Pi – What is it?

Subject Area(s)	measurement, number & operations, reasoning & proof, and science & technology
Associated Unit	None
Associated Lesson	None
Activity Title	Let's Take a Slice of Pi
Header	

Insert Image 1 here, right justified to wrap

Image 1

ADA Description: students working on Pi activity

Caption: the students discussing how to calculate distance as robot travels along a circular path

Image file name: Pi_students.jpg

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Grade Level	5 (4-5)
Activity Dependency	None
Time Required	Two 45-minute lessons
Group Size:	4
Expendable Cost /Group	US$2

Summary

Working as a team, students discover that the value of pi (3.1415926…) is a constant and applies to all different sized circles. The team builds a basic Lego robot and programs it to travel in a circular motion. The robot is required to have a marker/highlighter attached to the chassis so that while the robot travels the programmed circular path, a circle can be traced on ground. Using students' measurement skills, they measure the circumference and diameter of the circle and calculate pi via the pi and circumference relationship; circumference of a circle divided by the diameter is the value of pi.

Engineering Connection

Pi (represented by π) is a remarkable constant that is found in all branches of mathematics, physics, chemistry, engineering concepts and calculations. In fact, many formulae in engineering, science, and mathematics involve the value of pi [2]. Many students take the meaning of this value for granted and simply memorize that pi is approximately 3.1415… simply because the value was told to them. This activity instead promotes the learning of pi in an engineering-team-effort way by allowing students to be the researchers,

	discoverers, and ultimately uncover the approximated value of pi in a hands-on way.
Engineering Category	(3) relates math concept to engineering/the use of technology
Keywords	build and design, circle, circumference, constant, centimeter, decimals, diameter, endpoints, formula, fraction, inches, irrational number, line segment, perimeter, pi, program, radius, ratio, software, units

Educational Standards

NYS Math: 5.PS.3, 5.RP.1, 5.CM.9, 5.R.2, and 5.A.1 [1]

Pre-Requisite Knowledge

Familiarity with measurement using a ruler, division & multiplication skills, and the use of Mindstorms software

Learning Objectives

After this activity, students should be able to:

- Build and program a basic Lego NXT Robot
- Measure the diameter and circumference of a circle
- Calculate, know, and understand the concept and value of pi

Materials List

Each group needs:

- Lego kit
- Marker/highlighter
- Computer with Mindstorms software
- Large piece of white paper (smaller pieces and tape them together)
- Ruler (with centimeter markings)
- Yarn
- Tape
- Circular objects (to trace out circles of roughly 3, 5, & 7 inches in diameter)
- 3 pieces of white printing 8.5”x11” paper
- Notepad and pen

Introduction / Motivation

It has been said that the universe would not be able to function without the remarkable concept of pi. However, the exact value of pi could not be properly expressed in the number system that we use; that is pi is an irrational number that cannot be expressed as a fraction and therefore it has an endless amount of decimal representations. Nonetheless, mathematicians have been able to estimate the value of pi to be 3.14… (Who can recite the first 5 decimals of pi?) Knowing this value of pi, we can calculate the circumference of a circle given the diameter or radius.

Insert Image 2 here, centered

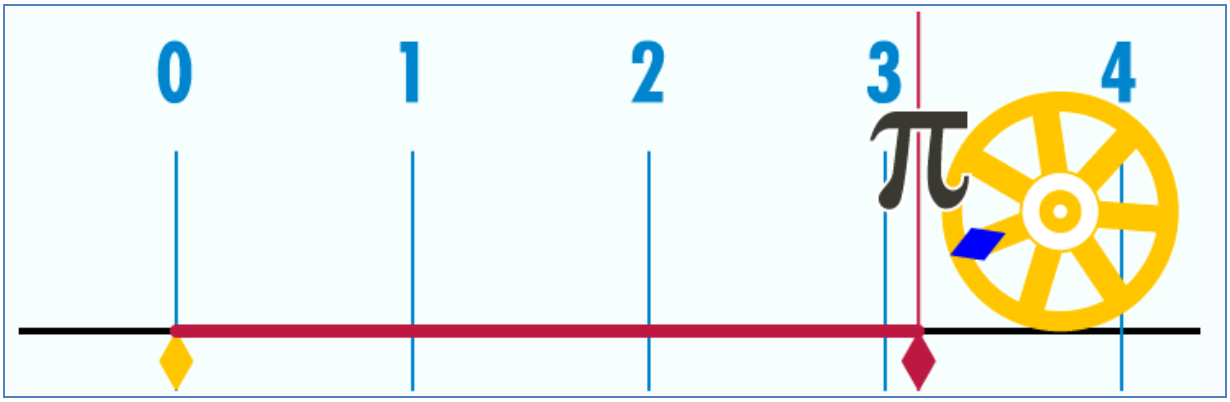

Image 2
ADA Description: 3.14159 unit of diameter is the value of pi
Caption: Image 2: shows that pi is the ratio of circumference (length of circle) to the diameter of the circle
Image file name: pi-unrolled.jpg
Source/Rights: Copyright © Wikipedia (http://commons.wikimedia.org/wiki/File:Pi-unrolled.gif)

The importance of the pi was recognized throughout history, some even suggest that it has been discovered about 4000 years ago. Around 2000 B.C., both the Babylonians and the Egyptians had recognized the concept of pi and incorporated it in their architecture [3]. However, at that time, both civilizations did not have a clear idea of what the value of pi was exactly – nonetheless they had a rough estimated value. It was not until later, the Greeks mathematicians (namely Archimedes) were able to improve upon the approximated value that the Babylonians and Egyptians used. Amazingly, today we know more than six billion digits of pi's decimals. Now does anyone want to calculate 6 billion decimal digits of pi? Surely no one does; therefore this effort was made possible all with the help of an advance powerful computing tool – the computer.

Vocabulary / Definitions

Word	Definition
Diameter	any straight line segment that passes through the center of the circle and whose endpoints are on the circle
Radius	any line segment from a circle's center to its perimeter
Circumference (of a circle)	is the length that makes up the closed curve of the circle
Pi	a constant whose value is the ratio of any circle's circumference to its diameter

Procedure

Before the Activity

- Gather all required materials
- Make sure all the Lego kits are complete with the parts properly divided
- Prepare the ground working area with large piece of white paper and secure it onto the floor
- Divide the class into groups of 4, (optional: assign roles to each person of the team – otherwise let the students choose)

With the Students

1. Discuss and go over the definitions of diameter, radius, and circumference
2. Write on the board (in a sentence form) of the relationship of pi with circumference and diameter; that is pi = circumference ÷ diameter.
3. Directly underneath the sentence relationship, write the relationship in a mathematical format: π = C/D where C is the circumference and D is the diameter.
4. Emphasize the ratio relationships written. Rearrange relationship to show that C = π*D => C = 2*π*R
5. Pass out the required materials to each group
6. Have students complete a brief pre-activity experiment:
    a. Refer to the pre-activity worksheet (Pre_Activity_Worksheet.doc)
    b. Make sure to print out enough copies for the class
    c. First gather all the materials listed on the worksheet
    d. Once students are finished with the worksheet, go over the assessment part of the activity to ensure that students understand the concept of pi, circumference, and diameters
7. After discussion of pre-activity experiment, each group can start the activity.

a. Open up the Lego kit and find the instruction manual to build the standard robot chassis – titled Lego Mindstorms Education
b. In the lower level of the kit, look for the battery charger and re-chargeable battery package of the NXT brain – put them together according to page 5's (left side of the page) instruction and start charging the NXT
c. Go to page 8 of the manual and follow the building instructions (Step 1) up to page 22 (Step 17).
d. In order to attach a marker/highlighter onto the chassis, follow the steps detailed in Figure 1.1.
e. Once the robot is built, load the Mindstorms software on the computer
f. Create a new program file and name it "dragTurn". This makes the robot do a drag turn (a circle would be traced by the marker onto the paper) – follow Figure 1.2 for programming instruction
g. Download "dragTurn" onto NXT and make sure that the marker is touching the secured large piece of paper.
h. Run the program and watch the robot do a drag turn and marks the ground with a circle
i. Create a new program file and name it "pointTurn". This makes the robot do a point turn and traces a smaller circle onto the paper – follow Figure 1.3 for programming instruction. Download the program onto NXT and run the program. Watch the robot make a point turn and draws a small circle on the paper (make sure to give the robot enough space that the two circles drawn via "dragTurn" and "pointTurn" do NOT overlap)
j. For each of the circle drawn by the robot, measure the circumference and diameter of note them down
    i. Have students repeat Steps 6b-6f for both the circles drawn by the robot

Insert Figure 1.1 here,
centered

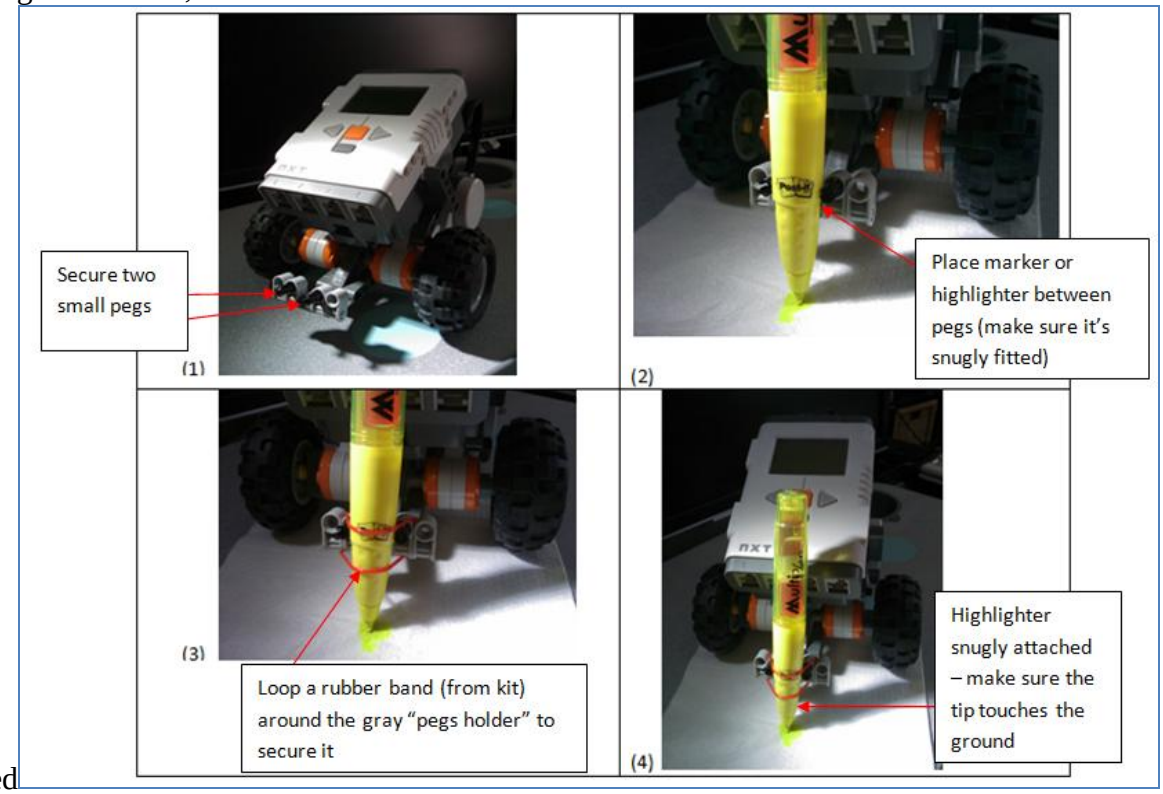

Figure 1.1
ADA Description: instruction on how to attach a marker/highlighter onto the robot's chassis
Caption: Figure 1.1: follow steps 1 through 4
Image file name: instruction.jpg
Source/Rights: Copyright © Carole Chen 2009

Insert Figure 1.2 here,
centered

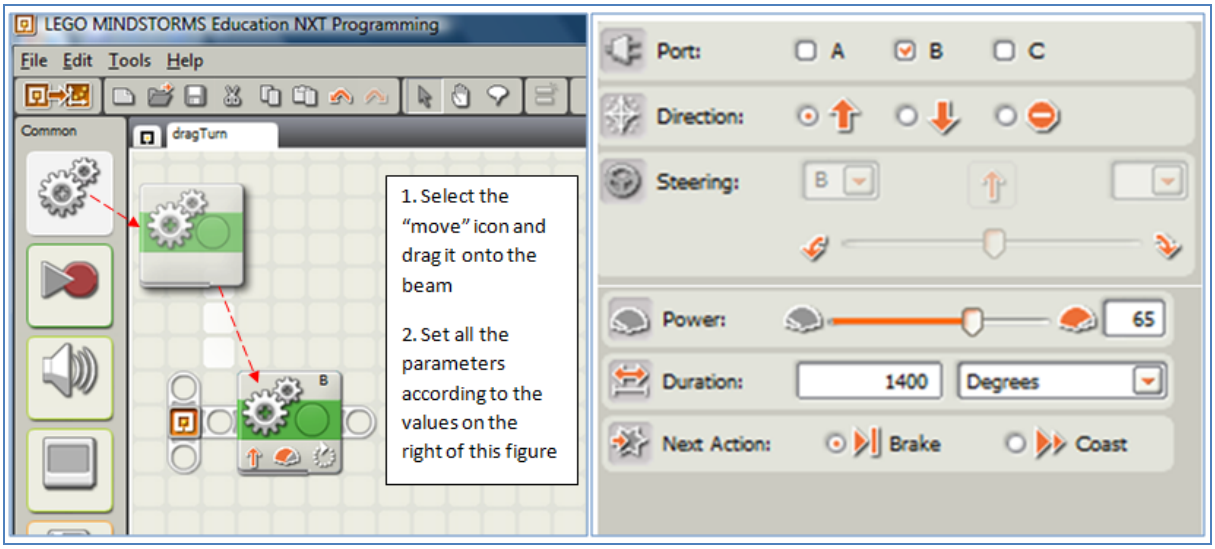

Figure 1.2
ADA Description: drag turn program
Caption: Figure 1.2: follow the instruction/values to program robot to do a drag turn
Image file name: dragTurn.jpg
Source/Rights: Copyright © Carole Chen 2009

Insert Figure 1.3 here, centered

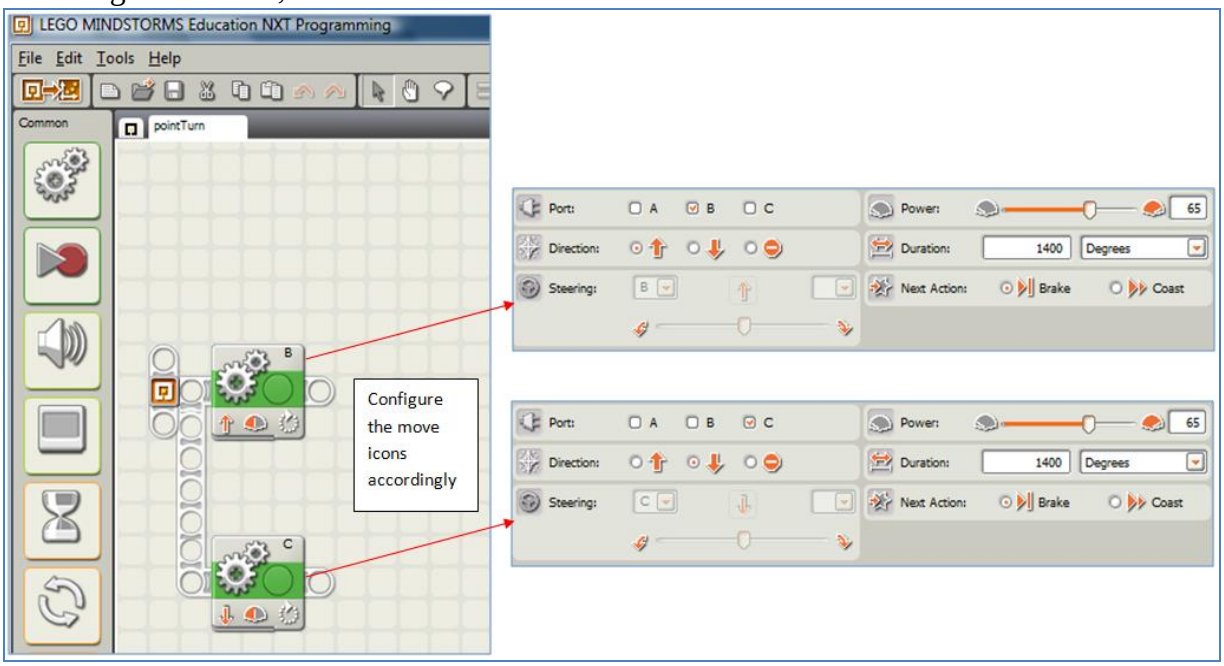

Figure 1.3
ADA Description: point turn program on NXT 2.0 software
Caption: Figure 1.3: follow the instruction/values to program robot to do a point turn
Image file name: pointTurn.jpg
Source/Rights: Copyright © Carole Chen 2009

Attachment

- Pi_Pre_Activity_Worsheet.docx (available also in pdf)

Troubleshooting Tips

- If robot does not travel the point turn as programmed, make sure that the surface of the ground is completely flat and that the paper is taped securely on the ground (without bumps)
    - If that does not fix the problem, try programming the "pointTurn" using the help panel on the right side of the Mindstorms software
    - "Robot Educator" panel → "Common Palette" → "07. Point Turn" → "Programming Guide"
- If the robot does not travel the drag turn as programmed, try using a "curve turn" as shown in the "Robot Educator" panel under "Common Palette" also

Assessment

Pre-Activity Assessment

How accurate is your pi?

Take an average of three pi values obtained from the 3 different sized circles drawn by the students. Compare this average value of pi to the known pi – 3.14159…What does that say about the circles you drawn? Good or bad?

Activity Embedded Assessment

Different circles, same pi?

After explaining that all circles have the same value of pi and that pi is a constant, ask students to predict the pi value of the circles that the robot draws.

Post-Activity Assessment

How accurate is Robot's pi?

Take an average of two pi values obtained from the 2 different sized circles drawn by the robot. Compare this average value of pi to the known pi – 3.14159… How off was the value? What does that say about the circles the robot drawn? Good or bad?

Activity Scaling

- For upper grades, estimate the circumference of the robot's tires and based on this value and the number of rotations that the robot has traveled, the student can calculate a rough estimate of the circle's circumference. (This will only work if the robot is programmed for exactly 1 round).

References

[1] www.nysed.gov

[2] en.wikipedia.org/wiki/Pi

[3] www.scientificamerican.com/article.cfm?id=what-is-pi-and-how-did-it

[4] Mindstorms Education instructional manual in kit #9797 – item #4297091

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