of the slides. Kinesthetic is provided through the hands-on exercises.

4 Required Hardware

*Learning Roomba* uses the iRobot Roomba (www.irobot.com) because it is almost ready to use off the shelf, relatively inexpensive, and does not limit the complexity of student programs. This section describes the specific robot base used, where the computation is performed, the communication link, the camera used (for the Localization Module), and a breakdown of the current total costs to use the materials in a classroom.

4.1 Robot Base

As mentioned, the Roomba was chosen to support this work. However, there are many different models of Roombas available from iRobot. Most of the models will work with the code and examples provided, but the more expensive models add features that are useful only for their intended purpose (cleaning). Since they will be used solely for robotics education, the more inexpensive models are sufficient. In particular, the Roomba 410 (Figure 1) or the Roomba Create (Figure 2) are ideal. The primary difference between the two models is that the former was developed as a consumer vacuum cleaner while the later was designed as a research and education robot. So, the Roomba 410 retains the vacuuming capability while the Roomba Create has payload capabilities and programmable capabilities. The vacuuming capabilities, payload capabilities, and embedded programmable capabilities are not used by *Learning Roomba*, so either model would be acceptable. Other considerations between the two models include:

- Roomba Create is a little cheaper.

- Roomba Create has better odometry sensors in my experience. This means that the Roomba Create will stay straighter when it is supposed to and more accurately get to a desired destination.
• Roomba 410 comes with a rechargeable battery; the Roomba Create uses 12 AA batteries out of the box. A rechargeable battery pack can be purchased separately but that negates the cost advantage.

• Roomba 410 comes with a virtual wall. The virtual wall is used in some of the Modules, but only a limited number in the classroom are necessary. Also, they can be purchased separately.

The total costs are provided separately for the base Roomba Create, Roomba 410, and a Roomba Create with rechargeable battery and virtual wall package. If affordable, the Roomba Create with rechargeable battery and virtual wall unit package is ideal and allows for future use beyond just Learning Roomba.

Figure 1: iRobot Roomba 410

Figure 2: iRobot Roomba Create
4.2 Robot Computation

A BlueTooth adapter is selected to link a normal computer (laptop or desktop) to the Roomba. BlueTooth devices are wireless devices that can pair with another device wirelessly. Once they are paired, the two devices can communicate information back and forth. The programs are run on a computer. Commands are sent wirelessly to the Roomba and sensor data is sent wirelessly back to the computer.

The advantage to this approach is that it is relatively inexpensive (under 100 US Dollars), allows students to compile and run programs without tethering to the Roomba, and allows students to take advantage of the processing power of a full computer. In addition, using the software architecture, the number of Roombas to support a classroom can potentially be reduced. Furthermore, all the Roombas in a classroom can be managed from one computer which can help you reduce connection and hardware issues. The specific BlueTooth devices used are discussed in the next section.

One topic that has not yet been discussed is a computer to use to write and run the programs. While a computer is especially important to this approach since that is where the programs are run, a computer would be necessary with any of the approaches to write programs. The software tools provided run on Apple MacOSX and Microsoft Windows (and should run on Linux as well although that is untested). So, the only special requirements of the computer are support either Apple MacOSX or Microsoft Window (or Linux but it is untested), able to be networked to the other classroom computers, and have BlueTooth capability (although only one computer in the classroom needs BlueTooth capability). Many computers come with BlueTooth capabilities built-in; if not, a USB adapter can be purchased inexpensively. The computation and memory requirements are modest, so the computer does not need to be fast. Many schools already have computers available that can be used. If not, a sufficient computer can be purchased from either Dell (www.dell.com) or Apple (www.apple.com) for under 600 US Dollars.

4.3 Robot Communication

All communication to the Roomba is done through a BlueTooth connection to a device on the Roomba. There are two BlueTooth devices that can be used. Both are commercially available. The first is a RooTooth BlueTooth wireless Roomba connection dongle shown in Figure 3. It is available from SparkFun Electronics (www.sparkfun.com) for 100 US Dollars. The RooTooth is plugged into the Roomba’s 7-pin serial port and can be used with either the Roomba 410 or the Roomba Create. The other option is the Element Direct Bluetooth Adapter Module shown in Figure 4. It is available from Element Products, Inc. (www.elementdirect.com) for 60 US Dollars. The downside to the Element Direct Bluetooth Adapter Module is that it can only be used with the Roomba
Create. It plugs into the Roomba Create’s 25-pin expansion port.

Both BlueTooth options are functionally equivalent besides for the connection port used. They both pair with a BlueTooth enabled computer and use the same code to interact with them. Pairing is a process of having two BlueTooth devices, in this case a computer and the Roomba BlueTooth device, recognize and talk to each other. Therefore, the Element Direct Bluetooth Adapter Module is recommended for Roomba Create purchases (because it is cheaper), and the RooTooth is recommended for Roomba 410 purchases (because the Roomba 410 cannot use the Element Direct Bluetooth Adapter Module).

Figure 3: RooTooth Bluetooth Wireless Roomba Connection

Figure 4: Element Direct Bluetooth Adapter Module
4.4 Camera

For some of the modules, a webcam is used to watch the Roomba remotely, track the Roomba, or even localize the Roomba in its environment. A webcam provides visual information about the environment. To take advantage of these features, a webcam is necessary. A Logitech QuickCam Communicate MP camera (www.logitech.com) can be purchased for under 50 US Dollars (See Figure 5).

![Logitech QuickCam Communicate MP Webcam](image)

Figure 5: Logitech QuickCam Communicate MP Webcam

4.5 Hardware Costs

Table 1: Cost estimates to support a 20-student classroom

<table>
<thead>
<tr>
<th>Item</th>
<th>Roomba 410</th>
<th>Roomba Create</th>
<th>Roomba Create Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Roombas</td>
<td>$750</td>
<td>$650</td>
<td>$1150</td>
</tr>
<tr>
<td>5 BlueTooth Adapters</td>
<td>$500</td>
<td>$300</td>
<td>$300</td>
</tr>
<tr>
<td>3 Virtual Wall Units</td>
<td>N/A</td>
<td>$90</td>
<td>$90</td>
</tr>
<tr>
<td>1 Webcam</td>
<td>$50</td>
<td>$50</td>
<td>$50</td>
</tr>
<tr>
<td>1 Network Switch</td>
<td>$60</td>
<td>$60</td>
<td>$60</td>
</tr>
<tr>
<td>6 Computers</td>
<td>$3600</td>
<td>$3600</td>
<td>$3600</td>
</tr>
<tr>
<td>Total w/o Computers</td>
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<td>$1150</td>
<td>$1650</td>
</tr>
<tr>
<td>Total w/ Computers</td>
<td>$4960</td>
<td>$4750</td>
<td>$5250</td>
</tr>
</tbody>
</table>

A single robot kit can effectively support 4 students, but a 3 to 1 student to robot ratio would be better if it is affordable. Therefore, for a classroom of 20 students the following resources are needed: 5 robots, 6 computers (1 for the
5 Teams

The students should work in teams of 3 or 4. The reason for teams is that it reduces the number of required robots and the students can learn from each other. Often students are good at solving different types of problems, so grouping those students benefits all the students. However, homework assignments should be done individually to ensure that one student is not monopolizing the resources.

6 How to Setup Hardware and Software

6.1 Roomba and BlueTooth Hardware

Setting up the Roomba and BlueTooth hardware is fairly straightforward. The Roomba documentation explains how to start using the Roomba and how to charge it. Setting up the BlueTooth device differs depending on which BlueTooth adapter is used. For the Rootooth adapter, plug the Rootooth into the Roomba’s serial port (See Figure 6). For the ElementDirect BlueTooth Adapter Module, plug the module into the Create expansion port (See Figure 7). That is all you need to do to setup the Roomba and BlueTooth hardware.

Figure 6: Roomba with the Rootooth adapter installed
6.2 Network

The classroom computers need to be configured in a network such that all the computers can communicate with each other uninhibited by firewalls. Some school districts have policies for setting up networks and have IT professionals that are able to do so. If not and the computers are specifically purchased for supporting a robotics curriculum, there are many guides available on the Internet for setting up a local network.

6.3 Pair to the BlueTooth Adapters

One computer needs to be designated as the communication hub between the network and the Roombas. This computer needs to have BlueTooth capabilities and should be the teacher’s computer. Setting up a BlueTooth adapter differs depending on the Operating System that the computer is running on.

6.3.1 MacOSX

1. First, make sure the BlueTooth adapter (either the RooTooth or the ElementDirect BAM) is installed. If so, press the Power button on the Roomba to turn it on.

2. Bring up the System Preferences and choose the Bluetooth preferences (See Figure 8).

3. Verify that BlueTooth is turned on (See Figure 8) and then click on the “+” button. The BlueTooth Setup Assistant should appear.

4. Click the Continue button. Select “Any Device” and then click the Continue button (See Figure 9).

5. Select the BlueTooth device from the list (See Figure 9). It will be either “BlueRadios” for the RooTooth or “Element Serial” for the ElementDirect BAM. The type will be Unknown. If the device does not appear in the list, make sure the Roomba power is on. Click the Continue button.
6. Click Continue again (See Figure 9). A window will appear to enter a Passkey (See Figure 9). If you are using the RooTooth, the Passkey is “default”. If you are using the ElementDirect BAM, the Passkey is “0000”. Click Continue.

7. If successful, you can close the window. Repeat the process for each Roomba, but this process only needs to be done once for each BlueTooth device. Once the BlueTooth devices are paired, they can be used immediately in the future without these steps.

6.3.2 WindowsXP

1. First, make sure the BlueTooth adapter (either the RooTooth or the ElementDirect BAM) is installed. If so, press the Power button on the Roomba to turn it on.

2. Bring up the BlueTooth preferences or settings (See Figure 10). Note: the BlueTooth preferences tool varies from computer to computer, so the tool that you have available might not look the same as the screenshots shown here. If you need any additional help setting up a BlueTooth device, you can often find information on the Internet related to pairing a BlueTooth device with the specific hardware that you have.

3. Verify that BlueTooth is turned on and create a new connection (See Figure 11). The computer should perform a scan for available devices. “BlueRadios” or “Element Serial” should appear in the list. If you need a Passkey, it is “default” if you are using the RooTooth and “0000” if you are using the ElementDirect BAM.

4. If successful, you can close the tool. Repeat the process for each Roomba, but this process only needs to be done once for each BlueTooth device. Once the BlueTooth devices are paired, they can be used immediately in the future without these steps.
6.4 Roomba Network

The Roomba Network is a set of software components that communicate with each other. Services are enabled that student programs can interact with. To turn on the Roomba Network, a server needs to first be started on the network. To do so, double click on the “roomba.jar” file included in the LearningRoomba directory (provided as part of the distributed materials). A window similar to the one shown in Figure 12 should appear. Click on the Start Server button. The GUI should now show “Server Started at Address: “x.x.x.x” (See Figure 13). The address provided within the double-quotes should be given to the students as they write their programs (how this is used is covered in the first Module).

The next step is to start a service for each of the Roombas. For each Roomba, click on the “Start” button next to the label “Roomba”. A new window should appear (See Figure 14). Give the Roomba a common name, such as “Bob”,...
and select a port used to communicate with the Roomba. With MacOSX, the port should be something like “/dev/cu.BlueRadios...” (for the RooTooth) or “/dev/cu.ElementSerial...” (for the ElementDirect BAM). With WindowsXP, the port should be something like “COM41” where the number varies. There should be multiple entries if you have more than one Roomba connected. Choosing the right one may be a process of trial and error, and so it may be easier to start up each Roomba one by one.

The student’s programs connect to this server and can either use any available Roomba service or specify one by name. It is a good idea to put labels on the actual Roombas with their name that matches the name of the Roomba service. Doing so allows the students to look at a Roomba located in the classroom and tell their program to control that specific Roomba.

The rest of the services are covered in the later Modules when they are used.
6.5 Camera

On MacOSX, simply plug the QuickCam camera into the computer running a network Starter GUI (Figure 12). Any of the services that use a camera will ask you to select a camera from a list. Choose “Logitech Quickcam (MacOSX)”.

On Windows, the setup is a little more complicated. First, install the software that came with the camera on the computer running a network Starter GUI (Figure 12). Then, plug the QuickCam camera into the computer. Finally, install the Java Media Framework from the setup file found in the LearningRoomba toolkit directory. After everything has been setup, you can use the camera with these materials. Any of the services that use a camera will ask you to select a camera from a list. Choose “Logitech Quickcam (Windows)”.

Figure 12: Services Starter GUI

Figure 13: Services Starter GUI. Server Started
6.6 Student Programs

Student programs are written in the Java programming language through the BlueJ development environment. BlueJ needs to be installed on all the computers.

A setup installation package for Windows is found in the bluej directory included in the LearningRoomba directory (provided as part of the distributed materials). Follow the setup instructions. BlueJ can be started from a shortcut in the “Start” menu. Java JDK 6 may also need to be installed. An installer for that can be found on Sun’s website at http://java.sun.com/javase/downloads/index.jsp.

On MacOSX, the application just needs to be copied into the applications directory on the harddrive. Once it is there, double-click the application to start BlueJ. For convenience it is recommended to keep it accessible in the dock. To do so, right-click (or ctrl-click) on the BlueJ icon in the dock while it is running and choose “Keep in Dock” from the pop-up menu.

Once BlueJ is installed, it needs to be configured with the Roomba libraries. To do so, start BlueJ. Go to the “BlueJ->Preferences” menu option in MacOSX or “Tools->Preferences” menu option in Windows. Select the “Libraries” tab (Figure 15) and click the “Add” button. Locate the “roomba.jar” file located in the LearningRoomba directory. Click the “Ok” button and close the program.

Figure 14: Roomba Starter GUI

Figure 15: BlueJ Library Preferences
Writing a program in the development environment and running it is covered in Module 1.

7 Other References and Resources

There are many other resources available that cover the topics of robotics. Specific resources that pertain to a Module are included in the Teacher’s Guide for that Module. A full list of some of the supported references and resources is also provided here. My full Master’s Thesis is also available at: http://gicl.cs.drexel.edu/wiki/LearningRoomba.


The *PA Academic Standards for Science and Technology* provides information about the types of materials that should be covered at specific grades related to science and technology. This is a great resource to ensure that the materials are presented in an appropriate way for the different age groups.


The *Robotics Primer* is similar to *LearningRoomba*. It is also geared for pre-college students using the iRobot Roomba. Some of the exercises can be used in conjunction with *LearningRoomba* to cover some of the topics not addressed in *LearningRoomba*. Another use of this book is to use it as a student textbook to accompany the classroom lectures.


*Karel the Robot* is an introductory course to programming aimed on pre-college students. If the students do not have any experience with programming, this may be a good curriculum to precede the *LearningRoomba* materials.


*Hacking Roomba:ExtremeTech* covers projects related to modifying the Roomba, both hardware and software, to perform new tasks. The code used to directly communicate with the Roomba through the BlueTooth
Serial Device was built by Tod E. Kurt for this book.


*Mobile Robots* is a good resource discussing the lower-level details of mobile robotics. This may be a useful resource for older students interested in the electrical components of robots.


This is another resource on robotics projects, but these projects are not focused on the Roomba.


A background textbook covering introductory AI topics. This is likely an advanced resource for students, but is provided if students are interested to discover topics that are taught in colleges.


This is another resource similar to *Introduction to Ai Robotics*.


*Mind, man, and machine* discusses philosophical issues related to robots. If students are interested in the blurry lines between human, robots, and machines, this is a good resource to have them read.


*Vehicles* introduces seemingly intricate behaviors out of simple sensor responses. Some of the examples from this book are used in the Modules.