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**Abstract**

This curriculum outlines content and resources for a hands-on workshop on learning robotics; spanning 1 week or 15 hours of dispersed class time. Specifically, by building upon middle/high school student's programming skills without them having prior knowledge. Documents are formatted into lesson plans, instructor resources and “Studies” (group discussions on robotics). MATLAB/SIMULINK is utilized as an accessible and intuitive learning environment and as a means for implementing code on robots. Videos are provided to help demonstrate concepts as well as for instructors to learn about the Simulink code before carrying out each lesson. Robotics, learned through group discussions, instructor guided lessons and experimentation with the miniQ robot presents engineering as a broad domain. The attempt therefore, is to link learning robotics in the classroom to real world applications and tangible, creative processes. Moreover, to cover skills found in the Common Core Standards and the Next Generation Science Standards.

**Primary Learning Objectives**

Students will

1. Understand how to write code in MATLAB and Simulink
2. Learn how to create MATLAB functions in Simulink
3. Learn how to create Stateflow charts in Simulink
4. How to use Stateflow/MATLAB together to program the MiniQ robot
5. Discuss applications and topics in robotics

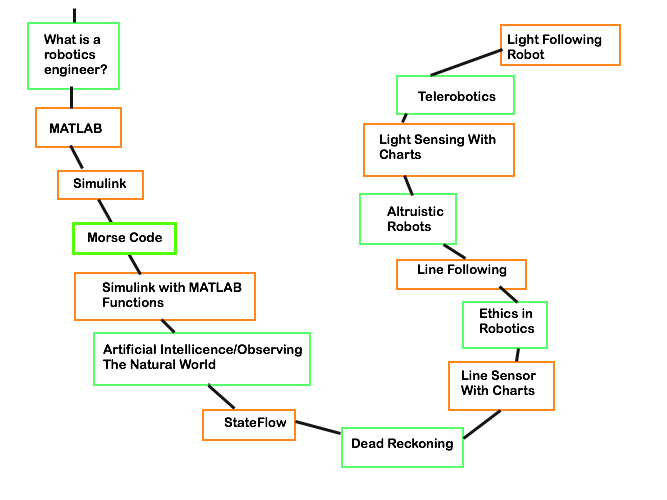
**Course Materials**

Each unit is outlined in a separate folder which contain the following elements:

**For the Lecture:**

* **Lesson Plan** - Recommended sequence of activities for the classroom, you could print or project this document for the students to follow
* **Study** - Interspersed within the curriculum are “Studies” which involve group discussions on a theme in robotics. There are five studies within this curriculum and this can be referenced by the green boxes in the graphic below.
* **Video Tutorials (Folder)** – Contains videos referred to in the Lesson Plans. The lesson plans also have YouTube links to these videos.
* **MATLAB Code/ Simulink Models (Folder)** – Contain the code files for the Unit
* **Instructor Reference:** Additionalresources for the instructors for specific activities in the lesson plan

**Activities:** The culmination of each lecture is a completed Simulink model which you can experiment with after the instructor led explanation. In many cases, a classroom activity is to refine and improve the Simulink models provided. These activities fall within the categories referenced by the orange boxes in the graphic below.



**Course Overview**

|  |  |
| --- | --- |
| *Unit* | *Contents* |
| Videos | * [Complete Video Playlist](https://www.youtube.com/watch?v=HxX2UZShVN4&list=PLbKgkJRTrYFyBls6qET4aCPPsMYVdmXQh) * [Introduction to the MiniQ Video](https://www.youtube.com/watch?v=dbSTZhcmeY0&feature=youtu.be) |
| Unit 1 | * *Study 1:* What Is a Robotics Engineer? * [Basic Math in The Command Window](https://www.youtube.com/watch?v=HxX2UZShVN4) * [MiniQ Motors from Command Window](https://www.youtube.com/watch?v=IBor4kHFt0g) * [MATLAB Functions in the Command Window](https://www.youtube.com/watch?v=mha1G8z3qi4) * [User Interface to Test Motors in the MATLAB Command Window](https://www.youtube.com/watch?v=8bZJqgUQSrQ) * *Taking It Further*: PhotoSensor Robot from Command Window |
| Unit 2 | * [Introduction to Simulink + Basic Math](https://www.youtube.com/watch?v=uLheskCv3Ds) * [The Simulink “Magic Box” Concept](https://www.youtube.com/watch?v=czuAarO-4cE) * [Simulink: MATLAB Functions with Lights](https://www.youtube.com/watch?v=UVssb7datAo) * *Study 2:* Morse Code * [Simulink: MATLAB Functions with Motors](https://www.youtube.com/watch?v=Os2-6kis2ZA) |
| Unit 3 | * [Setting Up External Mode: Using Simulink for Sensor Readings](https://www.youtube.com/watch?v=CXeHnf8yrtU) * [Color Machine with Motors: Functions for Obstacle Avoiding Robot](https://www.youtube.com/watch?v=bupeRE5uw04) * *Study 3:* Observing The Natural World + Artificial Intelligence * [Color Machine with Motors: Introduction to Stateflow Charts](https://www.youtube.com/watch?v=PkmYo7yGHs0) * *Study 4:* Dead Reckoning “Parking Bots” * [Dead Reckoning with StateFlow Charts](https://www.youtube.com/watch?v=B-bKLx2vvyU) * [Dead Reckoning with StateFlow Charts Advanced (adding color)](https://www.youtube.com/watch?v=wnUcv7pPSrI) |
| Unit 4 | * [“Stay In Box” Concept](https://www.youtube.com/watch?v=an2q7YK7Sd4) * *Study 5*: Ethics In Robotics * [Line Following:](https://www.youtube.com/watch?v=an2q7YK7Sd4)    + Stay in Box With Line Sensors   + Two Sensor Line Following   + Bang Bang Line Following * *Taking It Further*: PID Line Following With Proximity Stop * *Study 6*: Altruistic Robots |
| Unit 5 | * [Introduction to MiniQ Light Sensors:](https://www.youtube.com/watch?v=Js8bdidWZ40) * *Study 7*: Telerobotics * [Light Following Robot](https://www.youtube.com/watch?v=6Beln84oOZ8) |

**Required Materials**

1. [MiniQ Robot (complete kit)](http://www.dfrobot.com/index.php?route=product/product&product_id=555#.V50yu5OAOko)
2. Computers with the following installed:
   1. MATLAB
   2. Simulink
   3. Stateflow
   4. MATLAB Coder
3. Electrical Tape
4. Flashlights
5. Projector For Mirroring Instructor’s Computer Screen
6. Stands for MiniQ robots (can be 3D printed)
7. AA batteries (4 per miniQ robot)

**Educational Standards**

This curriculum has relevance to both the Common Core (CC) and Next Generation Science Standards (NGSS). It is up to the instructor to either scale up or scale down the importance of each of these aspects interspersed throughout the curriculum. The letters in red brackets are used as a key to associate a standard covered with a part of a lesson, noted in the instructor reference documents.

Common Core English Language Arts Standards:

* CCSS.ELA-LITERACY.RST.6-8.2  
  Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (a)
* CCSS.ELA-LITERACY.SL.8.1  
  Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly. (b)
* CCSS.ELA-LITERACY.SL.8.1.C

Pose questions that connect the ideas of several speakers and respond to others (c)

* [CCSS.ELA-LITERACY.SL.9-10.1](http://www.corestandards.org/ELA-Literacy/SL/9-10/1/)

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively. (d)

* [CCSS.ELA-LITERACY.SL.11-12.1](http://www.corestandards.org/ELA-Literacy/SL/11-12/1/)  
  Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively. (e)

Common Core Math Standards:

* CCSS.MATH.CONTENT.7.EE.B.4

Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (f)

* CCSS.MATH.CONTENT.HSF.IF.A.2

Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context. (g)

* CCSS.MATH.CONTENT.HSF.BF.A.1

Write a function that describes a relationship between two quantities.\* (h)

\*= Common Core High School Modeling Standard

Next Generation Science Standards:

* (MS-ETS1-4) Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. (i)
* [(HS-ETS1-4) Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales.](http://www.nap.edu/openbook.php?record_id=13165&page=91) (j)

**Advice and Tips for Instructors**

*Suggestions:*

The following are suggestions for running this course. Depending upon your context (classroom space, number of students, time frame) it is likely that you will have to integrate the curriculum material differently:

1. Student organization: This curriculum is suited for grades 8-12. It is possible to include 7th graders however, there will be some concepts which they may find advanced. A class size of 10 is manageable, but this depends upon the capabilities of an instructor and how easily they can answer questions from students. This is an important consideration because there can be hardware issues which arise and these should be taken into account.
2. Hardware management: Make sure to have MATLAB/Simulink installed on all computers prior to the workshop beginning. A projector should be available to mirror the instructor’s computer screen during lessons. It is useful to have the Arduino IDE installed in case the miniQ robot has to be initialized (code cleared off of it). To initialize the miniQ you can download a blank Arduino sketch onto the robot from the Arduino IDE. This will deal with errors which sometimes appears when deploying code to the hardware in MATLAB.
3. So the robot doesn’t roll off the table during testing, it it is essential that some sort of stand be made so the robot can sit without its wheels touching the ground.
4. There are a variety of instructional ‘modes’ accounted for in this curriculum. From lecture based instruction, to group discussion and collaborative activities. The typical classroom progression should be as follows: covering a Unit lesson plan, testing Simulink models, discussing a robotics “study.”
5. After hours: This workshop is designed so all work is completed within the workshop hours. However, homework can be assigned related to the “studies” lessons and how students can read and/or watch some of the videos (which are truly meant for instructors but can be used with students as well) before coming to class.
6. Material budget: The miniQ robot chassis was chosen for this project and the cost of a completed kit comes in around 80$. You will also want to have a supply of electrical tape for the line following exercises.
7. The hardware (nuts and bolts) on the miniQ robot tends to be brittle so be sure to purchase some micro hardware so the motors or the battery holder can be screwed on again if they fall off.
8. Each robot runs off of four AA batteries and these supplies should be factored into a budget as well. A hot glue gun should also be available for if the wheels become too loose and fall off of the motor shafts.
9. Handouts: The lesson plan document can be photocopied and handed out to students so they can follow along with the instructor’s pacing on the projector. The “Study” documents can also be photocopied and handed out as a student as those classes take place.
10. Pacing: In pilot tests this course ran over a 5 days, with 3 hours of class time periods per period. Each day included 30 minutes of cumulative break time for students. The pacing of instructional material was adapted to account for this. The curriculum map graphic which describes the 15 separate areas covered can help you decide what to cover daily. On this graphic, “study” lessons are boxed in green (these account for at least one hour class time) while MATLAB/Simulink code is boxed in orange. Try to progress through at least one and a half of these boxes graphics daily. Nonetheless, avoid being rigid with the lesson progression as there will be times when it benefits to focus on a topic in more detail.
11. Encourage students to help each other as a part of the classroom management plan. This empowers them and makes it easier for you to carry on with your instruction if some peer tutoring takes place. This is especially helpful because this curriculum was designed for a wide range of ages (13-18). Therefore, to account for this, and the range of abilities which will inevitably become apparent, have stronger students pair up and help those in need. Faster students and those in 11th and 12th grade should also cover the “taking it further” exercises in each lesson plan.
12. Frequent breaks, or at least one 10 minute break per hour, is extremely helpful for getting students re-energized and refocused on tasks at hand.
13. When pilot tested, this curriculum worked extremely well when combined with aspects of CAD/3D design. If the means are available (3D printer), have students design attachments for the miniQ robot such as shovels. This personalization of their robot gives students a sense of pride and added realism to the idea that they are “robotics engineers.”
14. Dealing with adversity: In the event that difficulties arises during the curriculum always have a contingency plan in place. If the MATLAB/SIMULINK hardware is not working or the miniQ robots are damaged jump ahead to a “Study” lesson until the issues can be resolved or have students create mathematical models in Simulink (reference: Unit 2, “Magic Box”).

*Instructional Tips:*

1. Review the Lesson Plans and Instructor Reference before running each individual class to give you a basic framework to work with throughout a class period. Instructors should review the tutorial videos listed within each “Unit” to familiarize themselves with the “example files” used with the miniQ robot.
2. Sections listed with “Study” and a number are associated with discussion based lesson plans. These lessons further integrate the curriculum into the Common Core Standards and National Grade School Standards and take up one hour of class time.
3. Time frames for each task depends upon the style of the instructor therefore pacing through each sequence is likely to differ. As a result, each unit’s lesson plan is formatted as a running document. Mark off where you left off and began each day within the unit documents as you progress through the course.
4. On the first day, review the Table of Content and Syllabus with students. Show the Introduction To MiniQ video to demonstrate what the end goal of the classroom process is- programming the robot.
5. Have the “Unit” document open on a projector prior to students arriving in the classroom
6. Each “Unit” Document should be photocopied for students to refer to if they are having difficulty following/seeing the projector
7. The zip file of videos and .slx files should be on each student’s computer (desktop) so they can refer to these files through each class period
8. **Have students open up completed models rather than build them from the beginning.** There will be times though when students will want to see novel combinations of code and you should encourage these moments by demonstrating the construction of a model, that is, if your proficiency with MATLAB/Simulink allows.
9. As a part of the classroom management plan, allow students to roam around the classroom to help others in need. This can control the dynamic between those who are faster than the rest and if you have mixed age groups in the classroom.
10. Take a break during each class period to give students time to refresh their minds (10 minutes per hour).

*Recommended Sequence for Instructors:*

|  |  |
| --- | --- |
| Introduction (on day 1) | -Abstract  -Instructor Advice  -Syllabus  -Table of Content |
| Daily | -Read through Unit lesson plans + experiment with Simulink files from the example folder  -Refer to video and instructor references accordingly |

*Recommended Sequence for Students:*

|  |  |
| --- | --- |
| Introduction (on day 1) | -Syllabus  -Table of content + video |
| Daily | -Follow along through Unit Lesson plan document (videos are optional)  -Experiment with Simulink files  -Participate in “Study” lesson discussions |