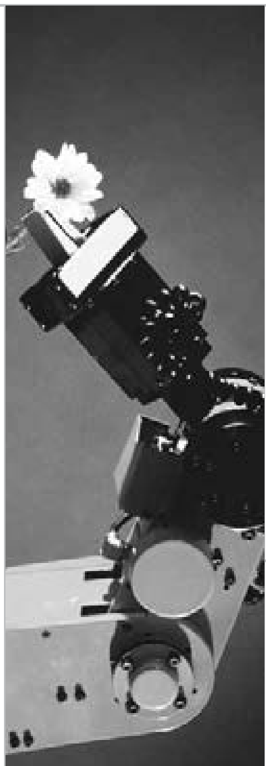

STARTING AND TEACHING basic robotics IN THE CLASSROOM:

MODERN, ENGAGING ENGINEERING IN TECHNOLOGY EDUCATION

BY
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> *"Teaching robotics can be challenging for a teacher; however, if the students are actively engaged in STEM concepts through robotics, then it is really worth an educator's time and effort.*

WHY TEACH ROBOTICS?

All technology educators have favorite lessons and projects that they most desire to teach. Many teachers might ask why teach robotics when there are many other concepts to cover with the students? The answer to this question is to engage students in science, technology, engineering, and math (commonly referred to as STEM) concepts. According to D. J. Barnes, "Studies show that robotics generates a high degree of student interest and engagement" (Barnes, 2002). In order for students to grasp concepts, they must want to learn. Robotics can be the vehicle for creating this will to learn STEM concepts. Typically there is a low number of female students enrolled in technology education classes due to lack of interest. However, "researchers noted that female students in particular are more likely to appreciate learning with robots than traditional SET teaching techniques" (Nourbakhsh et al., 2005). With this in mind, robots can engage all students to want to learn STEM concepts.

Students can be interested and engaged with robots while learning each area of STEM: science, technology, engineering, and math. Carnegie Mellon University Robotics Academy conducted "a case study analysis of an implementation of the robotics curriculum in an eighth grade technology classroom to assess whether mathematics ideas were salient as students were engaged with the tasks. Indeed, when prompted by the teacher during whole-class discussion, students brought in a wide range of formal mathematics ideas, such as measurement, algebra, geometry, statistics" (Carnegie Mellon Robotics Academy, 2008). The science aspect of robotics involves the students' experimentation and modifications with the robots. This can be very engaging, because the students are designing their own plans for the robot to follow. When the students are engaged in designing and creating successful solutions, they are acquiring engineering skills to solve the robotic challenges. According to Vex Robotics, "The study of robotics, by its very nature, captures all four legs of STEM very well, while a competitive environment increases motivation and desire to succeed" (Vex, 2010). The technology portion of robotics involves operating the robots and using tools and materials to build prototype solutions, such as building longer gripper fingers on the robot to pick up items from a long distance. Building a solution involves hands-on learning. As reported by Resource Area for Teaching, "When hands-on activities are employed, teaching is more fun, and students are more motivated to learn" (Resource Area for Teaching, 2012). As one can see, robotics can effectively engage students through STEM concepts. After an educator realizes this, he/she may obtain robotic equipment. Once the equipment is obtained, the teacher must understand how to set up and maintain the devices and how to teach students basic robotics.

BASIC ROBOTIC CLASSROOM LAYOUT DESCRIPTION

When teaching robotics, teachers must answer two questions for setting up robots in a classroom:

- What is the class size that will be taught robotics?
- Is there enough room for the students to move around while operating the robots?

The size of the classroom and the number of students involved is important because robots can be damaged if their components strike something or someone. More importantly though, a student can be injured by a robot when there is a lack of room for both students and robots during activities. An effective student group method for the teacher is to assign no more than three students to a group. For optimum robotic use, a technology lab (material processing workshop) should be utilized so that students can walk freely about the room in order to make robotic modifications comfortably and safely. If workbenches are available, an effective robot layout method for the teacher is to set up no more than two robots per workbench, depending on the reach of the robot arm and grippers.

MAINTENANCE AND PROCEDURES FOR ROBOTS AND MATERIALS

The maintenance of the robots and robotic accessories is important in order to have the equipment last for many years or until it is appropriate to upgrade the robotic items. There are four concerns for robot maintenance:

- Testing wire connections from a robot to a teach pendant (robot controller)
- Replacing robotic parts
- Lubricating the gears periodically
- Inspecting the tightness of screws and bolts in the robot

While the students are operating the robots, sometimes they unintentionally extend robots' joints beyond the maximum operating lengths. If this occurs, the teacher must reconnect the wires that often become unplugged from the main circuit boards or even solder the wire connections back together. If the wires become unplugged from the circuit boards, frequently the students themselves will attempt to reconnect the wire(s) to the circuit board, which can result in inaccurate robotic movements from the teach pendant (robot controller). If a DC circuitry is used by the robot, improperly wiring the circuits back up can result in burning out the power transformer. Robotic manuals should be compiled and saved in case the parts of a robot break. If the parts break, the teacher can use the manual to identify the specific parts that need to be replaced. Parts can break on a robot from continuous use. Wear and tear can be reduced by lubricating the robotic gears with grease. A robot operator can clearly observe a difference between smooth robotic operations and rough, struggling movements. RobotWorx stated "Grease allows industrial robotic arms to function properly, smoothly, and withstand wear" (RobotWorx, 2009). Once a teacher knows that the gears are moving smoothly, then he/she must check the tightness of the screws. As the students are operating the robots, the screws on the equipment slowly loosen. According to Intelitek, when a teacher is performing periodic inspections, he/she must "Check all bolts and screws in the robot arm using a wrench and screwdriver. Retighten as needed" (Intelitek Inc., 2002). Maintaining the robots and robotic material is a major responsibility due to the high cost of this equipment.

Common materials used with robotics are blocks or cylinders for students to practice transferring items with a robotic arm. These items can be made from wood. The blocks can be made from wood boards, and the cylinders can be made from dowel rods, which can be significantly cost-efficient as opposed to precisely made aluminum blocks and cylinders.

OBJECTIVE RESULTS AND EVALUATION

In order to determine if the robotic lessons were successful, a teacher must answer three questions:

- Is robotics part of the state curriculum for your course?
- Was the equipment and content material appropriate for the students?
- Most importantly, did the students walk away from the classroom with a basic knowledge of robotics and of engineering with robots?

These questions are not easy to answer because getting the right answers in education can be done in numerous ways. Rubrics are used for evaluating student projects. According to Mertler, "a good proficient score is equal to a letter grade of B" (Mertler, 2001). A good suggestion for evaluating the success of the robotic lessons is to see if a large majority of the students earned letter grades of "B" or higher for the robotic quiz and activities. If a large majority of the students earned scores of "B" (typically a score of 80–89%) or higher, then the robotic lessons were successful and the students likely mastered the basic concepts taught. If the scores of all the students are higher than "B," a teacher can always make modifications and additional challenges for the students to learn and enjoy.

CONCLUSION

Teaching robotics can be challenging for a teacher; however, if the students are actively engaged in STEM concepts through robotics, then it is really worth an educator's time and effort. After reading this article, a technology education teacher should have a general understanding of how to set up and maintain robotic equipment, and then be able to properly teach and assess the robotic lessons. With time and effort, an educator can observe students becoming engaged in STEM concepts with basic robotics. The experience will be mutually stimulating and enjoyable for both the facilitator and pupil.

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LESSON 1 – INTRODUCTION TO ROBOTICS

Class time: 90 minutes

Standards:

- **ITEEA *STL* 18G** (Grades 6-8): Students should learn that transportation vehicles are made up of subsystems, such as structural, propulsion, guidance, control, and support, that must function together for a system to work effectively.
- **ITEEA *STL* 12K** (Grades 6-8): Students should be able to operate and maintain systems in order to achieve a given purpose.
- **ITEEA *STL* 10H** (Grades 6-8): Students should learn that some technological problems are best solved through experimentation.

Objectives:

- Students will be able to identify the parts of a basic robot.
- Students will be able to create a robotic hand with movable fingers (degrees of freedom).

Tools/Materials:

- Teacher's computer with a projector or a blackboard
- Paper for student note taking
- Scissors, cardstock, straws, string, hot glue guns, and hot glue sticks

Warm Up (Bell work) on the board:

1. What do you know about robots?
2. Why do you think robots need movable joints? (A visual example of a robot with a joint labeled "joint" should guide the students with this question.)

Lesson: Robot Basics

There will be a class discussion about robotic parts. The robotic parts information was written by Tom Harris, author of *How Robots Work*. In this lesson, the students will write down the definitions of the robotic parts and then be quizzed on these definitions in Lesson 2.

The class discussion will be on the following robotic parts:

1. Actuator – A system or device that moves the robotic parts. This can be a motor. Some actuators use hydraulic or pneumatic systems (these systems use compressed gas).
2. Electrical circuit – Where the actuators' wires are plugged.
3. Reprogrammable – You can rewrite a program to create or change a robot's behavior.
4. Degrees of freedom – The different ways a robot can move.
5. Base – The bottom portion of a robotic arm.

6. Shoulder – This part is mounted to the base and moves similarly to a human shoulder.
7. Elbow – This joint is between the forearm and shoulder.
8. End effector – These are suited to a particular application. One common end effector is a simplified version of the hand, which can grasp and carry different objects.

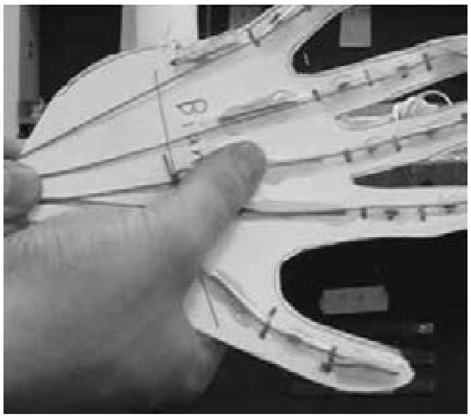
Activity: Robotic Hand

1. Before beginning the robotic-hand activity, the teacher will display to the students a finished robotic-hand example. The hand should look similar to the product in Figure 1.
2. The teacher will state the goal of the robotic hand, which is to create a cardstock hand with moveable fingers in order to create degrees of freedom.
3. The teacher will distribute the materials and tools to the students.
4. The teacher will instruct the students to trace one of their hands onto a sheet of cardstock, and then cut out the traced hand. This task should take about two to four minutes to complete.
5. The teacher will instruct the students to cut 15 small pieces of straw (about ½-inch long for each piece), and then to glue three small pieces of straw onto each finger. The purpose of the small pieces of straw is to prevent the strings on the fingers from getting tangled. Small pieces of straw are used instead of full-length straws because full-length straws that are glued down onto the cardstock fingers can be difficult to bend. If the fingers cannot bend, then the objective for creating degrees of freedom (moveable joints) will not be met. This task can take about 20 minutes to complete.
6. The teacher will instruct the students to cut five pieces of string. Each piece of string should be about 8-10 inches in length.
7. The teacher will instruct the students to insert a string through the straws of a finger, and then to glue the top end of the string (the end that is near the tip of the finger) to the tip of the finger. This step will be repeated for each finger. After completing this task, the students should be able to demonstrate functional degrees of freedom with their robotic hands by pulling the bottom ends of the strings. When the bottom ends of the strings are pulled, the top ends of the strings will pull down (bend) the fingers toward the palm of the robotic hand.
8. In the last six minutes of class, the students will clean up the classroom or technology lab.

Lesson Conclusion:

1. The teacher will inform the students that they created degrees of freedom with their robotic hands.
2. The teacher will inform the students that there will be a robotic quiz based on the robotic terms. The quiz will be given next class (Lesson 2).

Figure 1: Robotic Hand Example



LESSON 2 – MECHANICAL GRABBER

Class time: 45-60 minutes

Standards:

- **ITEEA *STL* 10H** (Grades 6-8): Students should learn that some technological problems are best solved through experimentation.
- **ITEEA *STL* 11H** (Grades 6-8): Students should be able to apply a design process to solve problems in and beyond the laboratory-classroom.
- **ITEEA *STL* 18G** (Grades 6-8): Students should learn that transportation vehicles are made up of subsystems, such as structural, propulsion, guidance, control, and support, that must function together for a system to work effectively.

Objectives:

- Students will be able to design and create an end effector.

Tools/Materials:

- Robotic quiz (This should be written by the teacher. The quiz questions should instruct the students to write the definitions of the robotic terms from Lesson 1.)
- Scissors, cardstock, straws, string, 1 wood board about ¾ inch thick x ½ inch wide x 30 inches in length per student, coping saws, hot glue guns, and hot glue sticks

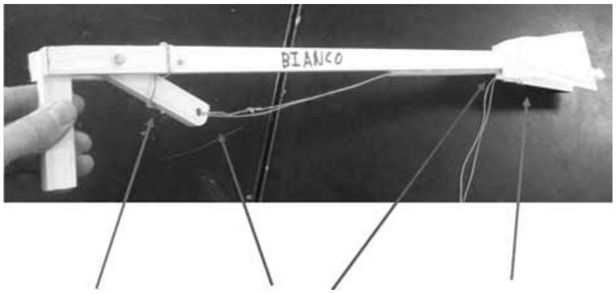
Warm Up (Bell work) on the board:

What is the purpose of the end effector on a robot?

Lesson: Robotic Quiz and End Effector Design

1. The teacher will distribute the robotic quizzes and instruct students to take the quiz.

Figure 2: Mechanical Grabber Example



2. The teacher will collect the quizzes when all the students finish.
3. The teacher will discuss the Mechanical Grabber challenge and constraints.
   Challenge: To design and build a grabber that can pick up a sheet of paper.
   Constraints:
   - Use only the tools and materials provided by the teacher.
   - The end effector must be able to open and close via a string.
4. The teacher will instruct the students to make two sketches of end effectors they want to create. Next, the teacher will instruct the students to list the pros and cons of each sketch.
5. The teacher will instruct the students to draw the final design of their end effector.
6. The teacher will distribute the materials to the students.

Activity: Creating the Mechanical Grabber

1. The teacher will instruct the students to create the arm of the grabber.
2. The teacher will instruct the students to create the end effector, and then to attach a string to the end effector. (Suggestion: For function and mainly "looks," encourage the students to have a trigger system for the string attachment. This system can create an intrinsic motivation for the students. An example of this trigger system is in Figure 2.)
3. In the last eight minutes, the teacher will instruct the students to test the mechanical grabbers by picking up a sheet of paper, if not a heavier object, with the end effectors of the mechanical grabbers. The students will have two minutes to test their mechanical grabbers.
4. In the last six minutes of class, the students will clean up the technology lab.

Lesson Conclusion:

1. The teacher will inform the students that they designed and created end effectors.
2. The teacher will inform the students that the next lesson will involve operating robotic arms.

LESSON 3 – ROBOTIC ARM BASIC FUNCTIONS

Class time: 45–60 minutes

Standards:

- **ITEEA *STL* 18G** (Grades 6-8): Students should learn that transportation vehicles are made up of subsystems, such as structural, propulsion, guidance, control, and support, that must function together for a system to work effectively.
- **ITEEA *STL* 12K** (Grades 6-8): Students should be able to operate and maintain systems in order to achieve a given purpose.
- **ITEEA *STL* 10H** (Grades 6-8): Students should learn that some technological problems are best solved through experimentation.

Objectives:

- Students will be able to operate basic robotic arm functions within the work envelope.

Tools/Materials:

- Stopwatches for each group of students and the teacher
- Robotic arms, markers, a large sheet of paper per group of students
- Yard sticks, meter sticks, or measuring tape for measuring the robotic work envelope
- 3 wooden cubes per group of students (cube dimensions: ¾" inch x ¾" inch x ¾" inch)
- 1 aluminum can (soup can) per group of students

Warm Up (Bell work) on the board:

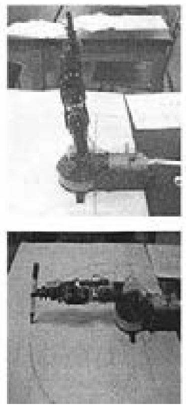
List the tasks that can be completed with a robotic arm.

Lesson/Activity: Robotic Arm Operations

1. The teacher will demonstrate to the students a robotic arm picking up and dropping a wooden block in order to display a basic robotic function (transferring).
2. The teacher will assign groups of students to the robots.
3. The teacher will instruct the students that they will be finding the lengths of a robotic arm's work envelope. The work envelope is the area within which the robotic arm can move.
4. The teacher will instruct the students to extend their robotic arm as far as possible and then measure the length of the robotic arm. The students should record the measurement.

An example of a robotic arm extended as far as possible is in Figure 3.1.

Figure 3: Basic Functions



5. The teacher will instruct the students to place a large piece of paper under the base of the robotic arm. The base should be near an edge of the paper in order to have enough room on the paper to draw an arc with the robotic arm.
6. The students will extend the robotic arm as far as possible, and then move the arm to be parallel to the work surface (desk or workbench). An example of this position is in Figure 3.2.
7. The teacher will instruct the students to put a marker into the gripper fingers of the end effector. This task will be completed by opening the fingers, and then closing them onto the body of the marker.
8. The teacher will instruct the students to draw an arc on the paper using the robotic arm. (This task can be completed by moving the arm from side to side.)
9. The teacher will instruct the students to measure the diameter of the drawn arc on the paper, and then to record the measurement.
10. The teacher will distribute small stationary supply items to each group of students, such as large paper clips or erasers.
11. The teacher will instruct the students to attempt to pick up these items with the robotic arm. After a few minutes of attempting this task, the teacher will instruct the students to write down the items that the robotic arm can pick up and cannot pick up and then to write an explanation for these performances.

Extension Activity: Fastest Operator Challenge

1. The teacher will distribute the three wooden cubes and an aluminum can to each group.
2. The teacher informs the students that they will be competing against each other to see who can transfer the three wooden cubes into an aluminum can (soup can) the fastest in each group. Each student in each group will be given three minutes to put the cubes into the can. The students and the teacher will have stopwatches for this activity.

Lesson Conclusion:

1. The teacher will inform the students that they have measured a robotic arm's work envelope and operated the basic functions of a robotic arm.

ADVANCED ROBOTIC CHALLENGE: ROBOTIC MARBLE MAZE

Class time: 90–180 minutes

Standards:

- **ITEEA *STL* 3F** (Grades 6-8): Students should learn that knowledge from other fields of study has a direct effect on the development of technological products and systems.
- **ITEEA *STL* 10H** (Grades 6-8): Students should learn that some technological problems are best solved through experimentation.
- **ITEEA *STL* 11H** (Grades 6-8) : Students should be able to apply a design process to solve problems in and beyond the laboratory-classroom.

Objectives:

- Students will be able to design and create a robotic marble maze using slope and rolling friction.

Tools/Materials:

- Robotic arms, cardstock, cardboard, scissors, tape, one marble and stopwatch per group of students

Warm Up (Bell work) on the board:

What do you know about slope and rolling friction?

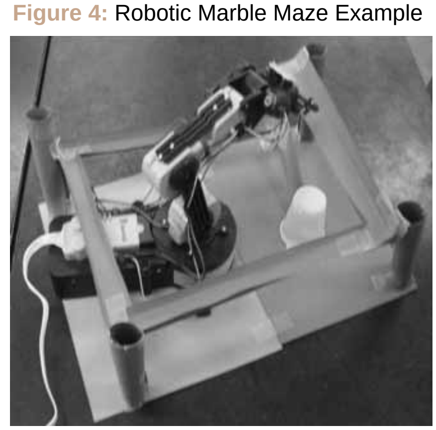
Lesson: Slope and Rolling Friction and Maze Design

1. The teacher will demonstrate to the students a robotic arm picking up a marble, and then placing it in a marble maze in order to display an example of a marble maze and a marble traveling through a maze. (See Figure 4.)
2. The teacher will ask the students how rolling friction and slope affects the speed of the traveling marble in the maze. (The answer is that rolling friction slows down the traveling speed of the marble and that the height of the slopes can affect the traveling speed.)
3. Discuss the challenge and constraint of the maze with the students.

   Challenge:

   - To design and create a maze for a marble to roll as fast as possible completely around a robotic arm.

Figure 4: Robotic Marble Maze Example



- The marble must be lifted from the maze's platform to the top of the maze without knocking over the maze.
- The marble must travel from the top of the maze to the bottom.

Constraint:

- Use only the materials provided to the group by the teacher.

4. The teacher will instruct the students to create four different top view sketches of a maze and then circle their best sketch.
5. The teacher will assign the students into groups.
6. The teacher will instruct the groups of students to pick the best sketch in their group to use as their marble maze.

Activity: Robotic Marble Maze

1. The students will create the marble maze based on the design of the best sketch in their group.
2. The groups of students will construct their mazes in the classroom or technology lab.
3. In the last six minutes of class, the students will clean up the classroom or technology lab.

Lesson Conclusion:

1. The teacher will inform the students that they created rolling friction and slope with the mazes.
2. The teacher will inform the students when the mazes will be tested.

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