PARSIPPANY-TROY HILLS TOWNSHIP PUBLIC SCHOOL DISTRICT

MTH525 ROBOTICS - HIGH SCHOOL

Authored by: Kathy Effner
Marty Meiden

Reviewed by: Tali Axelrod
Pam Freund

Approval Date: August 21, 2018

Parsippany-Troy Hills Township Public Schools
292 Parsippany Road   Parsippany, NJ 07054
www.pthsd.net

I. OVERVIEW

Students will begin this full year elective Robotics course learning about engineering and engineering problem solving. The design and programming of their robot and the relevant STEM and Robotics principles will be investigated. Working in small groups, students will be given introductions to build, program and test a robot. Students will be presented with a wide variety of engineering challenges such as playing a sport-like game, completing an obstacle course, and picking up and sorting objects based on size/color. The course will culminate with students competing head-to-head with their robots. Student teams will be required to complete an engineering notebook which will journal their process.

The curriculum will focus on mechatronic principles and programming using a hands-on, project-based learning style. There will be an emphasis on cooperative education and problem solving.

II. RATIONALE

Robotics will be offered to a wide range of students who have varying abilities and interests. Each individual will have the opportunity to explore new venues that they most likely have not experienced before. Robotics provides strong interdisciplinary connections to areas of mathematics, science, engineering, and technology. Students will consistently be afforded the opportunity to make real-world connections to robotic devices that are currently being utilized in society today. The engaging nature of Robotics makes it very appealing to many High School students.

The Robotics curriculum is aligned with the New Jersey Student Learning Standards for Science, 21st-Century Life and Careers, and Technology.

III. STUDENT OUTCOMES New Jersey Student Learning Standards

In accordance with district policy as mandated by the New Jersey Administrative Code and the New Student Learning Standards, the following are proficiencies required for the successful completion of the above named course.

The student will:

1. Work in teams to solve problems that closely align with real world issues and needs using robotic technology.
2. Manage projects by successfully completing a variety of performance-based robotics tasks.
3. Communicate effectively with their partners to ensure that the robotics projects are properly constructed and effectively utilized.
4. Process information in a manner that enables them to formulate solutions to real world technology-based problems using robotic interventions.
5. Synthesize and assimilate knowledge to help better understand complex problems, and to develop effective strategies to achieve workable solutions.

6. Become researchers and innovators who are technologically literate in today's society.
7. Keep an engineering notebook to record the design process. This is basically a "diary" that designers keep as they progress through the process.

Link to NEW JERSEY STUDENT LEARNING STANDARDS

- 3 - English Language Arts
- 4 - Mathematics
- 5 - Science
- 8 - Technology
- 9 - 21st Century Life and Careers

Modifications/Differentiation and Adaptations:
For guidelines on how to modify and adapt curricula to best meet the needs of all students, instructional staff should refer to the Curriculum Modifications and Adaptations included as an Appendix in this curriculum. Instructional staff of students with Individualized Education Plans (IEPs) must adhere to the recommended modifications outlined in each individual plan.

IV. ESSENTIAL QUESTIONS AND CONTENT

Overarching Essential Questions:

a) How can an autonomously programmed robot be designed to perform specific tasks using a variety of sensors that acquire information about the world external to the robot?

b) How can autonomous robots be designed and used to perform manual and repetitive tasks safely? In the workforce? In the home?

c) How do engineers solve problems, use creativity and innovation, create teams and use the engineering design process in an increasingly complex world?

d) Since a very large part of designing is redesigning where the first solution to a problem is rarely the best, improvements continue to suggest themselves. How does one decide when the design- and redesign- process has reached its ultimate goal?

Content:

Introduction to Engineering

- What does an engineer do?
- How does having constraints placed on a design change the engineering process?
- Why is making a prototype so important in the design process?
- What have you learned from the iterative process?

Introduction to Robotics

- What is the relationship between wheel size, motor rotation, and distance traveled?
- How can geometry of circles help us to program and properly control the movement of the robot's motion?
- Explain how the different subsystems work together.
- How does the installation of sensors improve the functioning of the robot?

Introduction to programming and Joystick

- How does the driving base influence the capability of the robot?
- How can you use the design process when building the driving base?
- Explain how the microprocessor functions.
- Explain how you were able to use the joysticks in conjunction with the VEXnet system to pick up and score the bottles or cans in your classroom challenge.
- Explain how you can improve your score in the classroom challenge using the control system of the robot.

Introduction to CAD

- How do you troubleshoot and maintain the robot?
- What are the benefits and limitations of using the EV3 software as a way to program and control robots?
- What strategies can be used to minimize programming problems and errors when working with robots?
- In what ways does programming resemble the written English language, in what ways is it different?
- Why are feedback systems important in the design of robots?
- How does the type of input impact the type of sensor to be used in the design of a robot?
- What are the limits of a robot's capability with regard to the sensory data they collect?
- Why must the purpose of the robot be factored into the design/implementation of sensors?
- What types of time management and planning skills are needed to work collaboratively in your team?
- Which items in the classroom require 3D modeling software in order to be designed and manufactured?
- Which types of engineers use CAD and how do they use it in their day to day job?
- Why do designers create virtual models?
- For what would a designer use a rendered image of a design?

The Game!

- What are frequency and amplitude of sound waves and how do they affect the robot's sensor?
- How does the robot's speed, direction, light sensor position, and sensitivity affect the robot's ability to accurately track lines?
- How do varying conditions affect the detection capabilities of the ultrasonic and touch sensor?
- How can you maximize the number of points you can score during the game?
- How can you keep your opponent from scoring efficiently during the game?
- How do you choose what features of the robot are needed to play the game?

Object Manipulation

- How does gear rotation affect the speed and/or power of the robot?
- How do you vary the gear ratios of a robot and how does this affect the distance and speed of a robot?
- Why would you choose one type of a manipulator over another type?
- How can your data from your test improve your redesign?
- What are the benefits of creating a virtual model and simulating your design before building it?
- Can you suggest an improved workflow for creating the manipulator design?
- Can you suggest improvements to the manipulator design?

Speed, Power, Torque and DC Motors

- How does gear rotation affect the speed and/or power of the robot?
- How do you vary the gear ratios of a robot and how does this affect the distance and speed of a robot?
- Why would you want to increase your speed and lower your power?
- Why would you want to increase your power and lower your speed?
- How does the change in the load affect your current draw?
- How would the position of the load on the arm affect the load on the motor?
- If the load was too great for the motor, how could we reposition our load and what effect would it have on the reach of the robot?

Mechanical Power Transmissions

- How does gear rotation affect the speed and/or power of the robot?
- How do you vary the gear ratios of a robot and how does this affect the distance and speed of a robot?
- How do the different types of gears provide an advantage in your arm design?
- How do the mathematical calculations help you to determine what type of gear ratio is needed in your design?
- How would a larger gear on the motor shaft and the smaller gear on the scoop shaft affect the movement of the scoop compared to the motor?
- How do you think a larger gear on the motor shaft and a smaller gear on the scoop shaft would affect the load on the motor?

Drive Train Design

- How does gear rotation affect the speed and/or power of the robot?
- How do you vary the gear ratios of a robot and how does this affect the distance and speed of a robot?
- How does gear rotation affect the speed and/or power of the robot?
- How do you vary the gear ratios of a robot and how does this affect the distance and speed of a robot?
- How can you use friction to your advantage when you create your robot drivetrain?
- How can you use geometry to help select the most efficient drivetrain for your robot?

Lifting Mechanisms

- How does gear rotation affect the speed and/or power of the robot?
- How do you vary the gear ratios of a robot and how does this affect the distance and speed of a robot?

- Explain how the degrees of freedom will allow you to design a robot that is able to transfer motion as it manipulates game objects.
- Explain how a linkage system allows a robot to score on a high goal in a game situation.
- Explain how passive assistance can provide your robot with a mechanical advantage

Systems Integration

- How does gear rotation affect the speed and/or power of the robot?
- How do you vary the gear ratios of a robot and how does this affect the distance and speed of a robot?
- How does the process of system engineering allow for the development of a well integrated structure?
- How does the integration of system engineering early in the design process provide benefits to the overall design?

Testing and the Iteration Process

- How does gear rotation affect the speed and/or power of the robot?
- How do you vary the gear ratios of a robot and how does this affect the distance and speed of a robot?
- What was your favorite part of the competition robotics experience?
- Did the game-play match your expectations? (i.e. Did the matches play out like you expected?)
- What would you improve about your robot design?
- Would you make any major changes or only minor changes?
- What would you improve about the design process if you had to start over?
- On what aspects do you wish you had spent more time?
- What was the most important life skill you learned during this process?
- Why was this process important to your experience?

Final Project

- How can we plan, design and implement a robot to meet the challenges given to us?

V. STRATEGIES

- Student projects
- Group discussion
- Individual conferencing

VI. EVALUATION

Projects: 60% - Construct, program, and test robot tasks

Homework/ Class Participation: 10% - Participation and the ability to work collaboratively and effectively in the Robotics classroom is critical to ensure equitable responsibility and mastery for each member of the team.

Quizzes and Assessments: 30% -Based on knowledge and understanding of Robotics vocabulary and procedure

VII. REQUIRED RESOURCES

Hardware

- VEX EDR V5 System

Software

- VEX Coding System

REQUIRED WEBSITES

http://curriculum.vexrobotics.com/curriculum-overview.html
http://cmra.rec.ri.cmu.edu/previews/robot_c_products/teaching_rc_cortex_v2/
vexrobotics.com

VIII. SCOPE AND SEQUENCE

Standards Covered throughout the entire course: 9.3.ST-ET.1,9.3.ST-ET.2, 9.3.ST-ET.3, 9.3.ST-ET.4, 9.3.ST-ET.5, 9.3.ST-ET.6, 9.3.ST-SM.1, 9.3.ST-SM.3

1. **Introduction to Engineering (About 10 days)**

Standards Covered: 8.2.8.B.5, 8.2.8.B.5, 8.2.8.E.4, 8.2.12.E.4, 8.2.12.E.2, 9.3.ST.4, 9.3.ST.5, 9.3.ST.5

Suggested Activities:

- Students identify things that have been engineered.
- Students develop a design team and learn the engineering process
- Students are given a challenge to build a tower using only 10 pieces of paper and have it stand for at least 30 seconds.

2. **Introduction to Robotics (about 7 days)**

Standards Covered: 8.2.8.A.1, 8.2.12.A.1, 8.2.8.B.5, 8.2.8.B.5, 8.2.8.D.3, 8.2.8.D.6, 8.2.8.E.4, 8.2.12.E.4, 9.3.ST.4, 9.3.ST.5, 9.3.ST.5

Suggested Activities:

- Discuss vocabulary related to robotics, such as frame, structures, control structure, sensors, drivetrain, etc.
- Research a type of robot used in the world today, example the Mars Rover. Students will report back to class after research.
- Build the robot and drive it in the classroom using a joystick.
- Journal about their experience building the robot in their engineering notebook.

3. **Introduction VexNet (6 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.E.3, 8.2.8.E.4, 8.2.12.E.4

Suggested Activities:
- teach control
- drive robot using control...Basketball, Slalom, & Labyrinth Challenges

4. **Programming Intro (3-5 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.D.6, 8.2.8.E.3, 8.2.8.E.4, 8.2.12.E.4. 8.2.12.E.3

Suggested Activities:
- Students will begin to program their robot. Students will program the robot to move forward, backwards at various speeds by controlling the power levels of the motors
- Students will be able to write functions to be called throughout their programs.
- Students will program their robots to complete a "point turn" (a turn in place, 90, 180 degrees).
- Students will program their robots to complete a "swept turn" (a turn around a certain wheel).
- Students will write programs to autonomously have the robot complete the Basketball, Slalom, & Labyrinth Challenges

5. **Introduction to AutoDesk Inventor (5-7 days)**

Standards Covered: 8.2.8.A.2, 8.2.12.C.4, 8.2.8.C.5, 8.2.8.D.6, 8.2.12.D.1, 8.2.12.D.3, 8.2.8.E.4, 8.2.12.E.4

Suggested Activities:
- The students will be able to create a 3D model using AutoDesk.
- The students will be able to animate 3D models.
- The students will be able to render 3D models.

6. **Class Competition (7 - 14 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.D.6, 8.2.8.E.3, 8.2.8.E.4, 8.2.12.E.4, 8.2.12.E.3

Suggested Activities:

- Students will be able to explain how the process of strategic design works.
- Students will be able to demonstrate the use of defining objectives to select game objectives.
- Students will be able to list all of the ways to score the most points in the game.
- Students will be able to create a cost–benefit analysis to demonstrate the strengths of different tasks.
- Students will be able to correctly produce entries in their engineering notebook.
- Students will compete in Swept Away Challenge.
- Students will debrief as a team on their successes/failures in their teamwork, strategy, and journal in their engineering notebook.
- Students will compete in Swept Away Challenge again.

7. **Robotic Arm Manipulation (7 -10 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.D.3, 8.2.8.D.6,8.2.12.D.1,

8.2.8.E.4, 8.2.12.E.4, 8.2.12.D.3, 8.2.8.E.3

Suggested Activities:

- Students will program the Claw of the robot to grab and release objects.
- Students will program the Claw of the robot to pick up and put down objects.
- Students will program their robot to begin in the corner of the field, drive to a location, pick up a ball, drive to the wall, and release the ball on the other side of the wall.
- Students will program their robot to clear three cans out of a circle using the claw.
- Students will journal the design process in their engineering notebooks.

8. **Object Manipulation (8 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.12.D.1, 8.2.12.D.3, 8.2.8.E.4, 8.2.12.E.4

Suggested Activities:

- Students will be able to research accumulators and manipulators in the real world and analyze the designs as well as the creator's possible reason for the design.
- Students will be able to present the basic concepts of manipulators and accumulators.
- Students will be able to design examples of each.
- Students will demonstrate their designs to the class.

9. **Speed, Power, Torque, & DC Motors (10 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.D.6, 8.2.8.E.3, 8.2.8.E.4, 8.2.12.E.4

Suggested Activities:

- Students will be able to explain the difference between speed, power and torque.
- Students will be able to demonstrate the concept of speed.
- Students will be able to demonstrate the concept of power.
- Students will be able to demonstrate the concept of torque.
- Students will be able to build and tweek the manipulator arm they previously designed.

10. **Mechanical Power Transmissions (10 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.D.6, 8.2.8.E.4, 8.2.12.E.4

Suggested Activities:

- Students will be able to demonstrate how mechanical power transmission systems are very important in the design and construction of competition robots.
- Students will be able to vary the gear ratio (and the mechanical advantage) in a system, which gives them the versatility necessary to accomplish whatever work needs to be done.
- Students will be able to determine gear inputs and outputs by calculating the difference between them, and determine their gear ratio accordingly.

11. **Drivetrain Design (10 days)**

Standards Covered: 8.2.8.A.2,8.2.8.A.3,8.2.12.C.4,8.2.8.C.5,8.2.8.D.6, 8.2.8.E.4, 8.2.12.E.4

Suggested Activities:

- Students will be able to demonstrate how applied force and friction are related.
- Students will be able to distinguish between static and kinetic friction.
- Students will be able to calculate wheel speed.
- Students will be able to demonstrate how to calculate a gear reduction.
- Students will be able to compare and contrast the different types of drivetrains, along with their benefits and drawbacks.

12. **Lifting Mechanics (11 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.C.5, 8.2.12.C.6, 8.2.8.D.6, 8.2.12.D.1, 8.2.12.D.3, 8.2.8.E.4, 8.2.12.E.4

Suggested Activities:

- Students will be able to differentiate the three degrees of freedom that are presented in the beginning of the unit.
- Students will be able to demonstrate the correct use of the calculations needed to choose a gear reduction

- Students will be able to distinguish between the use of a linkage system and a multi-state elevator in manipulator design.
- Students will be able to explain how passive assistance can improve a robot design.

13. **More Programming (15 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.D.6, 8.2.8.E.3, 8.2.8.E.4, 8.2.12.E.4, 8.2.12.E.3

Suggested Activities:
- Students will program robots using the shaft encoders for distance and autocorrect (straightness).
- Students will understand the difference between analog and digital ports and which sensors/servo.
- Students will program robots using sensors and servos to complete a variety of different tasks including Bumper switch, Potentiometer, Ultrasonic Range Finder, Gyroscope, and Servos.

14. **Systems Integration (7 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.D.6, 8.2.8.E.4, 8.2.12.E.4, 8.2.12.E.3

Suggested Activities:
- Students will be able to demonstrate how system integration works.
- Students will be able to demonstrate how they can use the six tips for integration in their design.
- Students will be able to complete their robots.

15. **Testing and the Iteration Process (10 days)**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.C.5, 8.2.8.D.6, 8.2.8.E.3, 8.2.8.E.4, 8.2.12.E.4, 8.2.12.E.3

Suggested Activities:
- The students will be able to demonstrate the role that testing plays in the design process.
- The students will be able to demonstrate how the information collected in the testing process is used in the different iterations of their robot design.
- The students will be able to demonstrate a systematic process to prioritize the improvements dictated from the data collected from their testing

16. **<u>Design Your Own Robot (30 days)</u>**

Standards Covered: 8.2.8.A.2, 8.2.8.A.3, 8.2.12.C.4, 8.2.8.C.5, 8.2.12.C.6, 8.2.8.D.3, 8.2.8.D.6, 8.2.12.D.1, 8.2.12.D.3, 8.2.8.E.3, 8.2.8.E.4, 8.2.12.E.4, 8.2.12.E.3

Suggested Activities:

- The students will be able to analyze an existing robot to identify potential areas for innovation that might include improvements relative to performance or cost, among other factors.
- The students will be able to explain how physical sketch models, 2D sketches, and 3D digital models can be used as visualization tools for design ideation.
- The students will be able to use Autodesk Inventor and/or Autodesk Fusion to create, render and animate custom 3D models.
- The students will be able to describe the importance of documenting and annotating a design in the design software.
- The students will be able to physically create a custom robot from a virtual prototype using Autodesk Inventor and/or Fusion and demonstrate that robot.