West Windsor-Plainsboro Regional School District
Robotics Engineering
Grades 9-12

Unit 1: STEM and Robotics	
Content Area: Engineering	
Course & Grade Level: Robotics Engineering Grades 9-12	
Summary and Rationale	
Not long ago, robots were mostly found in the realm of science fiction. In the 21st century, robots play a critical role in a variety of fields including manufacturing, medical, agriculture, military and more. Robots continue to take on a greater role in society as the year's progress. Knowing what robots are, what they can do, and how they work is important for the future generation of engineers. This unit will discuss where the journey between humans and robots began as well as the correlations between the field of robotics and the STEM fields.	
Recommended Pacing	
25 days	
New Jersey Student Learning Standards for 21st Century Life and Careers	
Career Ready Practices	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.CT.1:	Identify problem-solving strategies used in the development of an innovative product or practice.
9.4.12.CI.1	Demonstrate the ability to reflect, analyze and use creative skills and ideas.
New Jersey Student Learning Standards for Technology	
CPI #	**Cumulative Progress Indicator (CPI)**
8.2.12.ITH.1	Analyze a product to determine the impact that economic, political, social, and/or cultural factors have had on its design, including its design constraints.
8.2.12.NT.1	Explain how different groups can contribute to the overall design of a product.
Next Generation Science Standards (NGSS)	
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
Instructional Focus	
Unit Enduring Understandings	
● Engineering design is a complex process in which creativity, content knowledge, research, and analysis are used to address local and global problems. ● Decisions to develop new technology are driven by societal and cultural opinions and demands that differ from culture to culture. ● Engineers use science, mathematics, and other disciplines to improve technology. Increased collaboration among engineers, scientists, and mathematicians can improve their work and designs. ● Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed.	
Unit Essential Questions	
● What is robotics? ● What is a robot? ● How can robots be used to solve problems?	

- How have robots become such a critical component of 21st century society?
- How are robots used in different industries today?
- What is the interdependency between STEM and robotics?
- What are the steps in the Design Loop?
- Why is project management essential in the development of a technological system?

Objectives

Students will know:

- The history of robots and the field of robotics.
- How robots/robotics are utilized in modern society.
- The relationship between technology and society.
- The Design Loop is an essential process in problem solving.

Students will be able to:

- Implement the design process in the development of a robotic system.
- Develop an engineering notebook as a means of cataloging and documenting the design process.
- Utilize creative design techniques to develop a robotics system.

Evidence of Learning

Assessment

Common Assessment 1.1

Competencies for 21st Century Learners

x	Collaborative Team Member	x	Effective Communicator
x	Globally Aware, Active, & Responsible Student/Citizen		Information Literate Researcher
x	Innovative & Practical Problem Solver		Self-Directed Learner

Resources

- VEX Robotics - https://www.vexrobotics.com
- VEX Virtual Robotics Builder - https://www.vexrobotics.com/vexcode-vr
- Carnegie Mellon Robotics Academy
- Engineering Design: An Introduction (Karsnitz, O'Brien, Hutchinson)
- www.legoeducation.com

Unit 2: Fundamentals of Robotics	
Content Area: Engineering	
Course & Grade Level: Robotics Engineering Grades 9-12	
Summary and Rationale	
Engineers program robots using specific commands to perform intentional actions. Developing a product that solves a specific problem requires an understanding of the product's basic design needs. The same principle applies to the development of a robotic system. This unit will explore design elements of a robot, how different systems work together to achieve a goal and design-driven mindsets for innovation. This unit will focus on developing robotic systems that operate fully under human control, and it will provide a foundational understanding of how robotics systems and components work so that students can later design robots with autonomous capabilities.	
Recommended Pacing	
45 days	
New Jersey Student Learning Standards for 21st Century Life and Careers	
Career Ready Practices	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.CT.2	Explain the potential benefits of collaborating to enhance critical thinking and problem solving.
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities and utility for accomplishing a specified task.
New Jersey Student Learning Standards for Technology	
CPI #	**Cumulative Progress Indicator (CPI)**
8.1.12.CS.2	Model interactions between application software, system software, and hardware.
8.1.12.CS.3	Compare the functions of application software, system software, and hardware.
8.1.12.CS.4	Develop guidelines that convey systematic troubleshooting strategies that others can use to identify and fix errors.
Next Generation Science Standards (NGSS)	
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
Instructional Focus	
Unit Enduring Understandings	
● A computing system involves interaction among the user, hardware, application software, and system software. ● Successful troubleshooting of complex problems involves multiple approaches including research, analysis, reflection, interaction with peers, and drawing on past experiences. ● Digital tools differ in features, capacities, and styles. Knowledge of different digital tools is helpful in selecting the best tool for a given task.	
Unit Essential Questions	

- What are the parts of a robot?
- What are the necessary mechanical components needed to build a robot?
- What are the necessary electrical elements needed to build a build?
- What tools and machines are best utilized in the manufacturing of mechanical components?
- What is the relationship between power, steering, and motion?
- How does a designer or engineer successfully represent ideas using parametric modeling?
- How does one evaluate 3D design in terms of cost effectiveness and product suitability?

Objectives

Students will know:

- Robots are a combination of hardware and software that interact together to perform a task.
- The base parts and components needed to create a robot.
- The tools, machines, and resources best utilized for robotic construction.

Students will be able to:

- Assemble components to develop a working mechanical system.
- Utilize CAD as a means of planning and designing a mechanical system.
- Utilize technological tools and equipment properly and safely to create products and systems.
- Operate a variety of electrical components and use them in conjunction with mechanical elements.
- Use a variety of machining processes to develop custom parts needed for the development of a product.
- Interpret a 3D object in a virtual environment.
- Create and save design files in appropriate formats for desired production outcomes.

Evidence of Learning

Assessment

Common Assessment 2.1

Competencies for 21st Century Learners

x	Collaborative Team Member	x	Effective Communicator
x	Globally Aware, Active, & Responsible Student/Citizen		Information Literate Researcher
x	Innovative & Practical Problem Solver		Self-Directed Learner

Resources

- VEX YouTube Channel - https://www.youtube.com/c/VEXRoboticsInc/videos
- VEX Robotics with Autodesk Fusion 360 - https://www.autodesk.com/education/competitions-and-events/vex/recommended-software

Unit 3: Robotic Control Systems	
Content Area: Engineering	
Course & Grade Level: Robotics Engineering Grades 9-12	
Summary and Rationale	
While some robots require a human operator to carry out tasks, robots can also be engineered to perform autonomous behaviors based on environmental feedback. In this unit, students will learn how to create robotic systems that do not act strictly under human control. The incorporation of devices such as sensors and scanners allow a robot to collect data about its surroundings. This in turn allows robots to carry out certain functions or commands without operator assistance when certain conditions have been met. This unit will introduce students to the principles of robotic programming and situations in which they will be necessary. Students will engage in creating semi-autonomous robots through intelligent coding and innovative design.	
Recommended Pacing	
40 days	
New Jersey Student Learning Standards for 21st Century Life and Careers	
Career Ready Practices	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.CI.1	Demonstrate the ability to reflect, analyze and use creative skills and ideas.
9.4.12.CT.1	Identify problem-solving strategies used in the development of an innovative product or practice.
9.4.12.CT.5	Participate in online strategy and planning sessions for course-based, school-based or other projects and determine the strategies that contribute to effective outcomes.
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities and utility for accomplishing a specified task
New Jersey Student Learning Standards for Technology	
CPI #	**Cumulative Progress Indicator (CPI)**
8.2.12.ED.1	Use research to create a product or system that addresses a problem and make modifications based on input from potential consumers.
8.2.12.ED.5	Evaluate the effectiveness of a product or system based on factors that are related to its requirements, specifications, and constraints (e.g., safety, reliability, economic considerations, quality control, environmental concerns, manufacturability, maintenance and repair, ergonomics).
8.2.12.ED.6	Analyze the effects of changing resources when designing a specific product or system (e.g., materials, energy, tools, capital, labor).
8.2.12.NT.2:	Redesign an existing product to improve form or function.
Next Generation Science Standards (NGSS)	
HS-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
Instructional Focus	
Unit Enduring Understandings	
● With a growth mindset, failure is an important part of success. ● Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed. ● Digital tools differ in features, capacities, and styles. Knowledge of different digital tools is helpful in selecting the best tool for a given task.	

- Engineering design is a complex process in which creative steps are embedded in content knowledge, research, and analysis that can be used to address local and global problems.
- Engineering design evaluation, a process for determining how well a solution meets requirements, involves systematic comparisons between requirements, specifications, and constraints.
- Engineers use science, mathematics, and other disciplines to improve technology. Increased collaboration among engineers, scientists and mathematicians can improve their work and designs.
- Technology, product or system redesign can be more difficult than the original design.

Unit Essential Questions

- What is the cause and effect relationship between software and hardware?
- How do robotic systems collect, analyze and interpret data?
- How can servos be integrated into robotics systems for precise control and operation?
- How do different types of sensors allow robots to work in a variety of environments?
- How are robot sensors similar to human senses?
- How do actuators and effectors allow a robot to manipulate the objects around it to accomplish a task?
- How is mathematical data collected by sensors translated into commands and actions that a robot can follow?

Objectives

Students will know:

- Actuators and effectors allow a robot to manipulate the objects around it to accomplish different tasks.
- Robots can interpret conditions and collect data regarding light, distance, temperature color and touch
- A robot can be coded to modify its behavior based on data received from sensors

Students will be able to:

- Build a robot that demonstrates the concepts of range, precision and accuracy
- Program robotic systems to carry our semi-autonomous tasks.
- Utilize servo and stepper motors in order to develop a robotics system with precision control and operation.
- Incorporate a variety of different sensor systems that will allow robots to collect data for interpretation.

Evidence of Learning

Assessment

Common Assessment 3.1

Competencies for 21st Century Learners

X	Collaborative Team Member	X	Effective Communicator
	Globally Aware, Active, & Responsible Student/Citizen	X	Information Literate Researcher
X	Innovative & Practical Problem Solver	X	Self-Directed Learner

Resources

- https://renegaderobotics.org
- VEX Compatible Sensors - https://www.vexrobotics.com/catalogsearch/result/?q=sensor#q=sensor&idx=vex_magento_vexrobotics_products&is_v=1
- Intro to Programming VEX - https://www.cmu.edu/roboticsacademy/roboticscurriculum/VEX%20Curriculum/IQ%20-%20Intro%20to%20Programming.html

Unit 4: Advanced Robotic Controls	
Content Area: Engineering	
Course & Grade Level: Robotics Engineering Grades 9-12	
Summary and Rationale	
This unit is an expansion of the previous one. Students will continue to program robotic systems to carry out actions based on certain conditions. The goal will be to create devices that do not require any human operation or intervention and are capable of performing autonomously. This is also known as Artificial Intelligence (AI). AI deals broadly with the goal of automating decision making for complex tasks. AI has increasingly become a subject of ethical dispute in the STEM community. This unit will also explore that debate.	
Recommended Pacing	
40 days	
New Jersey Student Learning Standards for 21st Century Life and Careers	
Career Ready Practices	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.CI.1	Demonstrate the ability to reflect, analyze and use creative skills and ideas.
9.4.12.CT.1	Identify problem-solving strategies used in the development of an innovative product or practice.
9.4.12.CT.5	Participate in online strategy and planning sessions for course-based, school-based or other projects and determine the strategies that contribute to effective outcomes.
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities and utility for accomplishing a specified task.
9.4.12.IML.7	Develop an argument to support a claim regarding a current workplace or societal ethical issues such as climate change.
New Jersey Student Learning Standards for Technology	
CPI #	**Cumulative Progress Indicator (CPI)**
8.1.12.AP.2	Create generalized computational solutions using collections instead of repeatedly using simple variables.
8.1.12.AP.3	Select and combine control structures for a specific application based upon performance and readability, and identify trade-offs to justify the choice.
8.1.12.AP.6:	Create artifacts by using procedures within a program, combinations of data and procedures, or independent but interrelated programs
Next Generation Science Standards (NGSS)	
HS-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
Instructional Focus	
Unit Enduring Understandings	
● Programmers choose data structures to manage program complexity based on functionality, storage, and performance trade-offs.	

- Trade-offs related to implementation, readability, and program performance are considered when selecting and combining
- Complex programs are designed as systems of interacting modules, each with a specific role, coordinating for a common overall purpose. Modules allow for better management of complex tasks.
- Accurate information may help in making valuable and ethical choices.

Unit Essential Questions

- What is Artificial Intelligence (AI)?
- How is AI utilized in our modern society?
- What are the benefits and risks of AI?
- Why is there an ethical debate regarding AI?
- How can AI be utilized to enhance a robotics system and make it more efficient?
- What is an algorithm and how are they utilized in the development of an AI?

Objectives

Students will know:

- The history of AI and its place in modern society.
- How robots can function and operate without any human intervention.
- What human beings hope to achieve with AI.
- Like all technology, AI has risks and benefits which need to be carefully analyzed.

Students will be able to:

- Utilize their knowledge of sensors, motors, and mechanical design to develop and program an autonomous robot..
- Write a custom algorithm that will allow a robot to carry out a task without human assistance.
- Investigate the ethics of AI and develop their own opinions on the topic.

Evidence of Learning

Assessment

Common Assessment 4.1

Competencies for 21st Century Learners

x	Collaborative Team Member	x	Effective Communicator
x	Globally Aware, Active, & Responsible Student/Citizen	x	Information Literate Researcher
x	Innovative & Practical Problem Solver	x	Self-Directed Learner

Resources

- VEX AI - https://www.vex.com/vex-ai
- https://vexwiki.org/start
- See Unit 3 Resources

Unit 5: Robotics Capstone Project	
Content Area: Engineering	
Course & Grade Level: Robotics Engineering Grades 9-12	
Summary and Rationale	
This unit is intended to be a culminated effort and demonstration of the material learned throughout the course. The Robotics Capstone Project allows students to follow the design process to develop a solution to a technological problem. In this instance, students will be tasked with the development of a robotics system of their own design that helps meet a real-world challenge or need. This will include product research, brainstorming, modeling, prototyping, testing and evaluation. Students will provide their technological experience in robotics from conception to completion through the design, development, construction, and testing of their products.	
Recommended Pacing	
30 days	
New Jersey Student Learning Standards for 21st Century Life and Careers	
Career Ready Practices	
CPI #	**Cumulative Progress Indicator (CPI)**
9.4.12.CI.1	Demonstrate the ability to reflect, analyze and use creative skills and ideas.
9.4.12.CT.1	Identify problem-solving strategies used in the development of an innovative product or practice.
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities and utility for accomplishing a specified task
9.4.12.IML.3	Analyze data using tools and models to make valid and reliable claims, or to determine optimal design solutions.
New Jersey Student Learning Standards for Technology	
CPI #	**Cumulative Progress Indicator (CPI)**
8.2.12.ED.1:	8.2.12.ED.1: Use research to design and create a product or system that addresses a problem and make modifications based on input from potential consumers.
8.2.12.ED.2	Create scaled engineering drawings for a new product or system and make modification to increase optimization based on feedback.
8.2.12.ED.3	Evaluate several models of the same type of product and make recommendations for a new design based on a cost benefit analysis.
8.2.12.ED.4	Design a product or system that addresses a global problem and document decisions made based on research, constraints, trade-offs, and aesthetic and ethical considerations and share this information with an appropriate audience.
8.2.12.ED.5	Evaluate the effectiveness of a product or system based on factors that are related to its requirements, specifications, and constraints (e.g., safety, reliability, economic considerations, quality control, environmental concerns, manufacturability, maintenance and repair, ergonomics).

8.1.12.AP.4 :	Design and iteratively develop computational artifacts for practical intent, personal expression, or to address a societal issue.
8.1.12.AP.7 :	Collaboratively design and develop programs and artifacts for broad audiences by incorporating feedback from users.

Next Generation Science Standards		
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts	
HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	
HS-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	

Instructional Focus

Unit Enduring Understandings

- Engineering design is a complex process in which creativity, content knowledge, research, and analysis are used to address local and global problems.
- Decisions on trade-offs involve systematic comparisons of all costs and benefits, and final steps that may involve redesigning for optimization.
- Engineering design evaluation, a process for determining how well a solution meets requirements, involves systematic comparisons between requirements, specifications, and constraints.
- With a growth mindset, failure is an important part of success.
- Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed.
- Digital tools differ in features, capacities, and styles. Knowledge of different digital tools is helpful in selecting the best tool for a given task.
- Digital tools such as artificial intelligence, image enhancement and analysis, and sophisticated computer modeling and simulation create new types of information that may have profound effects on society. These new types of information must be evaluated carefully.

Unit Essential Questions

- What is the significance/importance of the project you wish to undertake?
- What kinds of technical expertise will you need and/or develop as a result of undertaking this project?
- What are the specifications/limitations of this project?
- How would you improve upon your design given the opportunity for redesign?

Objectives

Students will know:

- How to address a problem using robotics technology and the design process.
- Integrate different fields of engineering in conjunction with robotics.
- Incorporate math and science principles in relation to robotics and STEM.

- How to incorporate robotic systems to meet the changing needs of society.

Students will be able to:

- Research, identify, and evaluate a design challenge to solve a real-world problem.
- Use the design process to solve a problem by developing a system of hardware and software.
- Work collaboratively to build and program a robotic system.
- Design and construct working CAD models..
- Troubleshoot and evaluate technical difficulties as the result of the design process.

Evidence of Learning

Assessment

Common Assessment 5.1

Competencies for 21st Century Learners

x	Collaborative Team Member	x	Effective Communicator
x	Globally Aware, Active, & Responsible Student/Citizen	x	Information Literate Researcher
x	Innovative & Practical Problem Solver	x	Self-Directed Learner

Resources

- See Units 1-4 Resources