

How to Train a Robot

The technology in this lesson includes computers, graphing calculators, and small three-wheeled robots. This lesson is presented in three parts. Although these parts build upon one another, they may be presented separately. In the first part, "Logo," students study how to write programs using the computer language Logo. In the second part, "Basic," students program a robot, which is directed by a graphing calculator secured on its back. In the third part, "Maze," students measure and analyze the results of the calculator movements. The technology in this module allows students to learn logical thinking skills and develop problem-solving strategies in engaging hands-on activities.

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Introduction

Skill Level: Intermediate

Grade Levels: 9-12

Primary Content Area: Math

Cross Disciplinary: Science

Technology: Computer-Assisted Instruction

Preface

The technology involved in this lesson includes computers, graphing calculators, and small three-wheeled robots. This lesson is presented in three parts. Although these parts build upon one another, they may be presented separately. In the first section, "Logo Logic and Programming," students study how to write programs using the computer language Logo. The goal is to apply concepts such as pattern recognition and recursion to topics found in both geometry and algebra.

In the second section, "Introducing Robotics and the Calculator Controlled Robot," students program a robot, which is directed by a graphing calculator secured on its back. The robot is available through <http://www.smallrobot.com>. It can be operated by most Texas Instruments (TI) graphing calculators. Students are expected to create a variety of programs using TI BASIC to control and understand the movements of the robot.

In the third section, "C2 Robots in a Maze," students measure the results of the calculator movements. They are asked to analyze their results. These results are used to aid them in a maze activity.

The technology in this lesson allows students to learn logical thinking skills and develop problem-solving strategies in hands-on activities.

The lesson applies and extends students' skills, including:

- learning commands in Logo and TI BASIC,
- measuring linear distances and degree of angles to record results as data,
- using calculator tables and line graphs to analyze the data,
- interpolating and extrapolating graphically, and
- applying their analysis, understanding, and problem-solving skills to a maze challenge as an authentic assessment.

Standards

Students who successfully complete this integration module will address:

- Ohio K-12 Mathematics Academic Content Standards
 - Grades 8-10 Benchmarks: Measurement Standard C, E; Data Analysis and Probability Standard A; Geometry and Spatial Sense Standard D, E; Mathematical Processes Standard D, E, F, G
 - Grades 11-12: Benchmarks: Measurement Standard B; Mathematical Processes Standard B; Data Analysis and Probability Standard A
 - Grade 9: Measurement 4; Geometry and Spatial Sense 2, 3; Patterns, Functions, and Algebra 2, 8; Data Analysis and Probability 2
 - Grade 10: Measurement 1, 4, 5; Geometry and Spatial Sense 1, 4
- ISTE Technology Foundation Standards for All Students
 - (2) Social, ethical, and human issues: Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity.
 - (3) Technology productivity tools: Students use technology tools to enhance learning, increase productivity, and promote creativity.
 - (6) Technology problem-solving and decision-making tools: Students use technology resources for solving problems and making informed decisions.

Objectives

Students who complete the lessons in this integration module will:

- Learn Logo, a computer program.
- Work in small teams to complete the activities of this module.
- Build upon prior knowledge of geometric concepts and apply this knowledge to their data collection and maze designs.
- Analyze data, and extrapolate or interpolate from the data.
- Develop their proficiencies with a variety of technological tools, such as devices for collecting data and graphing calculator utilities that enable them to solve problems.
- Develop skills in problem solving, critical thinking, and logical reasoning.

Prerequisite Knowledge

Knowledge and skills that the students will need prior to starting this lesson:

- Length and angle measurement skills
- Graphing line of best fit
- Mean
- Use of graphing calculators for data analysis

Materials, Technologies and Resources

For each student or pair of students:

For the Logo activities —

- Logo software loaded on computers.
- One copy of the Student Manual, "Welcome to the Turtle World of Logo" (available online at <http://neoparaiso.com/logo/documentos/student-manual.doc> as a Word file, as Adobe Acrobat, or as a zip file for an Intranet.)
- One copy of the Screen Map, available at the same site.

For the C² Robot activities —

- One Texas Instruments graphing calculator (for example, 73, 83, 83 Plus, 86, or 89). The TI-92 and TI-92 Plus also will function with the robot, but they are difficult to mount on the robot base.
- One Calculator Guidebook (or a copy of the TI Basic Program section from it).
- Programming Guide for the Calculator Controlled Robot (C2 Robot), comes in kit or available from <http://www.smallrobot.com/ROBOT.PDF>.
- Program "Forward" and Worksheet in a Word document:
http://www.math.ohiou.edu/~moss/robot/forward_work.doc
<http://www.math.ohiou.edu/~moss/robot/Start.jpg>
- One length of shelf paper or other rolled paper, approximately 24 inches wide and at least 48 inches long for the student generated mazes.
- One each: marker, tape measure, and protractor.
- Transparent and masking tape.

For the class —

- One length of shelf paper or other rolled paper, approximately 24 inches wide and 48 inches long, marked with the initial challenge maze. A sample maze pattern using the start/stop line is provided, or create your own from http://www.math.ohiou.edu/~moss/robot/Sample_Maze.pdf.
- At least two C2 Robots for the class to share (available through <http://www.smallrobot.com/>, unit price \$98).
- Two or three rolls of painter's masking tape, which leaves no residual glue.
- Low-heat high-density overhead display unit for the calculator.

Optional —

- "Turn" measurement sheet (one per group or C2 Robot) from http://www.math.ohiou.edu/~moss/robot/forward_work.doc.
- TI-Graph Link and software (to download C2 Robot programs).
- Additional C2 Robot programs (download from <http://www.smallrobot.com/>).
- Graph paper or other paper for a TURN program data sheet.

Section One: Logo Logic and Programming

Start your students with Logo programming. For some Logo may be new software, for others this will be a review. (Students may have been introduced to a Logo program during elementary or middle school. Most have never used it at the high school level, but the program is powerful and challenging enough to be more than appropriate.) If you or your students do not have a Logo program on your computers, a free educational version of Logo called "MSW Logo" is available from <http://www.softronix.com/>. It is 1,736 KB in size and has a user-friendly Help file.

For the Logo investigations foundational to the robotics section in this module, students will need a copy of the booklet, "Welcome to the Turtle World of Logo" and a Screen Map. The booklet, written by Paul Dench, contains a series of exercises and instructions and a final project challenge. Both foundation topics and supplementary topics are described at his site (https://concordia.ciss.com.cn/technology/HELP/tutorials/turtle_web/index.htm) and will provide the information needed to understand how to write Logo procedure commands and to use certain more advanced commands (random variables and "IF" controls, for example). Additional Logo reference sites are listed in the Professional Learning section at the end of this module.

Students will work through the exercise booklet at their own pace during one or two class periods. They will learn how to write commands for the turtle which range from the straightforward ("To Square" or "To Decagon") to the sophisticated (combined procedures, or using a variable input ": Size", for example). Geometry students can be challenged to program the turtle to create scalene or isosceles triangles, or trapezoids, with variable lengths and widths. Students may introduce color to the pen or to the shapes.

The final guided discovery challenge (on page 15 of the booklet) is to combine simple shapes into a complex unit, and to combine the complex units to create an elaborate design on the computer screen. The task and the parameters for the students are well defined, but the task is open-ended, giving all students an opportunity to demonstrate the full extent of their learning. All students can succeed at the project challenge. The results can be used as a final assessment.

Throughout the Logo work, help students understand that Logo programming is similar to the more sophisticated programming in computers and other technology applications they enjoy. The logic development and sequencing are also beneficial thinking skills, which can transfer to other situations. You may wish to ask students to keep a journal of their experiences with Logo. The journal could be used to assess their progress and the depth of their thinking, and would provide a baseline of their understanding at the beginning of this unit.

Section Two: Introducing Robotics and the Calculator Controlled Robot (C² Robot)

The C² Robot Kits require some assembly. Clear instructions are provided in the manual. Allow time to familiarize yourself with the robot before attempting to use it with students.

Students will need to see the anatomy of the C² Robots and perhaps watch the robot move through the WANDER program (at <http://www.smallrobot.com/testpage.html>) to understand how the robot and calculator work together. The added advantage of a demonstration of the robot is to interest the students in the activity.

Newer versions of the robot have a base that covers the small circuit board on the belly of the robot; this can lead to problems if students are not careful when detaching the link cable from the calculator. Should the other end of the link cable come loose from the adaptor plug on the circuit board, the entire base must be removed. Remind students to be careful!

Use an overhead display to demonstrate how to key the program "Calibrat" into a calculator. Some students may have programmed calculators before; others may have little or no experience. The overhead makes it easier for all students to succeed.

```
PROGRAM:CALIBRAT
:Send({499})
:Get(R)
```

Discuss the function and need for this program with the class. Make sure students understand the importance of making accurate measurements and controlling variables, such as the surface on which they test the robots. One additional program, "[Forward](#)", is provided for this activity; many students will learn the programming commands readily enough to program independently in a short time.

You may have only one or two C² Robots in the classroom, making the robot a limited resource. The following suggestions may help you manage class activities.

- Arrange the learning environment so that the C² Robots are adequately supervised.
- To speed along the process, calculator links may be used to transfer the robot programs.
- The program could act like a function box. The students could enter a number, record the results, and then ascertain the relationship between the inputs and their corresponding results.
- The results achieved by the individual C² Robots may be different. Assign groups to work with a specific C² Robot. Label or color coordinate the C² Robots in some other way so that the students can identify them.
- Before taking a series of measurements, every group should run the "Calibrat" program. If either C² Robot does not travel in a straight line after calibration, additional arguments are provided to speed up or slow down the errant servo. Refer to the programming guide for the C² Robot.

- When students are running the "Forward" program, you can create a testing site by taping a tape measure parallel to the motion of the C² Robot. Have students set the C² Robot at zero, run the program, and then read off the distance traveled. (See diagram to right.) If students need more practice measuring, have them use a length of shelf paper to record results. Mark the wheel location after running the program for different periods of time and use a ruler or meter stick to measure the results for each time tested.
- Ideally each pair of students will repeat the robot runs three times and plot mean distances. If time is limited, use individual trials and plot the distances. Discuss validity and variance.
- Use TI-Graph link to backup the student programs. Consider allowing students to do the programming on the computers, using Graph Link software, available from the TI web site. This allows students to develop programs more quickly than typing them using the calculator key pad and catalog functions.

Note: Teachers may borrow graphing calculators from Texas Instruments. Contact TI-Cares through their workshop loan program at <http://education.ti.com/us/global/forms/loan.html>.

Note: Instructions on downloading calculator programs are available at <http://education.ti.com/us/resources/programarchive/programarchive.html>.

There is no loan program for the Norland C² Robots. There are many opportunities to write small grants that may be used to purchase them. You may want to start here:

<http://www.education-world.com/grants/>
<http://www.schoolgrants.org/welcome.htm>

You may wish to ask students to continue the journal they started when using Logo in Section One of this unit. The programming involved in this section is similar to and different from the programming of the Logo turtle. Ask students to reflect each day on the hardest task they worked on that day, explain how they attempted to solve the problems they encountered, and describe their successes. You may even wish to ask them to compare the thinking and the logic required for the two sections.

Section Three: C² Robots in a Maze

Explain to your students the process by which they will create mazes for each other. You may wish to write the rules for maze construction on the chalkboard or overhead, so students may refer to the rules during the construction process. Distribute the materials and establish the amount of time the students have to create the mazes (10 to 15 minutes should be sufficient.)

Suggested rules for maze construction: (These may be modified depending upon student needs and the time available.)

1. Total distance to travel: 1.5 meters
2. Total number of turns allowed: six
3. Each maze must begin and end with a T intersection marked "start" and "stop."
4. Straight line lengths must be at least 10 cm.
5. Angles must be between zero and 135. Angles between 136° and 180° are very difficult to manage with these robots without a wheel crossing a line.
6. The line may not cross itself.

While students are creating their mazes, circulate among the groups and review with them their data and graphs for the "Forward" and "Turn" C² Robot performance. Discuss the data with the students to evaluate the depth and accuracy of their interpretations.

After the time you established for maze construction has passed, ask groups to exchange mazes. Ask the students to evaluate the mazes to ensure they conform to the rules of construction. Mediate the maze analysis process. Verify any findings that the rules were violated and allow teams to correct errors. Tape the mazes to the wall so student teams may measure distances and angles. Each maze should list the name of the team that created it and the name of the team required to run it.

Ask students to write the programs to run the C² Robots through their mazes. Students may use Graph Link software and computers to do this, or the calculators themselves. Assist groups as necessary. Students may test their programs at a testing site; tile floors are useful for this.

When the students have written their programs, hold the Maze Running Robot Finals. You may wish to allow each group to test the program one time before the finals.

Suggested Competition Rules:

1. Robots must start on the T intersection marked Start and must end as close to the T intersection marked Stop as possible.
2. The distance in centimeters from the Stop intersection plus any penalty points (see rule #3) will be the team's score. Low score wins.
3. Robot wheels may not touch or cross any line. (A 5 cm penalty will be assessed for each infraction of this rule.)
4. No team may use its challenge maze for a practice run before the competition.
5. The time each robot requires to run the maze will be recorded; time will be used to break any tie between teams.

Invite as many judges as you have C² Robots. The judges will determine whether the front wheels cross a line during the trial, will measure the distance from the wheels to the Stop Line at the conclusion of the trial, and will determine each team's score, including penalty points. During the trial you will be able to determine how well the students succeeded at their complex tasks.

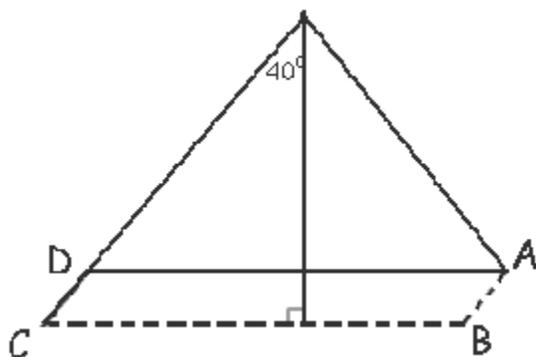
You may wish to film the finals. At the conclusion of all trials, celebrate the teams' successes, announce the final standings, and ask students to write an evaluation of the process. Ask them to write about what they learned in general during the robotics unit and to describe specifically what they learned about geometry, programming, teamwork, and technology. Ask them to make suggestions for improvements. The initial journals will be useful here as a record of their progress and the development of their logical reasoning skills, programming skills, and problem-solving strategies.

Assessment of Student Performance

The following assessments include questions requiring students to write short or extended responses about mathematics. Use the Ohio Graduation Test (OGT) scoring rubric to evaluate their answers. For sample OGT test items and more information, refer to <http://www.ode.state.oh.us/GD/Templates/Pages/ODE/ODEDetail.aspx?page=3&TopicRelationID=240&ContentID=4760&Content=26754>.

Logo Assessment

1. For a class at her high school, Sara was creating a geometric design. Students were asked to use Logo software for the project.



In her design AD is parallel to BC, and AB is parallel to CD.

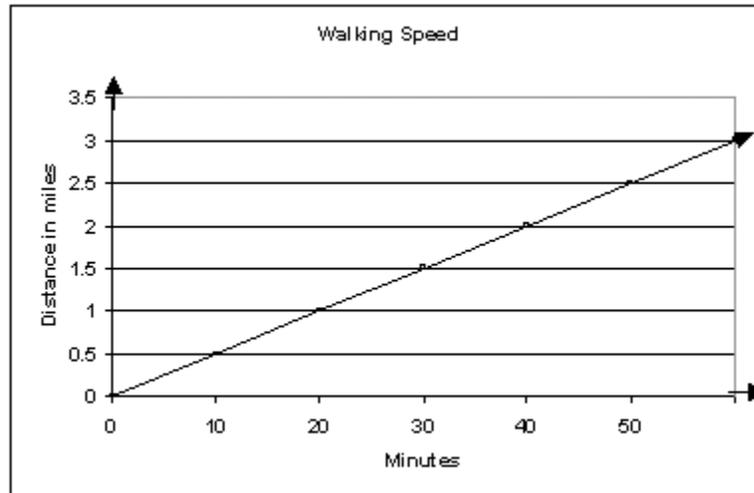
If the turtle moved from A toward B to draw AB, how many degrees did Sara need to program the turtle to turn at B to draw the line between B and C correctly?

Explain how you found the answer.

2. The Logo activities described here culminate in the students writing the programming necessary to create a complicated figure of two (or three) dimensions on the computer screen. (The project is described in the Student Manual.) The Logo program the students write for the project must use several procedures for "simple" shapes and assign variables for size control, and good style. Style is defined as properly organized procedures and "reverse path principles." Students may use random variables, "IF" controls, and color. Students who are successful in this performance-based assessment will be ready to move to the robotics activity.

C² Robot Assessment

1. The graph shows the speed Mr. Suliman averages on his walks every evening. If he were to walk for 90 minutes, how far would he walk, according to the graph? Explain how you found your answer.



http://www.math.ohiou.edu/~moss/robot/walk_graph.pdf

2. The culminating activity for the C² (Calculator Controlled) Robot activities (Maze Design and Tracking) provides an assessment of the depth and breadth of students' learning. Students will attempt to program the calculator to correctly follow the maze established by another group. Correct execution of the maze demonstrates understanding of programming and concepts of linear and angular measures. In addition to this programming, each group must hand in its programming code. In this way each group is assessed by its calculations and plan as well as its performance.

3. The following rubric serves as a general guideline and lists criteria to be used to assess the project in "How To Work the C² Robot."

4	The student group demonstrates a series of C ² Robot movements based on a particular plan, which may include a diagram of the given maze, segment measurements, angle measurements, and calculator movement commands to program the correct sequence. The group may list and number each line in the program by putting the command in one column and the corresponding expected movement in another column.
3	The student group follows a series of C ² Robot movements based on a particular plan, but excludes or incorrectly programs one command line. Therefore, the C ² Robot misses a command or turns the opposite direction.
2	The student group attempts to follow a series of C ² Robot movements based on a particular plan, but uses incorrect time measurements, or excludes or incorrectly programs two command lines. Therefore, the C ² Robot traverses incorrect distances, miscalculated turns, or misses a couple of commands, due to either poor measurements or miscalculation of time needed.
1	The student group lists the diagram of the given maze, segment measurements, and angle measurements, but there is no apparent plan or sequence of steps. The C ² Robot does not move, or moves unrelated to the maze.
0	No measurements are given; there is no apparent plan or sequence of steps. The C ² Robot does not move.

Classroom Extensions

Logo Extensions

Suggest that students return to Paul Dench's website and the section https://concordia.ciss.com.cn/technology/HELP/tutorials/turtle_web/index.htm. There are examples of advanced Logo programs that students can examine and test. The power of Logo as a programming language is revealed through this extension.

Challenge your students to create elegant designs using a 15-word or less command line or to create three-dimensional geometric figures.

Logo provides significant additional challenges for students who are interested. Have them follow Logo resources links from the Internet, such as <http://www.softronix.com/logo.html>.

Robot Extensions

Enter the experimental data into Lists on the graphing calculators. Determine the line of best fit. Try linear regression, least squares method, or power regression. Discuss each of the fits and the line of best fit.

The Norland website (<http://www.smallrobot.com/>) is updated from time to time to include programs written by students and activities developed by teachers using the C² Robots. If your students are interested in developing activities to share, they can contact the web master of the Norland site. For example, currently there is a description of an activity involving a golf ball, two meter sticks, a start line, and two competing robots. The first robot to reach the golf ball is the winner of that heat; the students ran multiple heats to determine the most efficient program and C² robotics team.

An additional lesson on robots, written by a high school teacher, can be found at <http://school.discovery.com/lessonplans/programs/robbie>. The discussion questions section is full of interesting topics.

Rossum's Playhouse (available online at <http://rossum.sourceforge.net/sim.html>) is a two-dimensional robot simulation intended to aid developers in implementing control and navigation logic. It allows applications to build a data-configurable robot that can interact with a simulated landscape or solve a virtual maze. Download the software (written in Java) and instructions.

Direct students interested in the history of robots to these links:

<http://prime.jsc.nasa.gov/ROV/history.html>

<http://inventors.about.com/library/inventors/blrobots.htm>

Resources

Print Resources

Jim Muller's Great Logo Adventure Book (Doone, 1998) primarily based on MSWLogo. Brian Harvey's books from MIT Press for more advanced programming.

Internet Resources

The following websites may be useful resources to share with students:

Robotics Links

<http://www.ifi.unizh.ch/groups/ailab/links/robotic.html>

This site has links for research laboratories, journals (refereed, in paper and online), robots, clubs, robotics companies, competitions, courses, and an index of AI lab links.

Robot Information Central

<http://www.robotics.com/robots.html>

This site has an extensive list of links. Any question teachers or students may have about robots or robotics will probably be answered here.

The Tech Museum of Innovation

<http://www.thetech.org/robotics/index.html>

Robotics, Sensing, Thinking, Acting, an excellent and interactive site.

Websites with information on technology in the classroom may be useful for shaping instruction utilizing technology. Among them:

Cradler, John. Summary of Current Research and Evaluation Findings on Technology in Education, Far West Laboratory, available at <http://www.wested.org/techpolicy/refind.html>

Additional Teaching Resources

Research Based Instructional Strategies

The Principal's Office with OSU/USI
<http://principalsoffice.osu.edu/index.php>

Assessment & Evaluation

Teaching Methods Resources
<http://www.mhhe.com/socscience/education/methods/resources.html#evaluation>

Alternative Instruction and Alternative, Performance-Based Assessment
<http://mathforum.org/~sarah/Discussion.Sessions/biblio.assessment.html>

Methods of Assessment
<http://jeffcoweb.jeffco.k12.co.us/isu/math/mathsd/assess/assessmeth.html>

Teaching Resources

The Math Forum Internet Mathematics Library
<http://mathforum.org/library/>

eTech Ohio
<http://www.etech.ohio.gov/>

Instructional Strategies
<http://www.sabine.k12.la.us/vrschool/instructstrat.htm>

St. Cloud State Instructional Technologies
<http://lrs.stcloudstate.edu/cim/courses/pine/strategy.html>

Extension Activities for Connecting Representations of Functions

Use the following URLs to locate additional learning experiences for teachers and their students.

Modeling Motion: High School Math Activities with the CBR
http://education.ti.com/educationportal/sites/US/nonProductSingle/activitybook_cbr_modeling.html

maths online
<http://www.univie.ac.at/future.media/moe/>

Assistive Technology Resources

National Institute on Disability and Rehabilitation Research (NIDRR)

<http://www.ed.gov/about/offices/list/osers/nidrr/about.html>

Information Technology Technical Assistance and Training Center

<http://www.ittatc.org>

Assistive Technology Act of 1998 - RESNA

<http://www.resna.org>

Sample Lesson Review and Analysis

1. The lesson meets the Ohio Academic Content Standards and learning outcomes.
 - The mathematical content addressed in this module includes measurement, data analysis, geometry and spatial sense, and mathematical process standards.
 - The indicators itemized are from grades 8-12.
 - This module covers substantive content in these areas.
2. The lesson incorporates technology appropriate for supporting learning goals, including Ohio academic goals, and individualized student needs.
 - The lesson uses a variety of hardware and software such as graphing calculators, robots, Logo, TI Basic, and mazes.
 - With the numerous types of activities, students with many varying learning styles can find success in learning.
3. The lesson incorporates technology appropriate for professional development requirements of the National Council for Accreditation of Teacher Education (NCATE) or other professional development licensure needs.
 - This lesson not only requires the use of hardware and software but also provides many support resources available for teachers and students.
 - The ISTE standards for teachers addressed by this module are listed and are met by this unit.
4. Technology is integral to learning in the lesson.
 - This lesson requires the learner to use technology.
 - The goals could not be met without the use of technology.
 - This module requires at least one robot.
 - Links to funding sources and to a calculator loan program is provided.
5. Technology use in the lesson empowers learners.
 - Students are empowered by having many resources and support materials. The pedagogy is aligned with how to address the needs of individual students.
6. The lesson promotes a variety of research-based instructional strategies and takes into account various learning and teaching styles.
 - Clear and precise directions are given to both the teachers and the students.
 - Links are provided for topics teachers and students may not have prior knowledge of.

7. The lesson engages students in learning that is anchored in their diverse needs.
 - Another highlight of this module is the potential for active engagement, increased time on task, increased enthusiasm, and learning for understanding and long-term memory.
 - Because of the many pedagogies used and because of students working in teams, students with diverse needs will tend to be addressed rather easily.
8. The lesson requires students to be active participants, explorers and researchers.
 - Students will be totally engaged in this module as has been shown in a pilot of the materials.
 - Students will be expected to be independent learners, researchers and explorers. They will be asked to search for information, use the information that is needed, make predictions based on the information, and then bring all the learning together in a culminating activity.
9. The lesson requires students to demonstrate conceptual understanding, not just recall.
 - Because of the interactive nature of this unit, students will have to learn a few things at the skill level such as how to use a graphing calculator and program in Logo. To complete the module students must apply and transfer knowledge to a real-world situation.
10. The lesson encourages students to develop understanding and create personal meaning through reflection.
 - The questions and assignments in this module require the students to construct their knowledge of how geometry integrates with programming and applies to working with robotics.
11. The lesson requires students to relate knowledge to real-world contexts.
 - Robots are used in many real-world applications. Understanding of how these robots work in this lesson can evolve into understanding how larger and more purposeful robots function.

The lesson promotes a variety of assessments that align with Ohio standards, learning outcomes, instructional strategies, and technology use.

- The assessments require thoughtful responses from the students.
- The assessments align well with the standards and instructional strategies used.

12. Lesson assessments promote teacher understanding of a variety of assessment tools and how to implement them.

- This module provides clear instructions for the assessment.
- A well-conceived rubric allows teachers ease in grading.

13. Lesson assessments support and expand upon students' learning and inform stakeholders.

- The authentic assessment task builds upon everything that the students have learned up to this point in the module.
- The mathematical content used in this module relies on previously learned concepts and applies them in an interesting way.

14. Lesson assessments are performance-based and advance higher-order thinking and knowledge construction.

- Because this authentic assessment is a culminating activity and because students only get one chance to run their program, responsibility is placed on the team members to do it right the first time.
- The application level of work does encourage higher-level thinking and knowledge construction.