LEGO Robotics

Measuring and Graphing Speed of a LEGO robotic car

Through this series of lessons students learn to build and program a LEGO Robotic Car in cooperative groups, measure and graph its speed. Mathematics, science, technology, literacy, and problem solving skills are innately woven into the activities.

Ready Set Tech Grant Application for
Teachers Network.org

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Project Description

LEGO Robotics - Measuring and Graphing Speed of a robotic car. Through these lessons students learn to build and program a LEGO Robotic Car in cooperative groups and measure and graph its speed. Students learn math, science, technology, literacy, and problem solving skills.

Curriculum Objectives

Students will:
1. Learn to identify what robot is, what jobs robots do in the world around them, and how robots help humans
2. Construct a robotic car using LEGO Mindstorms in a cooperative group
3. Identify the different parts of a LEGO Mindstroms Robot
4. Program a two-motor robot in a cooperative group using LEGO Robolab software and learn how to change a robot's speed and time variables
5. Measure and graph a robot's speed
6. Compare a robot's speed over two different surfaces
7. Make predictions on the distance their robot will travel in a given time

How the Internet is used to support content, reinforce process, standards, and goals:

The students will use the Internet to conduct four web quests to introduce them to the world of robotics and robotic construction.

The first web quest focuses on what a robot is and how robots are used in the world around them. The second web quest introduces students to the world of LEGO Robotics by having them explore creations on LEGO Mindstorms.com. The third web quest leads the students through step-by-step building instructions of their first robot. And in the fourth web quest students follow step-by-step instructions on how to program their robot's motor to move and stop on time.

Web quest 1:
What is a Robot?
http://www.occdsb.on.ca/%7Eproj4632/what_is_a_robot.htm

Web quest 2:
LEGO Mindstorms Image Gallery
http://mindstorms.lego.com/eng/inventions/advancedsearch.asp

Web quest 3: 1 Motor Car Bot Building Instructions
http://www.lego.com/eng/education/mindstorms/home.asp?pagename=qsg_build

Web quest 4: Pilot Course 1 – Stop the motor on Time
http://www.lego.com/eng/education/mindstorms/home.asp?pagename=qsg_pilot1

Why Robotics?

Technology is all around us, and the LEGO Mindstorms Robotics system gives students the opportunity to have an open-ended hands-on experience with technology in a way that is accessible, grounded in real-world problem solving, and is fun. Most students are familiar with playing with LEGO bricks, and this series of introductory LEGO Robotics lessons combines LEGO bricks with the Robolab programming software, and helps build student confidence with technology, as they are able to use old familiar materials in new and exciting ways. Through these lessons, the main ideas of robotics will be demystified by engaging students in experiences with the basic concepts behind robotics while reinforcing mathematics, science, technology and literacy standards.

Students will be challenged to:

1. Explore what is a robot

2. Explore LEGO Robots made by Mindstorms enthusiasts

3. Construct and program a 1 Motor Car Bot

4. Measure and graph 1 Motor Car Bot's speed

5. Work in cooperative groups

6. Keep an ongoing reflective record of work accomplished

Students are asked to observe technology in the world around them (in their homes, in the art world, and in industry), and bring their observations into their hands-on investigations. Students will use their understandings gained through their observations and investigations to develop, design, and test their own unique robotics project. And through these activities that challenge students to develop their own original solution for each problem presented, they will develop the "out of the box" thinking that is vital for scientific innovation. Each lesson is designed to be student centered, encouraging students to work out their own methods for exploring the materials and challenges presented. Students will construct their own understandings of robotic concepts, with the teacher in the role of the facilitator presenting information on a "need to know" basis. The lessons authentically call on math, science, technology, literacy and problem solving skills, as students will naturally need to draw upon them to help them through their investigations.

Standards Addressed in the Lessons

NYS Mathematics Standards (4th Grade)

Problem Solving Strand

- Explore, examine, and make observations about a social problem or mathematical situation
- Interpret information correctly, identify the problem, and generate possible solutions
- Represent problem situations in oral, written, concrete, pictorial, and graphical forms
- Use trial and error to solve problems
- Make pictures/diagrams of problems
- Use physical objects to model problems
- Work in collaboration with others to solve problems
- Verify results of a problem

Reasoning and Proof Strand

- Use representations to support mathematical ideas
- Justify general claims or conjectures, using manipulatives, models, and expressions

Communication Strand

- Provide reasoning both in written and verbal form
- Organize and accurately label work
- Share organized mathematical ideas through the manipulation of objects, drawings, pictures, charts, graphs, tables, diagrams, models, symbols, and expressions in written and verbal form

Connections Strand

- Recognize, understand, and make connections in their everyday experiences to mathematical ideas
- Connect and apply mathematical information to solve problems
- Model situations with objects and representations and be able to make observations
- Recognize the presence of mathematics in their daily lives
- Apply mathematics to solve problems that develop outside of mathematics
- Recognize and apply mathematics to other disciplines

Representation Strand

- Use verbal and written language, physical models, drawing charts, graphs, tables, symbols, and equations as representations
- Use standard and nonstandard representations with accuracy and detail
- Use mathematics to show and understand physical phenomena (e.g., estimate and represent the number of apples in a tree)

Number Sense and Operations Strand

- Develop an understanding of decimals as part of a whole

- Select appropriate computational and operational methods to solve problems
- Express decimals as an equivalent form of fractions to tenths and hundredths
- Understand various meanings of multiplication and division

Measurement Strand
- Select tools and units (customary and metric) appropriate for the length measured
- Use a ruler to measure to the nearest standard unit (whole, _ and _ inches, whole feet, whole yards, whole centimeters, and whole meters)
- Know and understand equivalent standard units of length: 12 inches = 1 foot 3 feet = 1 yard

Statistics and Probability Strand
- Design investigations to address a question from given data
- Collect data using observations, surveys, and experiments and record appropriately
- Represent data using tables, bar graphs, and pictographs
- Develop and make predictions that are based on data
- Formulate conclusions and make predictions from graphs

NYS Elementary ELA Standards

Standard 1: Language for Information and Understanding
- Students will listen, speak, read, and write for information and understanding. Students will collect data, facts, and ideas; discover relationships, concepts, and generalizations; and use knowledge generated from oral, written, and electronically produced texts.

Standard 2: Language for Literary Response and Expression
- Students will read and listen to oral, written, and electronically produced texts, relate texts to their own lives; and develop an understanding of the diverse social, historical, and cultural dimensions the texts and performances represent

Standard 3: Language for Critical Analysis and Evaluation
- Students will listen, speak, read, and write for critical analysis and evaluation in small group work, whole group discussions, in lesson handouts, and in reflective journals.

Standard 4: Language for Social Interaction
- During group work and class discussions, students will listen, speak, read, and write for social interaction.

NYS Elementary Science Standards

- Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop

solutions

Physical Science

- Investigate the use of common forces (pushes and pulls) on objects, such as those caused by gravity, magnetism, and mechanical forces

NYS Elementary Technology Education Standards

Engineering Design

- Investigate prior solutions and ideas from books, magazines, family, friends, neighbors, and community members
- Generate ideas for possible solutions, individually and through group activity; apply age-appropriate mathematics and science skills; evaluate the ideas and determine the best solution; and explain reasons for the choices
- Plan and build, under supervision, a model of the solution using familiar materials, processes, and hand tools
- Discuss how best to test the solution; perform the test under teacher supervision; record and portray results through numerical and graphic means; discuss orally why things worked or didn't work; and summarize results in writing, suggesting ways to make the solution better

Technology Systems

- Access needed information from media, electronic data bases and community resources
- Assemble and operate simple technological systems, including those with interconnecting mechanisms to achieve different kinds of movement
- Understand that larger systems are made up of smaller component subsystems

Tools, Resources and Technological Processes

- Assemble components using a fastening process
- Process materials into more useful forms
- Understand the importance of safety and ease of use in selecting tools and resources for a specific purpose
- Use simple manufacturing processes (e.g., assembly, multiple stages of production, quality control) to produce a product

Computer Technology

- Control computerized devices and systems through programming
- Describe how technology can have positive and negative effects on the environment and on the way people live and work

Management of Technology

- Participate in small group projects and in structured group tasks requiring planning, financing, production, quality control, and follow-up

Materials

Any LEGO bricks that you already have can be used, but many of the activities in the lesson plans require the **LEGO RCX** (the brain and heart of the robot) and LEGO Technic system bricks like gears, beams, axels, bushings, hubs and wheels. You can buy these parts individually, but it is more cost effective to buy a kit that includes the RCX and the other necessary pieces. Purchasing the larger set also supports a more open-ended experience. Once students become comfortable with the LEGO materials and concepts of robotics, you can encourage them to bring in and add materials of their choice that they wish to explore applying to their creations.

Computer

A computer is necessary for creating and sending the program to the LEGO RCX that will power the student's robotic creation. At least one computer in the learning setting is required. Students can take turns downloading their programs, and they can save and upload past programs from one main computer. If students are encouraged to plan their programming ahead of time on paper, there will be limited computer time needed, which allows for more hands-on physical interaction with their robotic experiments. The ideal situation is a wireless laptop lab in the classroom with each cooperative work group having their own computer to program with.

LEGO Robotics Invention System Set (RIS 2.0)

LEGO Robotics Invention System Set - $199.00 Available for purchase from LEGO.com: http://www.LEGO.com/shop This set has the largest amount of pieces (700+, including the LEGO RCX, a USB infrared tower, 2 motors, 2 touch sensors, and a light sensor). The set also comes with a PC-only LEGO Robotics software, but I recommend using the LEGO Robolab software as it is icon based, can be used with all levels of readers, and can be used on both a Mac and a PC. This set comes with a comprehensive book of building instructions.

LEGO Mindstorms - Team Challenge Set with Robolab Software

$226.00 Available for purchase from LEGO Education.com http://www.legoeducation.com□These Mindstorms sets are designed for use in classrooms and carry much less parts that the RIS 2.0, but the advantage of these sets is that the LEGO Robolab software is bundled together with the kit, they come in sturdy storage containers, and they provide a book of building instructions.

LEGO Robolab Software

LEGO Robolab Software - $69.00 Available for purchase from the LEGO Education website: http://www.LEGOeducation.com This icon-based software developed from the same technology that landed and navigates the Mars rovers on Mars. It can be installed on a Mac or PC, and has beginner (Pilot) to advanced (Inventor) levels of

programming. As this curriculum is an introduction to robotics, I only outline using Pilot level programming in the lesson plans, but I would not deter curious students from investigating inventor programming if they wish.

Lesson Plan Outline

Lesson 1

- What is a robot?
  Web Quest - Building background knowledge of robots
- *Robotics Notebook Entry* - Find an object in your house that is/isn't a robot and explain why

Lesson 2

- LEGO Mindstorms
  Web Quest - Exploring LEGO Mindstorms Inventions

Lesson 3

- 1 Motor Car Bot Parts List (PDF)
  Identify the parts necessary to build the robot
-

- 1-Motor Car Bot - Build
  Web Quest - Follow building instructions online - or print out instructions to build offline
- Observation Sheet (PDF)
  Illustrate robot and label its parts
- *Robotics Notebook Entry* - Write about your building and teamwork experience

Lesson 4

- Programming with ROBOLAB Software & Measuring and Graphing Speed☐☐1 Motor Car Bot Speed Sheet 1 (Pilot 1)☐☐1 Motor Car Bot Speed Sheet 2 (Pilot 2)☐☐Graphing Speed Sheet ☐☐Graph Paper
- *Robotics Notebook Entry* - Write about your building and teamwork expedience

Lesson 1

Guiding Question: What is a Robot?

Lesson Objectives: Build background knowledge of robots and the robotic industry.

Materials Needed: Computer with internet connection

Books:
Robots by, Clive Gifford (2003)
Robot by, Roger Bridgman (2004)

Web Quest Page:
WHAT IS A ROBOT (HTML)

WHAT IS A ROBOT (PDF)

Activity 1:

Read Aloud & Discussion:
Ask students if they know what a robot is, where they have seen robots and share excerpts and pictures of robots in Clive Gifford's *Robots* (2003), and in Roger Bridgman's *Robot* (2004). Have a short discussion on what jobs the students notice that robots perform in the world. Make sure to explain that a **robot** is **any machine** that can perform a task on its own **autonomously** after it is **programmed** by humans.

Small Group Activity:
In cooperative groups, distribute excerpts of *Robots & Robot* that the class has not read together and ask students to read, chart, and teach back to the class about jobs Robots perform in the world around them.

Share:
Have each group teach back their robot chart to the group

Actitivty 2:

Web Quest:
Review with students that a **robot** is **any machine** that perform a task on its own **autonomously** after it is **programmed** by humans, and today they will be exploring a website in groups (or pairs) that looks at what is a robot and what isn't a robot and why.

Have students explore
http://www.occdsb.on.ca/~proj4632/what_is_a_robot.htm
and answer the questions on the web quest page - each student is responsible to filling out his/her own web quest form.

WHAT IS A ROBOT(HTML)

WHAT IS A ROBOT(PDF)

Wrap-up/Share:
Have students share their observations/discoveries.

Homework:
Have students find an object at home that is or isn't a robot and explain why.

***Assessment**:*

Assessments will be measured based on informal observations on how well students interact during:

1. Read aloud & discussion
2. Small group work on identifying robots from texts
3. Small group work during web quest
4. Individual write up of web quest
5. Robotic notebook entry on finding an object at home that is/isn't a robot

Lesson 2

Guiding Question: What is a LEGO Mindstorms Robot?

Lesson Objectives: Build background knowledge of LEGO Mindstorms Robots

Materials Needed: Computer with internet connection & printer

Web Quest Page:
LEGO Mindstorms (HTML)
LEGO Mindstorms (PDF)

Activity 1:

Web Quest:
Have students explore
http://mindstorms.lego.com/eng/community/halloffame/default.asp
and answer the questions on the web quest page - students can work in groups/pairs on the web quest but each student is responsible to filling out his/her own web quest form.

Students are asked to print out 1 creation they liked from Mindstorms.com to share

LEGO Mindstorms(HTML)

LEGO Mindstorms (PDF)

Wrap-up/Share:
Have students share their observations/discoveries.

Homework:
Students who did not complete web quest form can do so for homework

Assessment:

Assessments will be measured based on informal observations on how well students interact during:

1. Small group work on identifying robots from website
2. Individual write up of web quest
3. Partcipation in whole group share

Lesson 3:
Guiding Question: How do you constructing a robot?

Lesson Objectives: Experience with constructing a robot
Building knowledge of LEGO Robotic elements

Materials Needed:

Parts for 1 Motor Car Bot

Web Links:
1 Motor Car Bot Building Instructions Online
http://www.lego.com/eng/education/mindstorms/home.asp?pagename=qsg_build

1 Motor Car Bot Building Instructions Printable Version
1 Motor Car Bot Building Instructions (PDF)

Documents:
1 Motor Car Bot Parts List (PDF)

Observation Sheet (PDF)

Activity 1:
Sorting and naming parts:
Have groups of students sort and name the LEGO parts for the 1 motor car bot
1 Motor Car Bot Parts List (PDF)

A good team building exercise is to have 1 student grab a LEGO with his or her eyes closed (after they are sorted and named) and try to guess what part it is. Team members can give hints of properties of the parts (it is black, it has 8 studs on top, etc.).

Activity 2:

Building: This can be a webquest where the students follow the instructions online

http://www.lego.com/eng/education/mindstorms/home.asp?pagename=qsg_build

Or this can be done without the use of the computer, following printed building instructions

1 Motor Car Bot Building Instructions (PDF)

In cooperative groups have students build the 1 Motor Car Bot. Each student should have a job to have group work run more smoothly.

1. Supplies Manager

2. Builder 1

3. Builder 2

4. Quality Control (does the model match the building instructions?)

5. Website building instructions controller or Happy Encourager

Observation Sheet:

Observation Sheet (PDF)

Once students have completed building the robot, have them draw and label the robot parts on the observations sheet.

LEGO Robotics Observation Sheet

Test Run:
Once students have completed building, have them take turns running the robot by pressing the green "run" button and observe what it does.

Wrap-up/Share:
Have students share their observations/discoveries.

Homework:
Have students write a reflection in their robotics notebook on what they learned today

Assessments:

Assessments will be measured based on informal observations on how well students interact during:

1. Small group work on identifying robotic parts
2. Small group work during robot construction
3. Individual write up of observation
4. Robotic notebook entry on what was built today

Lesson 4:

Guiding Question: How do you measure a robot's speed?

Lesson Objectives:

- Experience with programming a robot in 2 different programming modes (Pilot 1 & 2)
- Testing and measuring the distance the robot moves over a certain period of time = speed
- Speed = distance / time
- Graphing data collected

Materials Needed:

- 1 Motor Car Bot (constructed)
- Yard stick for each group
- LEGO Minifigure or LEGO Brick for each group
- 2 different surfaces to test the robot running on (a rug and a floor surface space)
- Computer with ROBOLAB Software - Pilot 1 programming
- Infrared tower for each computer used

Documents:

1 Motor Car Bot Speed Sheet 1 (Pilot 1)(PDF)

1 Motor Car Bot Speed Sheet 2 (Pilot 2)(PDF)

Graphing Speed Sheet(PDF)

Graph Paper(PDF)

Activity 1:

Pilot 1 Programming

Measuring the robot's speed over time - 1 variable

Pilot 1 programming in ROBOLAB allows users to program 1 motor to move forwards or backwards at a set power level for a selected number of seconds. Students will experiment with downloading a Pilot 1 program on to their robot and estimating and measuring how many inches it travels in 1, 2, and 4 seconds. They will test their robots travel in two different conditions and compare their results.

This activity can be done online following the directions on LEGO.com

http://www.lego.com/eng/education/mindstorms/home.asp?pagename=qsg_pilot1

Or without the internet using the following handout

1 Motor Car Bot Speed Sheet 1 (Pilot 1)(PDF)

Test Run:
Students will be test running their robots a number of times, so it may be a god idea to assign group roles.

1. Programmer
2. Directions Giver
3. Measurer
4. Robot engineer
5. Recorder

Wrap-up/Share:
Have students share their observations/discoveries

Homework:
Have students write a reflection in their robotics notebook on what they learned today, and finish their recordings if they did not in class

Activity 2:

Pilot 2 Programming - Measuring the robot's speed over time -2 variables

Pilot 2 programming in ROBOLAB allows users to program 2 motors to move forwards or backwards at a power level ***they select*** for a selected number of seconds. Students will experiment with downloading a Pilot 2 program on to their robot and estimating and measuring how many inches it travels in 1, 2, and 4 seconds ***and at 5 different power levels***. They will test their robots travel in two different conditions and compare their results.

This activity should be done following the Pilot 2 Speed Sheet
1 Motor Car Bot Speed Sheet 2 (Pilot 2)(PDF)

Test Run:
Students will be test running their robots a number of times, so it may be a god idea to assign group roles.

1. Programmer
2. Directions Giver

3. Measurer
4. Robot engineer
5. Recorder

Wrap-up/Share:
Have students share their observations/discoveries

Homework:
Have students write a reflection in their robotics notebook on what they learned today, and finish their recordings if they did not in class

Activity 3:

Graphing the Data

Students will take all of the data they collected in the speed activities and represent it in a bar graph. They then must communicate what they graphed to the class. Team members can work together, but each student must complete his or her own graph.

Graphing Speed Sheet(PDF)

Graph Paper(PDF)

Wrap-up/Share:
Have students share their observations/discoveries

Homework:
Have students write a reflection in their robotics notebook on what they learned today, and finish their graphs they did not in class

Assessments:
Assessments will be measured based on informal observations on how well students interact during:

1. Small group work during robot programming
2. Small group work during graphing
3. Individual work during graphing
4. Robotic notebook entry on what was built today

Sample Student Work


STAPLES

1 Motor Car-bot (1mcb) Speed Test

What we did:

We tested the robot on the ruler and we saw the speed went faster on the floor than it did on the rug.

What I observed:

I think that I observed the robot speed and I think we worked faster today than any other day.

My Conclusion: I think overall the robot runed faster on the floor and slower on the rug.

Graph 2 – Speed Test – with specified power level on motor

Data

Average Speed Floor

Power level 1: 9 inches per second

Power level 2: 9 inches per second

Power level 3: 9 inches per second

Power level 4: 12 inches per second

Power level 5: 13 inches per second

Average Speed Rug

Power level 1: 5 inches per second

Power level 2: 8 inches per second

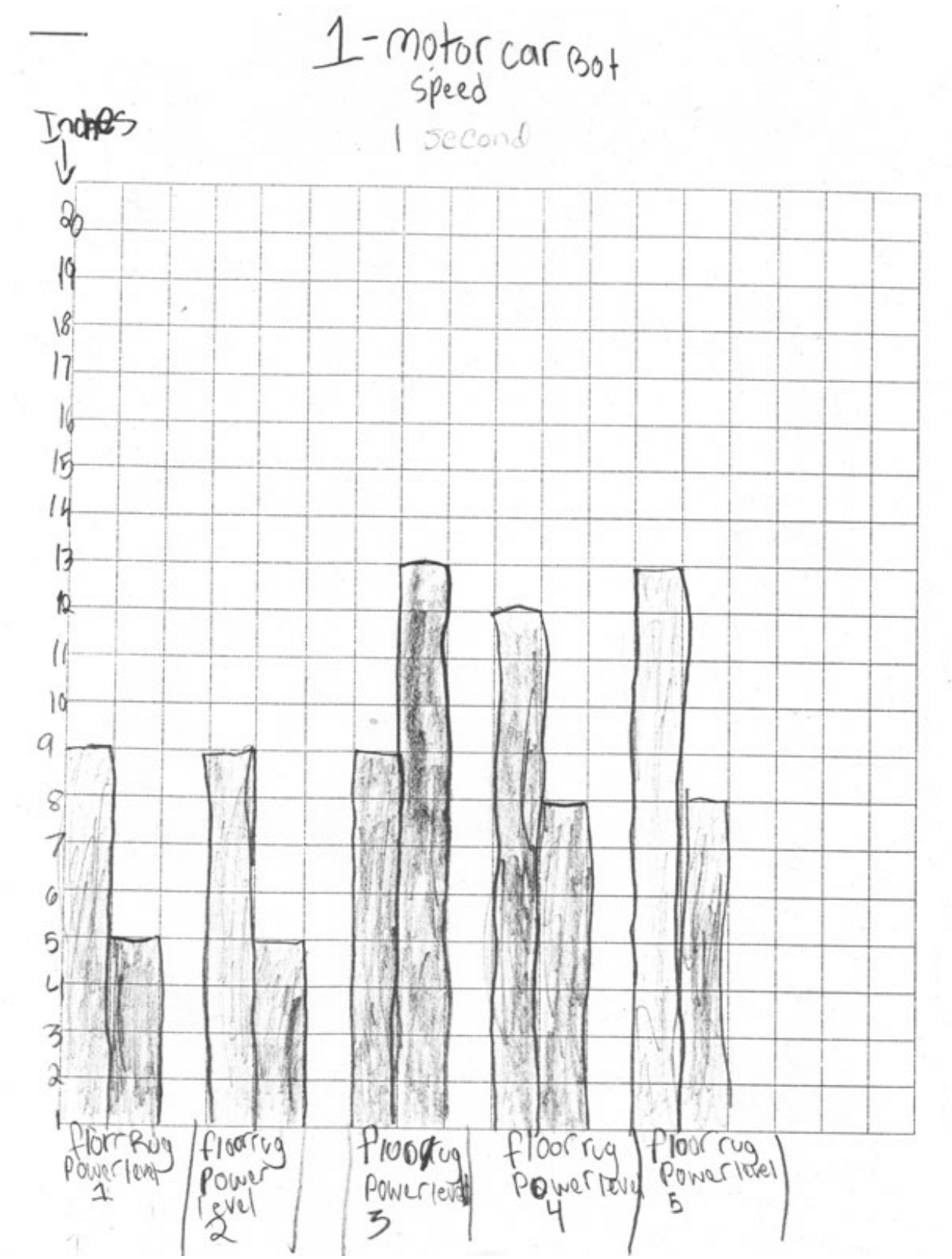
Power level 3: 13 inches per second

Power level 4: 8 inches per second

Power level 5: 9 inches per second

Your graph MUST have:

1. Your names listed on your graph
2. A Title
3. Labels for the axis
4. All data graphed
5. An area that says:
    - What you did (to collect the data)
    - What you observed
    - A conclusion you make about your observations


1-motor car Bot
speed
1 second
Inches
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
floor rug power level 1
floor rug power level 2
floor rug power level 3
floor rug power level 4
floor rug power level 5

Nick name: falling apart bot

HARD BOT

Today we got to build a hard bot. It was miserble are robot kept breaking. No matter how hard we tried to Put it together it broke just like that Worst of all we were missing a Piece lily was so upset she kept on saying "Why did they have to call it simple-bot?" until super maruem came to the rescue. Maruem said it was very delecet. She said if we worked as a team we could find the Piece. We did then maureem helped us build the Hardbot again. This is the funny Part we nick named called the robot: Falling apart bot! Me and lily agreed on where we would Put the Pieces. So it didnt really turn out to be that bad with a big help from Maruèem!


The robot is fragile.
Why did they call it the simple boot
We need help!
We have to do it again!
grrrr...
Bring it.
ummm..
Found it
Thank you
Thank you maruem
Your welcome

RESOURCES

There is a wealth of information on the web about LEGO Mindstorms. The best "Google" search words to use are "LEGO Mindstorms," "Robolab," and "LEGO Mindstorms MOC." (MOC means My Own Creation).

Following are some of my favorite LEGO Mindstorms websites and books that helped to inspire my LEGO robotics lesson plans. They are easy to navigate and are full of valuable inspiration!

WEBSITES

What is a Robot?

http://www.occdsb.on.ca/%7Eproj4632/what_is_a_robot.htm

1 Motor Car Bot Building Instructions

http://www.lego.com/eng/education/mindstorms/home.asp?pagename=qsg_build

Robolab Lessons

http://www.lego.com/eng/education/mindstorms/home.asp?pagename=qsg_pilot1

The Official Mindstorms Website (Loads of MOC's (My Own Creations) in the "Inventions" area)

http://mindstorms.lego.com/eng/inventions/advancedsearch.asp

BIBLIOGRAPHY

Resources for Children

***Books**:*

Bridgman, R. (2004). *Robot.* New York: DK Publishing, Inc.

DK Eyewitness picture book that gives a thorough overview of the world of robotics. Robotic engineering pioneers and their creations are mentioned in this visually stunning book. Some students will not want to put it down. Excellent motivator for personal robotic projects.

Gifford, C. (2003). *Robots*. New York: Kingfisher Young Knowledge.

Picture book introducing robots (real and fiction), robotics in industry, and in the art world. It discusses technology such as programming and sensors without getting too technical. I would strongly suggest avoiding the "fun and easy projects" section that shows how students can make their own

cardboard robot.

Horvatic, A. (1989). *Simple Machines.* Photographs by, Stephen Bruner. New York: E.P. Dutton

Photographs and straightforward explanations of five simple machines (the wheel, inclined plane, wedge, screw, lever). Excellent resource piece for children to get more information on how simple machines work.

Lampton, C. (1991). *Marbles, Roller Skates, Doorknobs.* Brookfield, CT: Brookfield Press.

Picture book detailing how wheels work.

Lampton, C. (1991). *Sailboats, Flagpoles, Cranes.* Brookfield, CT: Brookfield Press.

Picture book detailing how pulleys work on sailboats, flagpoles, and cranes.

Lindbloom, S. (1985). *How to Build a Robot.* New York: Thomas Y. Crowell Junior Books.

Chapter book that goes through a brief history of robotics, breaks up the different components of Robotics (motion, sense, and thought), and gives some advice on how to go about creating your own robot.

Lauber, P. (1987). *Get Ready for Robots.* Illustrated by, True Kelley. New York: Thomas Y. Crowell Junior Books.

Picture book that show the many robots around us and explains the many uses for robots in today's world. Excellent book to consider reading aloud on an intro to robotics day.

Macaulay, D. (1988). *The Way Things Work.* Boston: Houghton Mifflin Company.

For those students looking for more information on how gears work (for example), you can direct them to the stunningly descriptive visuals and mechanical explanations in this illustrated volume of Macaulay's famous work.

Walker, S. & Feldman, R. (2002). *Pulleys.* Minneapolis: Lerner Publications.

Picture book detailing how pulleys work.

Walker, S. & Feldman, R. (2002). *Wheels and Axels.* Minneapolis: Lerner Publications.

Picture book detailing how wheels and axels work.

Zubrowski, B. (1986). Illustrations by, Roy Doty. *Wheels at Work.* New York: William Morrow and Company, Inc.

Science project picture book on wheels. This book has hands on activities for making your own pulleys, windlass, gears, water wheels, windmills and a paddle wheel. There are also excellent explanations on how they work, but the focus of this book is to encourage students to explore making their own machines with wheels.

Video:

Zoom (Ch. 13) - "Robots", "First LEGO League"
Two short segments form PBS Zoom.

"Robots" - is an interview with James McLurkin from iRobot and what it's like to work in the robotics industry. He built his first robot at age 12 out of random scraps.

"First LEGO League" – Profiles a team of students who will compete in the First LEGO League competition. This segment focuses on team work, team jobs, and problem solving when building a robot in collaboration. Not all students are involved with building and programming; some are researchers, and team managers.

***Web*:**

EdHeads Website – Simple Machines Activity
www.edheads.org/activities/simple-machines/

Interactive game that helps teach about the functions of simple machines that you can find in your everyday life.

First LEGO League
http://www.firstLEGOleague.org

Students can go here for inspiration to start their own FLL team.

JP Brown's Serious LEGO Website
http://jpbrown.i8.com/index.html

This is the king of LEGO Mindstorms fan created websites. JP brown is the inventor of the famous Rubik's Cube® robot puzzle solver. Other amazing inventions are described in detail on this website as well.

LEGO Constructopedia
http://www.lego.com/education/default.asp?page=4_1

Tips for improving your construction of gears and pulleys.

Official LEGO Mindstorms Website
http://www.LEGO.com/mindstorms

Lots of LEGO Mindstorms MOC's (My Own Creations) for students to surf through for inspiration in the "Inventions" area.

The Museum of Science – Design your own robot
http://www.mos.org/exhibits/robot/bin/design.dcr

Virtual building tool to design your own Mars rover.

The Robotics Laboratory Website
http://robotics.megagiant.com/tips/lightsensors/index.html

History of Robotics, building instructions, building and programming tips. This site is all about LEGO Mindstorms.

Resources for Adults/Teachers

***Books*:**

Cyr, Martha N. (1998). *Teacher's Guide for Robolab Software*. LEGO Dacta: Billund, Denmark.

The teacher's guide to the LEGO Robolab software explains the *basics* of getting started with this software from Pilot programming to Inventor programming. There are a few tutorials in this guide to help a new teacher working with this software to get acquainted with how it works.

Goldman, E. (1999). *Simple Machines for Second Grade Students, A Curriculum Incorporating LEGO Dacta Early Simple Machines Building Kit.* New York: Bank Street College of Education.

This independent study is an excellent resource for ideas for lesson plans involving gears and pulleys with the LEGO Technic building system.

LEGO Mindstorms Robotic Invention System 2.0 Constuctopedia. (2000). The LEGO Company.

Brief explanations of the LEGO RCX, Mindstorms LEGO brick system and sensors, and Mindstorms Software. The four building instructions listed in this Constuctopedia are helpful for early LEGO Mindstorms builders to get some practice. The building instructions in this Constuctopedia take at least 1 hour or more to complete.

Papert, S. (1980). *Mindstorms, Children, Computers, and Powerful Ideas.* New York: Basic Books, Inc.

Seymour Papert's book on LOGO, how it was invented, how it works, and why computer programming is such a powerful mathematical and science teaching tool. This is a great read for supporting the pedagogy of the LEGO Mindstorms curriculum. Seymour Papert consulted with the LEGO Company on the development of LEGO Mindstorms.

Sato, J. (2002) *Jin Sato's LEGO Mindstorms, The Master's Technique.* San Francisco: No Starch Press.

Five building instructions for robots that can walk, move with wheels, turn, and have a grabbing hand. He also offers an overview of LEGO Mindstorms parts and functions as well as some handy construction tips.

***Web*:**

Carnegie Mellon University, The National Robotics Engineering Consortium Robotics Academy Website.
http://www.rec.ri.cmu.edu/education/roboticscurriculum/index_to_robotics.htm

Free robotics curriculum for download. I borrowed their TankBot building instructions for this course.

LEGO Robolab @ Tufts University's Center For Engineering Educational Outreach (CEEO)
http://130.64.87.22/robolabatceeo/

Free robotics curriculum ideas searchable by age and grade. I borrowed the CEEO parts lists for this curriculum.

Please refer to the many websites listed for children as well. They are full of useful information and inspiration.