AN INTRODUCTION TO ROBOLAB

Developing programming and engineering skills in the classroom

by
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Field Test Version

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Acknowledgement

This publication, *An Introduction to ROBOLAB*, *Field Test Version* was developed as a result of Texas teachers' requests for practical lessons to accompany their inservice training.

The University of Texas College of Engineering, with funding from National Instruments, provides a multi-day summer training for K-12 teachers in Control and Robotics using the Lego-Dacta ROBOLAB™ kits and software. This training, the DTEACh Institute (*Design Technology and Engineering for America's Children*), has resulted in many Central Texas teachers enriching and extending their curriculum with ROBOLAB™ in partnership with a National Instruments classroom volunteer.

The DTEACh team has selected one of our best classroom implementers, Mrs. Kathleen Crowe from Pflugerville Independent School District, to write up lessons for starting ROBOLAB™ that were effective in her fifth grade classroom. This writing effort has been made possible by the Ford Foundation.

We appreciate the support from all of our sponsors that are making it possible to bring critical thinking in science, mathematics, and engineering to our classrooms, making them more interesting places to learn.

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AN INTRODUCTION TO ROBOLAB

About the curriculum
An Introduction to ROBOLAB is a unit of lessons guiding students and teachers through the process of building science, mathematics, and engineering concepts using PITSCO/LEGO/DACTA materials and computer programming skills using ROBOLAB software. The first lesson focuses on building a strong car structure. Following lessons teach students about each aspect of ROBOLAB programming using Pilot Levels 3, 4 and Inventor Level 2. Although lessons are written for Pilot Level programming, they can easily be adapted for Inventor Level. During the final lesson, students will participate in a design brief requiring them to apply the skills they learned during the course of the unit. Teachers may take four to six weeks to complete the lessons.

Curriculum approach
The curriculum will help students develop engineering and ROBOLAB programming skills. The lesson structure will guide students through the design process of designing, building, testing, revising, and presenting. Using this approach, teachers will engage all learners in critical thinking throughout the course of each lesson, optimizing classroom time. Teachers may be flexible during lessons, spending more or less time with each lesson to adapt the schedule for students' needs.

Audience
Although all teachers will find the curriculum useful, *An Introduction to ROBOLAB* is particularly suited to teachers who are new to ROBOLAB software and PITSCO/LEGO/DACTA materials. Teachers may easily explore the materials and software along with students without having to "know all the answers." Each lesson is presented in steps along with vocabulary to help students understand and develop scientific and technical terms. A "Teacher Tips" section provides troubleshooting help and suggestions for teachers to use with their classes. "Extension Projects" are available at the end of each lesson for teachers and students who are ready to explore extra challenges.

Prerequisite skills
Previous experience with design briefs may prepare students for the sequence of each lesson. Because ROBOLAB requires students to construct flowcharts, teachers may want to practice using flowcharts in class prior to conducting the lessons in this guide. *An Introduction to ROBOLAB* is also based on teamwork. Students should have experience working cooperatively with others on a variety of tasks.

Materials
- 1 Team Challenge kit #9790 per 1 or 2 groups (students may work in groups of 3-4 students) includes: 1 RCX Brick, 2 touch sensors, light sensor, 2 motors, infrared tower
- computers
- ROBOLAB software 1.5 or higher
- *ROBOLAB: Getting Started* (The Lego Group; 1998) – a great supplement to help with programming, terminology, and troubleshooting

Lesson Preparation Suggestions
- Make copies of the pilot level plan sheets, pilot level icons, and rubrics resource pages for students to use in planning ROBOLAB programs.
- Have students create a "Robotic Journal or Log" for written reflections and evaluations after each lesson

AN INTRODUCTION TO ROBOLAB
Lesson One: Building Cars

OBJECTIVES:

Build a sturdy car using RCX Brick, leads, motors, and other Lego building materials.

MATERIALS:

- LEGO Team Challenge kit #9790 (1-2 groups of students per kit)
- Toy cars
- Graph paper
- Log, journal, or paper
- Rubrics (optional)- *Resource Section*

TIME:

Two to three 45 minute class periods.

VOCABULARY:

structure	reinforce	sturdy	wheel and axle
lead	RCX Brick	system	power
energy	motor	durable	

PROCEDURE:

Part One: Introduction

1. Explore the physical properties of toy cars. Recognize vehicles as a system. Identify the main parts that make up the system and allow the car to function: wheels, axles, body, source of power, etc.

2. Identify the energy used to make toy cars move such as mechanical, chemical, elastic, etc. Introduce LEGO materials students will be working with. Demonstrate how the RCX Brick works with a car you have a made ahead of time.

3. Allow time for students to explore the Lego pieces. For older students have them begin by doing an inventory of the kit to account and become familiar with each part.

Part Two: Planning

4. Place students into groups of 3- 4 depending on how many kits are available. List important features for the car to have: strength, ability to roll, power source (RCX Brick), etc. When discussing strength be sure that students are developing a car design that can withstand forces of being picked up and running into objects such as walls. Use Teacher Tips below to help students discover ways to attach motors to prevent them from falling off easily.

5. Each group should sketch out on graph paper a design for their car that includes placement of the RCX Brick, wheels, leads, motors, and other Lego pieces. Label all parts and materials. Include a side view design and a top view design of car. Groups should get designs approved by the teacher before moving on to the building phase. Lower grades may explain parts and materials.

6. Groups not meeting design requirements should continue working until expectations are met.

7. Conduct a debriefing session so each group may present their design idea to the rest of the class. Students contribute ideas and ask questions.

Part Three: Building

8. As groups receive design approval, assign Team Challenge kits so students may begin building.

9. Students will probably have to modify their original plans as they work with materials. A discussion may need to be held explaining that part of the design process is making adjustments to original designs to achieve the desired outcome.

10. As each group builds have them test the sturdiness of the structure making sure it can roll without falling apart.

11. Students may want to roll cars across the floor to check that structures roll in a straight line. If not check wheel and axle alignment and have students problem solve what to do to overcome the design problem.

TEACHER TIPS:

Attaching Motors:

- Try placing motors directly to the bottom of the RCX Brick. This is not a very sturdy design but can become strong by reinforcing motors from underneath with plates.
- Try building a frame to place the RCX Brick in. Motors can be attached onto the frame rather than the RCX Brick.
- Attach beams to each side of the RCX Brick using connecting pegs. Build onto the beams using other beams. Then attach motors directly to the beams rather than the Brick.

Leads: Motors attach to ports ABC.

Wheels: Encourage students to experiment with various wheel sizes. The surface cars will be traveling over will determine the best wheel combinations to use. Try using wheels with and without tires. Also try using gears and pulley wheels in place of traditional wheels.

Limited materials: If multiple groups are sharing RCX Bricks, then car designs should allow students to remove and replace Bricks easily.

ASSESSMENT

1. Each group should present their cars demonstrating sturdy designs and placement of parts. Emphasize how students attached motors and Bricks. Compare 3 and 4 wheel designs as well as the types of wheels and tires used.

2. Each student in the group should be able to explain how the group built the car giving reasons for the parts and placement they used. Encourage students to discuss obstacles they faced while building and how they problem solved solutions to design challenges.

3. Have students individually record their experiences in a journal or log. Lower grades may illustrate their responses.
   a. *If your car's structure changed once your group started building, explain the changes you made and why.*
   b. *Was your group pleased with the outcome? Why or why not?*

EXTENSION PROJECTS:

Try building cars using one, two, three, and four wheel designs. Compare how they are alike and different in their structures, movement, durability, size, parts, etc.

AN INTRODUCTION TO ROBOLAB
Lesson Two: Moving Cars

OBJECTIVES:

Use ROBOLAB software to program a car to go forward, backward, and stop.
Use time as a sensor to determine how long a car will travel.

MATERIALS:

- LEGO Team Challenge kit #9790 (1-2 groups of students per kit)
- ROBOLAB software 1.5 or higher- Pilot Level III
- Cars from Lesson One
- Pilot Level 3 Plan Sheet- *Resource Section*
- Pilot Level Icons- *Resource Section*
- Rubrics (optional)- *Resource Section*
- Log, journal, or paper

TIME:

Two to three 45 minute class periods.

VOCABULARY:

flowchart	power level	sensor	computer program
download	error	port	loop
infrared tower			

PROCEDURE:

Part One: Introduction

1. Once students have built sturdy cars they are ready to program actions for the car to take.

2. Gather students around a computer, preferably a teacher workstation with projector. Open up ROBOLAB software to Pilot Level III. Explain to students that they will "program" directions into the computer for the Brick to follow. The display on the screen includes two steps. Discuss each icon choice on the screen.

   - Motors may be placed on ports A, B, or C only. Click on motor icons to show forward and backward movement.

   - Discuss differences between power levels 1-5 under motor icons. Ask: *When would you use power level 1? When would you use power level 5?*

- Students may place a stop sign or lamp on ports not designated with motors. Ask: *How do you think the power levels 1-5 work for lamps.*

- Motors will run until signaled to stop. Step through three sensing options. Ask: *What do you think the difference is between using a touch sensor with an arrow facing in and one with an arrow facing out. When would you use a touch sensor?*

- Touch sensors may be placed on ports 1, 2, or 3.

- Discuss the difference between using a 1 second clock and 10 seconds. Ask: *What is the difference between running a car at power level 1 for ten seconds and at power level 5 for ten seconds?*
- Look at the light sensor and have students explain how this sensor might be used. Students can choose a sensor that detects light or one that detects darkness. Light sensors may be placed on ports 1, 2, or 3.

- Once a time, touch, or light sensor is chosen a second step will take place. Point out that the pattern of icons repeats so students will have to decide what the motors will do and what sensing device will be used to make the car stop.

- Once programmed, point out the icon to use to save the program. Students should save their work as they program to prevent having to start over in case of computer problems.

- Students may press the pink arrow at the bottom of the screen to indicate whether the program will run once or continuously.

- When ready press the white arrow to download the program into the RCX Brick.

<u>Part Two: Planning</u>

3. Assign groups the design challenge: Program your car to complete a simple course. Each car will begin at a starting line, move forward two meters, backward one meter, and stop on a point or bulls eye. Students should use time to sense how long the car should move.

4. Provide each group with a plan sheet. Students will cut out the icons they need and place them on the plan sheet to show what their program will look like. Once icons are placed and approved by the teacher students may program on the computer.

5. Mark each point in the course on a clear floor space with tape.

<u>Part Three: Programming and Testing</u>

6. Work with groups one at a time or as a class to program their cars. Remind students to save programs. They may need to come back to make changes.

7. Download programs and go to designated areas to test.

8. Revise programs and cars as needed. Work until time is up or cars are complete.

9. Hold a demonstration so all groups may present their cars.

TEACHER TIPS:

Downloading the first time: The ROBOLAB program will prompt the user to download “firmware.” This will take a few minutes. When batteries fail replace them one at a time in the RCX Brick to prevent losing programs.

Downloading troubleshooting:

- Open the Infrared Tower and make sure the battery is fresh and pushed up against the metal piece inside. Sometimes the battery comes loose and disconnects from the connection.
- Make sure all cables are pushed in completely.
- Make sure batteries in the RCX Brick are fresh.
- Sometimes if several students are trying to download programs at the same time the programs may download into the wrong RCX Bricks.
- Make sure rust has not formed inside the RCX Brick. This will prevent the Brick from functioning.

ASSESSMENT

1. Each group’s car should be able to move forward, backward, and stop along the path without falling apart.

2. Each member of the group should be able to explain the program, problems that occurred along the way, and how the group solved the problems.

3. Have students individually record their experiences in a journal or log. Lower grades may illustrate their responses.
   - *Explain how your group arranged the icons in the ROBOLAB program. Describe your program.*
   - *If your car’s structure changed once your group started programming, explain the changes you made and why.*
   - *Describe what your car did when you tested it for the class. Was your group pleased with the outcome? Why or why not?*

EXTENSION PROJECTS:

Rebuild cars with motors in various positions. Try the following:

- Place motors in the front of the vehicle.
- Place one motor at the front of the car and a second motor at the back opposite corner of the car.
- Use only one motor to make a car move.
- Use gears with motors to make the car move.

AN INTRODUCTION TO ROBOLAB
Lesson Three: Turning

OBJECTIVES:

Program a car to go forward, turn around an object, and return to the start line.
Modify wheels, wheel direction, and ROBOLAB power levels to make a car turn.

MATERIALS:

- LEGO Team Challenge kit #9790 (1-2 groups of students per kit)
- ROBOLAB software 1.5 or higher- Pilot Level IV
- Cars from Lesson One
- Pilot Level 4 Plan Sheet-*Resource Section*
- Pilot Level Icon sheet.- *Resource Section*
- Rubrics (optional)- *Resource Section*
- Log, journal, or paper

TIME:

Two to three 45 minute class periods.

VOCABULARY:

friction	force	acceleration

PROCEDURE:

Part One: Introduction

1. Ask students to describe another action their cars could take besides moving backward and forward. Discuss how they would program the car to turn. List ideas on the board. Students might suggest the following:
   Have wheels move opposite or against each other. Stop one motor while a second one continues to run. Program one motor on a low power level and the other motor on a higher power level. Ask:
   What might make it difficult for the car to turn? Discuss how to increase and decrease friction to make the car turn appropriately.

2. Gather students around a computer or projector and start ROBOLAB, Pilot Level IV.

3. Compare Level IV to Level III. Instead of just two steps students can add as many as they would like. Demonstrate adding and deleting steps.

4. Assign design brief: Program a car to move ahead one meter, turn around an object (bottle, brick, cone, etc.), and return to the start line.

Part Two: Planning

5. Provide groups with a Pilot Level IV plan sheet and icons. Students will cut out icons and place according to what they want their cars to do.

6. Students may need to modify car designs. For example, altering wheels may allow for easier turning.

7. Once RoboLab Plan Sheets are approved students may program on the computer.

8. Try having students create two programs using different approaches for turning. Students can program and try both methods to determine the most efficient turn.

Part Three: Programming and Testing

9. Work with groups to assist in troubleshooting. Remind students to save programs. They may need to come back to make changes.

10. Download programs and go to designated areas to test.

11. Revise programs and cars as needed. Work until time is up or cars are complete.

12. Hold a demonstration so all groups may present their cars. Compare wheel types used by each group as well as the program used to make the cars turn.

TEACHER TIPS:

1. Suggest changing wheel sizes to create a sharper turn. If too much friction is being created for the car to turn, try taking off the tires and leaving just the wheels.
2. Round sliders are provided in the Team Challenge kits to use in place of wheels to help vehicles make a sharper turn with minimal friction.

ASSESSMENT

1. Each group's car should be able to move forward, turn around an object, and return to the start line.

2. Each member of the group should be able to explain the program, problems that occurred along the way, and how the group solved the problems. Groups should explain how friction and power levels affected the project. Compare acceleration from the beginning to end of course.

3. Have students individually record their experiences in a journal or log. Lower grades may illustrate their responses.
   a. *Explain how your group arranged the icons in the RoboLab program. Describe your program and how you made the car turn. What did the group determine to be the most efficient method for turning?*
   b. *If your car's structure changed once your group started programming, explain the changes you made and why. How did friction and power levels affect this project?*

c. *Describe what your car did when you tested it for the class. Was your group pleased with the outcome? Why or why not?*

EXTENSION PROJECT:

Design and program a car to weave around 3 or 4 markers (bottles, cones, etc) to complete an obstacle course in the fastest time.

AN INTRODUCTION TO ROBOLAB
Lesson Four: Touch Sensors

OBJECTIVES:

Modify and program a car to move forward, touch an obstacle, turn around, and cross a finish line. Use a touch sensor to make a car change direction.

MATERIALS:

- LEGO Team Challenge kit #9790 (1-2 groups of students per kit)
- ROBOLAB software 1.5 or higher- Pilot Level IV
- Cars from Lesson One
- Pilot Level 4 Plan Sheet-*Resource Section*
- Pilot Level Icon sheet.- *Resource Section*
- Rubrics (optional)- *Resource Section*
- Log, journal, or paper

TIME:

Two to three 45 minute class periods.

VOCABULARY:

touch sensor obstacle

PROCEDURE:

Part One: Introduction

1. Show students a touch sensor and ask for ways they might use one on their car.
2. Assign design brief: Modify and program the car to roll forward from a start line, gently hit an obstacle such as a wall, turn around, and travel to a finish line.
3. Discuss ways students might attach touch sensors so that they will not fall off from impact with the obstacle.
4. Discuss speeds the cars should travel so they do not ram up against obstacles, breaking the cars.

Part Two: Planning

5. Students will need to modify cars to include a touch sensor.
6. Provide each group with a plan sheet. Students will cut out icons they need and place them on the plan sheet to show what their program will look like.

Part Three: Programming and Testing

7. Program on computers. Go to designated area to test cars. Revise ROBOLAB programs until cars can complete the task or time is up.
8. Hold a demonstration so groups may present their cars.

TEACHER TIPS:

1. Students may place the touch sensor directly in front of the car. Students will discover that the touch sensor will need to be reinforced to prevent it from falling off from the impact on the obstacle. Also try placing a LEGO piece in front of the touch sensor. When the LEGO piece makes contact with the wall, it will press the touch sensor causing the car to change direction.
2. Students will discover that the car may perform the entire task more easily if they make it back up from the wall before turning.

ASSESSMENT

4. Each group's car should be able to move forward, gently hit an obstacle such as a wall, turn around, and travel to a finish line.

5. Each member of the group should be able to explain the program, problems that occurred during the project, and how the group solved the problems.

6. Have students individually record their experiences in a journal or log. Lower grades may illustrate their responses.
   a. *Explain how your group arranged the icons in the ROBOLAB program. Describe your program and how you made the car complete the task.*
   b. *How did your group modify the car to make it complete the tasks? Where did your group place the touch sensor?*
   c. *Describe what your car did when you tested it for the class. Was your group pleased with the outcome? Why or why not?*

EXTENSION PROJECT:

Program a car to roll across an elevated flat surface such as a table without falling off. The car should move forward, sense the edge of the surface, stop, turn around, and travel in the opposite direction until reaching another table edge. A touch sensor should be placed on the car so that when it reaches a drop off, an arm or other structure will move to press the sensor. More than one touch sensor should be used. The vehicle should keep moving without falling off the edge of the surface.

AN INTRODUCTION TO ROBOLAB
Lesson Five: Light Sensors

OBJECTIVES:

Modify and program a car to follow a path into a garage.
Use a light sensor to make a car stop in a dark space.

MATERIALS:

- LEGO Team Challenge kit #9790 (1-2 groups of students per kit)
- ROBOLAB software 1.5 or higher- Pilot Level IV
- Cars from lesson one
- Pilot Level 4 Plan Sheet-*Resource Section*
- Pilot Level Icon sheet.- *Resource Section*
- Rubrics (optional)- *Resource Section*
- Log, journal, or paper
- Box with small opening

TIME:

Two to three 45 minute class periods.

VOCABULARY:

light sensor value

PROCEDURE:

Part One: Introduction

1. Discuss how a light sensor could be used on students' cars.
2. Assign design brief: Modify and program cars to travel along a path and stop once inside a garage (cardboard box). The path can be straight or may include turns and obstacles. A challenging course will require students to apply skills learned earlier.
3. Students will need to know how to read light values in order to make adjustments to their programs. Set up a light sensor on an RCX Brick ahead of time. Turn the Brick on and press the view button until it points to the light sensor port. Have students identify the light value of the classroom. Next determine the light value of the inside of the cardboard box and compare.

Part Two: Planning

4. Students will need to modify cars to include a light sensor.

5. Provide each group with a plan sheet. Students will cut out icons they need and place them on the plan sheet to show what their program will look like.

Part Three: Programming and Testing

6. Program on computers. Go to designated area to test cars. Revise ROBOLAB programs until cars can complete the task or time is up.
7. Hold a demonstration so groups may present their cars.

TEACHER TIPS:

Light sensors read values from 1to 100. A lower number indicates darker light. A higher number indicates a brighter light.

ASSESSMENT

7. Each group's car should be able to move forward, gently hit an obstacle such as a wall, back up, turn around, and travel in the opposite direction.

8. Each member of the group should be able to explain the program, problems that occurred along the way, and how the group solved the problems.

9. Have students individually record their experiences in a journal or log. Lower grades may illustrate their responses.
    a. *Explain how your group arranged the icons in the ROBOLAB program. Describe your program and how you made the car complete the task.*
    b. *If your car's structure changed once your group started programming, explain the changes you made and why.*
    c. *Describe what your car did when you tested it for the class.*

EXTENSION PROJECT:

Make a path of electrical tape on the floor. Students will program cars to follow the path using a light sensor.

AN INTRODUCTION TO ROBOLAB
Lesson Six: Design Brief Challenge

OBJECTIVES:

Incorporate skills from previous lessons to design, build, and program a robot.

MATERIALS:

- LEGO Team Challenge kit #9790 (1-2 groups of students per kit)
- ROBOLAB software 1.5 or higher- Pilot Level IV (Inventor Level 2- optional)
- Pilot Level 4 Plan Sheet-*Resource Section*
- Pilot Level Icon sheet.- *Resource Section*
- Rubrics (optional)- *Resource Section*
- Log, journal, or paper

TIME:

5-10 45 minute class periods.

VOCABULARY:

tools palette	function palette	modifiers	string tool
error message	text	land	jump

PROCEDURE:

<u>Part One: Introduction</u>

1. Review building and programming skills students have learned. Have students brainstorm other types of robots they could build and program. Decide which ROBOLAB level the class will work with.
2. If introducing Inventor Level 2, pull the program up on a teacher work station or computer for the class to view. Show how to access and "pin" the Tool and Function Palettes to the screen. An example program appears on the screen. Click on the arrow in the tools palette. Click on the screen and drag the arrow across all icons except for the stop lights. The icons will be highlighted. Click "delete" to erase the icons.
3. Step through each palette. The functions palette will have the same icons students are already familiar with. Click on the "modifier" (power level) icon and pin the palette to the screen. Identify port icons and power level icons.   Click on the "wait for" (clock) icon and pin the palette to the screen.
4. Drag icons using the arrow tool onto the screen to create a simple program. Arrange the icons into steps similar to pilot level to help students organize their programs. Place modifiers under motors and sensors. After creating a program, wire with the string tool. Students must understand how to click on the "begin" and "end" of each icon to wire. Dragging the string tool across all icons will not connect the icons together.

5. Practice deleting bad wires by pressing “Control –B” on a PC and “Apple-B” on a Mac.
6. Point out the white arrow at the top left of the screen. If it is broken double click and an error list will appear. Step through how to use the error list to fix mistakes. If the arrow is not broken the students will be able to download their program.
7. Also show students how to use the Help to learn about parts of icons and troubleshoot problems.
8. Introduce design brief. Have groups select projects from a list or assign all groups the same project to complete. Discuss materials, time, and specifications constraints and the importance of having them.

<u>Part Two: Planning</u>

9. Groups of students should design their projects on graph paper.
10. Approve designs.

<u>Building:</u>

11. Groups build projects according to designs. Students will need to modify original ideas as they work.
12. Students should make sure projects are sturdy before planning ROBOLAB program.

<u>Part Three: Programming and Testing</u>

13. Provide each group with a plan sheet. Students will cut out icons they need and place them on the plan sheet to show what their program will look like.
14. If using Inventor Level 2, students may place icons on a piece of plain copy paper. Make sure the program is organized into clear steps. Try having students write labels for each step to make sure they understand what their programming is supposed to do. Also use a pencil or marker to “string” the icons together.
15. Once approved, students may program on the computer.
16. Download program into RCX Brick and test robot. Troubleshoot problems. Revise and retest until project is complete or time is up.
17. Hold a class demonstration.

TEACHER TIPS:

Inventor Level 2:

- Pressing the space bar will allow students to switch back and forth between the arrow and string tools.
- Pressing the tab key will allow students to switch between the arrow, hand, text, and string tool.
- Students may program time in decimals (e.g. 1.5 seconds) by using the “wait for time” modifier. Place the “modifier constant” under the clock icon and type in the amount of time needed.
- A “land” and “jump” modifier is available for programs that need to repeat steps.

Students may need to combine other materials with LEGO pieces to complete their projects.

Refer to *Design Brief Suggestions* in the Resource Section for project ideas.

ROBOLAB: Getting Started (The Lego Group; 1998) is a helpful resource to use with Inventor Level 2

ASSESSMENT

10. Groups should discuss the structure and design of their projects.

11. Each member of the group should be able to explain the program, problems that occurred along the way, and how the group solved the problems.

12. Have students individually record their experiences in a journal or log. Lower grades may illustrate their responses.
    a. *Describe what your group built.*
    b. *Describe your program and how you made the robot complete the task.*
    c. *If your robot's structure changed once your group started programming, explain the changes you made and why.*
    d. *Describe what your robot did when you tested it for the class.*
    e. *What would you change to improve your project? Why?*

RESOURCE

SECTION