Lego Robotics - Lego Mindstorms Curriculum

Introduction:

For my final project, I wanted to redesign a Lego Robotics course at the Science Discovery Center on East Campus using the Lego Mindstorms kit. Though the information and curricula is available to create a productive Lego Robotics class, the format and execution of Lego Robotics at the Science Discovery Center did not fully tap into the full learning potential available. The course was designed primarily using the format of a previous Lego Robotics course using WE-do kits. These kits limit the students in terms of the quality and number of sensors, pieces, and overall complexity; thus using the same format for the new Lego Robotics class using Lego Mindstorms also limits student potential.

With the main motivation of creating a better designed Lego Robotics course, I have selected and crafted 5 different sessions for a traditional 5 week course. These sessions were chosen to try to engage students to use their full learning potential, while maintaining the fun and creative atmosphere that is required for an after school course. In order to develop certain skills, we chose to incorporate a simple worksheet that will guide the students through each activity, but will not be a hindrance on motivation.

The format of the class will be adapted from the previous course, but with slightly more rigid learning goals in mind. Because of the difficulty and complexity of some of the robots, the course will be restricted to 10 - 12 year old students. The classroom will consist of tables made to accommodate 2 students. The class will start up with a warm up period; here a video can be watched, and a discussion about relevant topics can ensue. After the warm up period, the students can begin building their robots, using the construction guides provided for each robot. After the construction of the robot, the students then need to program the robot to do a certain task. Throughout the construction and programming parts of the session, the students will be
reminded of the questions from the learning guide. In some sessions, the guides will ask for quick questions that relate to the warm up video, while others may require a picture to be drawn. All sessions’ learning guides will contain a design challenge as tool to develop a variety to skills. In addition, the use of explicit learning goals also allow for the more engagement of students as the skill levels of the students may vary quite dramatically.

Course and Motivation:

The Lego Robotics 2 class that uses the Lego Mindstorms was a course originally developed to be modeled after a Lego Robotics 1 course that uses the WE-do technology. Moving up to the Lego Mindstorm kits, students are able to further explore the use of more complicated building tasks, along with more precise and complicated sensors. Because of this added level of complexity, I saw it appropriate to slightly alter the format of the course to adjust to this increased difficulty. The set up of the class room is designed to mimic those of studio physics or workshop physics courses; these classrooms which have no real “front” help promote student learning. As Redish claims, the workshop physics design is different than traditional classrooms, but allows students to build concepts using technology; concept building being one of workshop physics strengths. In addition, using a similar format to the workshop physics model for Lego Robotics will be effective in using Peer Instruction, which tries to address the failures of “teaching by telling”, as discussed in McDermott. The classroom is set up for students to work together in pairs of two. Each pair will have a kit of Legos and computer to program the robots.

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1 Redish, Edward. "9: Workshop and Studio Methods." Teaching Physics With The Physics Suite
Each session will start with a warm up video. The warm up video has been designed to explicitly let the students know that the class is officially starting, as the students usually begin to tinker and construct as soon as they arrive. This lets the instructor get a bit of control on the class as a whole, but also lets the class open with exploring concepts. The warm up video is chosen to try to incorporate concepts that will later be addressed, in addition to creating motivation for the students to build their robots. After the warm up video, students begin to build their robots using construction instructions printed from an online source. Upon completion of the robot, the students will begin to explore programming the sensors that dictate the mechanics to the robot. A new element to the course that will be added is a simple learning guide for the students. The learning guide is used very similarly to physics tutorials described in Redish Chapter 8. Because of the nature of the course as an after school activity, students are not required to answer any of the questions on the learning guide, but are encouraged to look at some of the questions throughout the entire course. The learning guide, accompanied with the construction and programming of the robot aims to develop students constructionism by “Learning-by-making”. DiSessa states “Providing an environment that encourages engaged learning is a very different proposition from a curriculum that specifies only what is to be learned”, and the learning guide is designed to do just that. It allows for students of varying skill levels to explore different aspects of the robot. An important aspect of the leaning guide is the design challenge. The design challenge allows students who finish early to explore additional sensors and aspects of their robot. The design challenge also incorporates originality and uniqueness to each robot.

3 www.nxtprograms.com
4 Redish, Edward. "8: Recitation and Laboratory-Based Methods." Teaching Physics With The Physics Suite. 143-67
5 Papert, Seymour. "Situating Constructionism." Constructionism. By Idit Harel and Seymour Papert
6 DiSessa, Andrea. Changing Minds: Comptuers, Learning, Literacy
Each session, thus each learning guide, focuses on developing different aspects of student learning. In many of the sessions, numerous aspects repeatedly come up. In order to help develop young students context dependence of cognitive responses as stated by Redish in Chapter 3\(^7\), real world connections is one of the topics the learning guide emphasizes. This is addressed in a multitude of approaches including using the warm up video to show modern day robotics, thinking of real world applications of various robotics, and orders of magnitude estimation. Not only are real world connections emphasized, through the use of the learning guide, instructors are there to help students develop meta cognitive skills. By asking the students, “What”, “Why”, and “How” as detailed in Schoenfeld\(^8\), instructors begin to help these young students to think about their thinking. Some aspects of the learning guide implicitly address this by asking questions regarding the planning and reasoning behind the programming of the robot. The learning guides also have questions that aim to improve students’ skills in analogy and representation. Students are encouraged to develop representation skills by drawing and labeling pictures. Also, skills such as attributing motion to charts are developed by asking the students to think about relative motion resulting from various programming scripts. These skills may eventually develop to address the concerns of representation as discussed by Kohl and Finklestein\(^9\). By using the learning guide with design challenges as an additional tool to teach the Lego Robotics class, various aspects of student learning are engaged. Some of these skills are usually addressed in the hidden curriculum of a traditional classroom, but as an after school activity, these skills can be explicitly explored through the learning guide. Hopefully, this new curriculum of Lego Robotics

\(^7\) Redish, Edward. "3:There's More than Content to a Physics Course: The Hidden Curriculum." Teaching Physics With The Physics Suite. 52-67
\(^8\) Schoenfeld, Alan. *Whats All the Fuss About Metacognition*
will allow the students to learn a great deal more on a much greater breadth of skills and concepts.

This new, slightly more rigid, format of the Lego Robotics course will demand explicit learning goals, but allows for students to still have fun and enjoy robotics. Using the warm up as a tool for concept introduction and student motivation, each session will focus on predetermined skills. The instructor is in place to help direct student learning in addition to a learning guide that accompanies each session. This curriculum is aimed at tapping into the full learning potential available from using Lego Mindstorms; the format of a warm up video, robotic construction and programming, and the learning guide and design challenges are all designed to engage students in a different manner. Future goals would be developing some sort of survey to see if the curriculum is actually making a difference to the students. Hopefully future surveying would allow for additional adjustments to be made in order to increase learning.
Session: Golf Putter
Robot: http://www.nxtprograms.com/mini_golf/steps.html
Warm Up: http://www.youtube.com/watch?v=grWIC9VsFY4

1. What are a few examples of levers in everyday life?

2. Draw and label a picture of an everyday lever. Include the fulcrum.

Design Challenge!
Can you add a sensor to control when the putter turns on?
Session: Golf Putter
Robot: http://www.nxtprograms.com/mini_golf/steps.html
Warm Up: http://www.youtube.com/watch?v=grWIC9VsFY4

Learning Goals:
Real World Physics Connection, Representation and Drawing Models, Levers

Overview:
The golf putter session asks students to build a putter that will swing around and hit a ball. The construction instructions provided do not include use of a sensor. Using the Bill Nye the Science Guy warm up video, students will get an overview of simple machines, most specifically levers.

Learning Tasks:
The first question on the learning guide asks the students to think of a few examples of levers in everyday life. The whole session is based upon the concept of levers from the warm up video. Asking the students to think of everyday levers forces the students to associate the golf putter to concepts learned from the Bill Nye video. In addition, question one helps student to start creating connections with physics and the real world by relating the concepts learned from the video to real life. This ability to relate physics to the real world may prove useful later in life, especially in scientific disciplines [1]. The second question of the learning guide asks the student to draw and label a picture of an everyday lever. Once again, this helps the student associate physics concepts to the real world. This question also begins to develop the students’ ability to draw models and representations.
The Design Challenge of the session asks the students to add a sensor to golf putter that can trigger the putt. This can be accomplished in a numerous ways and sensors. The students can add the distance sensor to only kick when a ball is in range, or the student could use the touch sensor as a button to trigger a putt. This design challenge emphasizes the elicit-confront-resolve mentality.
Session: Bumper Car

[http://www.nxtprograms.com/bumper_car/steps.html](http://www.nxtprograms.com/bumper_car/steps.html)

Warm Up: [http://www.youtube.com/watch?v=7kA4BO7Yvdo](http://www.youtube.com/watch?v=7kA4BO7Yvdo)

1. With a partner, discuss which sensor would be best if you were to build a vacuuming robot? Explain why!

2. Draw a map for the planned motion path for your bumper car.

**Design Challenge!**
Can you make your bumper car move in a random manner? Can you make your car move the same way without using the bumper?
Session: Bumper Car
[http://www.nxtprograms.com/bumper_car/steps.html](http://www.nxtprograms.com/bumper_car/steps.html)

Warm Up: [http://www.youtube.com/watch?v=7kA4BO7Yvdo](http://www.youtube.com/watch?v=7kA4BO7Yvdo)

Learning Goals:
Real World Physics Connection, Peer Instruction, Representation

Overview:
In this session the students are asked to make a bumper car. The bumper car uses a touch sensor which will tell the car if it get bumped or not. The warm up video is a robotic vacuum cleaner which the motion of the bumper car can potentially mimic. This session emphasizes the real world connection of physics and robotics along with the use of peer instruction.

Learning Tasks:
The learning guide acts as a discussion guide primarily for this session. Question one asks the students to think about which sensors would be best for replicating a vacuuming robot. This should naturally lead the students to think about the motion of the robot and possible mechanism that would cause that type of motion. This is why questions two asks the student to think about the map of how the bumper car will move. The task of looking at a real world product and trying to mimic it directly allows students to see the connection and potential of the robots they are building. In addition, the wording in question one is meant to promote peer instruction. The words “with a partner” and “would be best” tell the students to come up with original ideas and discuss it with the partner. Hopefully, the students debate with each other possible sensors and designs that would be best for this type of motion. Question two is aimed to developing students’ connection of motion and representing motion. The design challenge asks the students to try to incorporate different sensors and random motion. This is just an extension of question one as it forces students to think about different types of motion and how to achieve them using different
sensors. Possible answers to the design challenge include using the distance sensor instead of the touch sensor, or a combination of both.
**Session:** Hand Generator Car


**Warm Up:** [http://www.youtube.com/watch?v=nUYTU5nhsW4](http://www.youtube.com/watch?v=nUYTU5nhsW4)

1. Can you think of something in everyday life that uses an electric motor? Can you think of something in everyday life that uses an electric generator?

2. If you carefully note how much the car wheels turn for each rotation of the crank, you will notice that one full turn of the crank results in somewhat less than one full turn of wheel rotation. This is because the electric generator is not 100% efficient. There are some losses due to friction and other things. For example, if the car wheels turned 270 degrees for each 360 degrees of rotation of the hand crank, then the generator would be $\frac{270}{360} = 0.75 = 75\%$ efficient. Can you estimate the efficiency of your generator?  

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**Design Challenge!**

Can you add gears to either the car or the hand crank to change the speed of the car? Can you make your car move with an electric motor instead of the hand generator?

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10 [http://www.nxtprograms.com/generator_car/steps.html](http://www.nxtprograms.com/generator_car/steps.html)
**Session:** Hand Generator Car  
**Warm Up:** [http://www.youtube.com/watch?v=nUYTU5nhsW4](http://www.youtube.com/watch?v=nUYTU5nhsW4)

**Learning Goals:**  
Real World Connection, Electric Motors and Generators

**Overview:**  
In this session, students start with a video from Bill Nye. This video educates the students about electric motors and electric generators. The students are then asked to build a simple hand generator car that doesn’t use the traditional electric motor. This session focuses on the relationship of electric motors and generators.

**Learning Tasks:**  
This session is quite a bit different from the other sessions as it focuses more on physics concepts rather than robot construction and programming. The warm up video is a little bit longer and takes more time to explain concepts that may be new to the students. Although there is a chance some students may never have had any prior knowledge of motors and generators, the combination of the video and the first question should be enough to allow students to understand the relationship of motors and generators. Question two of the learning guide is lengthy and may take more attention to solve, but for advanced students, this question should be manageable. It also serves as another potential source of a real world connection to physics. As suggested by Mahajan, estimation problems may help students quickly apply numerical calculations to real world situations. The design challenge is also more focused around physics than robot building and programing. Using gears of different sizes and noting their effects, the students can take an elicit-confront-resolve method to the design challenge.

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Session: Door Alarm
Warm Up: http://www.youtube.com/watch?v=eaRcWB3jwMo

1. Before you use the computer, discuss with a partner your plan for programming the door alarm.

2. After you have built, programmed, and tested your door alarm, discuss with your partner how you could improve the program to make the door alarm work better. Describe why this new program is better than the first.

Design Challenge!
Try to see if you can find ways to enter the room undetected, then see if you can modify the mechanical design or the program to fix those weaknesses.
Session: Door Alarm
Warm Up: http://www.youtube.com/watch?v=eaRcWB3jwMo

Learning Goals:
Peer Instruction, Meta-cognition

Overview:
The warm up video for this session is designed to motivate students about the potential of the Lego Mindstorms kit. This should help motivate the students to expand upon their creativity as the door alarm is quite simple. Because the door alarm is such a large potential for modifications, students are asked questions that help with peer instruction and meta-cognition as they complete various stages of the learning guide.

Learning Tasks:
The first question of the learning guide asks the students to discuss a plan for programming the robot. Initially this question promotes peer instruction, as the students will most likely debate the best way to program the door alarm, but it also serves as a starting point for the meta-cognitive development. As one programming plan becomes established, the second question forces the students to rethink their original plans. By explicitly asking the students to explain why their new program is better than original untested program students should naturally find flaws within their original train of thought. Using the programming on computer as a visual aid can also assist students assess their original plans. This is the starting point for developing students ability to think about their thinking process, or meta-cognitive skills. The design challenge is just an extension of question two, asking for additional design modifications along with programming modifications. Throughout the session the instructor should focus on asking the students “What”, “Why”, “How” regarding their robots.
Session: Hammer Car
Warm Up: http://www.youtube.com/watch?v=T500ecHP3pE

1. With your partner, discuss which BattleBot you thought was the most effective. Explain why!

2. Can you make the Hammer Bot hit a target automatically without you pressing the touch sensor?

Design Challenge!
Can you add any additional sensors or add mechanisms to your robot? Think of ways to make your own BattleBot.
**Session:** Hammer Car  
**Warm Up:** [http://www.youtube.com/watch?v=T500ecHP3pE](http://www.youtube.com/watch?v=T500ecHP3pE)

**Learning Goals:**  
Peer Instruction, Real World Connection

**Overview:**  
The warm up video is used to motivated students for the last session. Competition drives students, and for the last session, time permitting, students can test their robot designs against each other. The learning guide ties together the idea of creating their own robots by asking students questions that will hopefully motivate them to naturally want to build their own robot. Real world connections may be made from existing robot designs and mechanisms.

**Learning Guide:**  
The first question on the learning guide directly uses the warm up video to engage in peer instruction as the students debate over which BattleBot they thought was the most effective. This will hopefully give them a lot of ideas later in the session when they have the freedom to create their own robot. In addition, question one shows real world potential of robotics, even if it’s in the entertainment business. Question two of the learning guide asks the students to automate the robot. This is the first stepping stone used for the students to eventually make robots that are capable of battling against each other. Question two, in combination with question one should hopefully motivate the students enough to pursue the design challenge on their own will and desire. The design challenge explicitly calls for creativity as there are a number of modifications that can be made to each robot. Some ideas include making a spinning attack wheel, or a flipping mechanism. The use of the learning guide as a whole guides the students through the process of making their own battle bots.
Works Cited


Schoenfeld, Alan. *What's All the Fuss About Metacognition*.