Vex Protobot Plus Kit Curriculum Guide Index

The following syllabus is designed for use as a two plus semester course

INTRODUCTION & VEX PARTS NEEDED

This index is divided into five sections: Standards, Curriculum Organization, Introduction to VEX robotics, Introduction to Robotics Engineering, and Robotics Labs. Each of the titles in the index is a hyperlink that will take you to that specific lesson in the curriculum.

STANDARDS

Curriculum Organization

Introduction to VEX Robotics System

Introduction to Robotics Engineering

Robotics Labs

Robotics Labs cont.

How Robotics Aligns with Standards

Information Addressing how this Robotics Curriculum Addresses Content Standards

This section describes how robotics as a content area aligns with National Science, Mathematics, and Technology Standards. Below you will see the format that we are using to align the standard and how robotics can align with the standard.

Standard	**Robotics Link**
On the left is a description of the standard or particular point of the standard that is addressed through robotics.	*On the right* is a description of how robotics in general and this curriculum in particular addresses this standard.

Science Standards Addressed

From the National Science Education Standards (NSES)

Systems, Order and Organization

The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once. A system is an organized group of related objects or components that form a whole. The goal of this standard is to think and analyze in terms of systems. Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Prediction is the use of knowledge to identify and explain observation, or changes, in advance. The use of mathematics allows for greater or lesser certainty of predictions. Order is the behavior of units of matter, objects, organisms or events in the	Robots are excellent examples of systems, with many heterogeneous components interacting in organized, methodical ways to achieve results as a whole that they could not have achieved separately. Examples include: • Navigation systems (e.g. sensor tells the robot where it is, programmable controller tells the robot how to interpret this information, motors move in order to achieve the desired result) • Sensing systems (electrical, mechanical, and programming elements of a sensor) • Power & transmission systems (motor, axle, gear, wheel) • Manipulator systems • Lifting systems, vision systems, etc. Each system can be broken down into subsystems.

universe – can be described mathematically. Types and levels of organization provide useful ways of thinking about the world	Robotics technology is built upon a series of behaviors that can be measured mathematically and are understandable and predictable. There are many examples that are easy for students to manipulate and understand: • Gears and mechanical advantage • Sensors and electronic control • Wheel diameter and its effect on distance traveled • Rotation sensor readings and robot path planning

Evidence, Models and Explanation

Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations and computer simulations. Scientific explanations incorporate existing scientific knowledge and new evidence into logical statements. Terms like “hypothesis,” “model,” “law,” “theory,” and “paradigm” are used to describe various scientific explanations.	The investigations included in this curriculum allow students to collect evidence to investigate scientific principles. Robots physically demonstrate many scientific concepts to make them more clear and understandable. Examples include: • Electronics and basic circuitry, which can be demonstrated using touch sensors and the VEX power supply • Gear trains, which demonstrate the ability to mathematically predict mechanical advantage and speed. • Light sensors, which can detect infrared as well as visible light

Constancy, Change and Measurement

Although most things are in the process of becoming different – changing – some properties of objects and processes are characterized by constancy; the speed of light, the charge of an electron, the total mass plus energy of the universe. Energy can be transmitted and matter can be changed. Nevertheless, when measured, the sum of energy and matter in the system, and, by extension, the universe, remains the same. Mathematics is essential for accurately measuring change. Different systems of measurement are used for different purposes. Scale includes understanding that different characteristics, properties, or relationships with a system might change as its dimensions are increased or decreased. Rate involves comparing one measured quantity with another measured quantity, for example, 60 meters per second.	Robots rely on the use of many innate constants in their basic operation. Ultrasonic sensors, for instance, calculate distance based around an assumed value for the speed of sound. In calculating the distance a robot travels per spin of its motor, fundamental mathematical relationships govern the elements of change and constancy between the different factors involved. For example, the ratio between the diameter and circumference of the wheel is constant ($C=\pi d$). On the other hand, a robot doesn't always need to use the same wheels – they can change – yet, no matter what the size of the wheel, the distance traveled per turn of the wheel remains proportional. Measurement is fundamental to all aspects of robotics, from matching dimensions of parts to ensure that they can connect properly, to measuring how far your robot went, to measuring how well a prediction matched a result.

Evolution and Equilibrium

Evolution is a series of changes, sometimes gradual and sporadic, that accounts for the present form and function of objects, natural systems and designed systems. The general idea of evolution is that the present arises from materials and forms of the past. Equilibrium is a physical state in which forces and changes occur in opposite and off-setting directions. For example, opposite forces are of the same magnitude, or off-setting changes occur at equal rates.	Every robot design has a story. As they build and modify their robot designs, students can trace the evolution of their creation as they adapt it in different ways that allow it to complete different tasks, building upon lessons learned from their previous designs. Equilibrium appears in many different forms as a design factor that students will encounter in designing their robots. For example, a robot's top speed is an equilibrium point between the physical force of friction and the force generated by the motor.

Form and Function

Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world.	When designing robots, form always follows function. Whether the design decision involves using large versus small wheels, making the motor power high versus low, or selecting the sensing device the robot will use, all decisions are based on what the robot is expected to do: its function. All of these decisions will affect the final shape of the robot: its form.

Science as Inquiry – Content Standard "A"

As a result of activities in all grades, all students should develop: • Abilities necessary to do scientific inquiry • Understanding about scientific inquiry Students should be engaged in activities that: • Begin with a question • Allow them to perform an investigation • Gather evidence • Formulate an answer to the original question • Communicate the investigative process and results	The guided investigations in Robotics Engineering are targeted at specific relevant questions about robotics technologies and concepts that lead to rich exploratory experiences. Some investigations focus on specific portions of the inquiry process, such as evidence-gathering or hypothesis evaluation. Others begin with a question and seek an answer using general inquiry processes. Explanation and evaluation are primary abilities applied in answering questions, not simply calculations or summarization.

Physical Science – Content Standard "B"

As a result of activities in all grades, all students should develop an understanding of: • Properties and changes of properties in matter • Motions and forces • Transfer of energy By using simple objects, such as rolling balls and mechanical toys, students can move from qualitative to quantitative descriptions of moving objects and begin to describe the forces acting on the objects. Understanding of energy will include light, heat, sound, electricity, magnetism, and the motion of objects.	Robotics is able to demonstrate many applied physical concepts. Here are a few examples: • Mechanical advantage (gears) • Basic circuitry (sensor operation) • Digital and analog electronics (sensors) • Light (lamp, light sensor) • Sound (ultrasonic, sound sensors) • Speed (motors) • Friction (robot movement) Quantitative measurement is a staple of all investigations.

Science and Technology – Content Standard "E"

As a result of activities in all grades, all students should develop: • Abilities in technological design • Understandings about science and technology Students should begin to differentiate between science and technology. In the middle school years, scientific investigations can be completed by activities in which the purpose is to meet a human need, solve a problem, or develop a product rather than explore ideas about the natural world.	Robotics is the premier example of the marriage of science and technology, especially as related to the solving of problems or human needs. Every investigation students conduct with the robot is motivated by the need to advance the performance of the robot in order to meet performance criteria, connecting the "need to know" with the "ability to do".

Mathematics Standards Addressed

From the National Council of Teachers of Mathematics (NCTM) Standards

Numbers and Operations

• Understand numbers, ways of representing number, relationships among numbers and number systems. • Understand meaning of operations and how they relate to one another. • Compute fluently and make reasonable estimates.	Robotics uses numbers and operations in nearly all lessons, for example: • Calculating distance with rotational sensors (equations, equalities) • Gears, gear ratios and speed (ratios and proportions) • Light sensors and threshold (inequalities) • Wheel circumference, radius and diameter (geometric relationships)

Algebra

• Represent and analyze mathematical situations and structures using algebraic symbols. • Use mathematical models to represent and understand qualitative relationships. • Analyze change in various contexts.	Robotics lessons that involve algebra include the following: • Conditional statements (inequalities) • Programming sensors and thresholds (inequalities) • Measuring turns (equalities, solving equations) • Gears and speed (ratios, direct and indirect proportionality) • Passing parameters in functions

Geometry

• Precisely describe, classify, and understand relationships among types of two and three-dimensional objects using their defining properties. • Specify location and describe spatial relationships using coordinate geometry and other representational systems.	Robotics situations involving geometry include: • Wheel rotations and circumference (diameter, circumference) • Identifying locations in order to program a robot to move from point to point (connected path segments) • Interlocking gears and gear ratios (discrete combinations of radii)

Measurement

• Understand measurable attributes of objects and the units, systems, and processes of measurement. • Apply appropriate techniques, tools and formulas to determine measurements.	Understanding the significance and meaning of measurements are central to the understanding of robotics: • Distance the robot travels (linear measurement, meter stick) • Amount a motor turns (angular measurement) • Directional change of the robot (angular measurement, protractor) • Speed of the robot (rate measurement, meter stick, built-in timer) • Physical quantities measured by sensors (touch, sound, light, distance) • Detectable region of a sensor (ultrasonic sensor, meter stick, 2D graph paper)

Problem Solving

• Build new mathematical knowledge through problem solving. • Solve problems that arise in mathematics and other contexts. • Apply and adapt a variety of appropriate strategies to solve problems. • Monitor and reflect on the process of problem solving.	In the lessons, there are both guided and open-ended design problems that involve designing, building, and programming needed to create autonomous robots. • How do I get a robot to move a certain distance? (solved through measurement and the verification and use of a proportionality relationship) • What does the sound sensor measure? (solved by graphing the sensor readings with tones of varying volume and pitch, then seeing which one indicated an orderly relationship)

Reasoning and Proof

• Recognize reasoning and proof as fundamental aspects of mathematics. • Make and investigate mathematical conjectures. • Develop and evaluate mathematical arguments and proofs. • Select and use various types of reasoning and methods of proof.	Reasoning in robotics comes in many different forms, including the following: • Experimental reasoning, proof using measurements and physical evidence (Wheels and Distance) • Reasoning using equations, proof by solving (Measured Turns) • Reasoning about graphs, proof by observing trends (Frequency and Amplitude)

Communications

• Organize and consolidate their mathematical thinking through communications. • Communicate their mathematical thinking coherently and clearly to peers, teachers, and others. • Use the language of mathematics to express mathematical ideas precisely.	Each Activity and Investigation includes worksheet questions that require the student to reflect on what they have accomplished or experienced, and describe it or some aspect of it in their own words to someone else. Emphasis is placed upon explaining reasoning in addition to showing calculations. The Engineering Design Challenge includes opportunities for students to communicate with their peers and teachers what they have learned and accomplished.

Connections

• Recognize and use connections among mathematical ideas. • Understand how mathematical ideas interconnect and build on one another to produce a coherent whole. • Recognize and apply mathematics in contexts outside of mathematics.	One of the strongest features of using robotics to teach math, science, engineering, technology and communications is its ability to make links between multiple disciplines. Students are able to take what they know and connect it to what they are learning, synthesizing new knowledge as they continue.

Technology Standards Addressed

From the International Technology Education Association (ITEA) Standards

The Nature of Technology

1. Students will develop an understanding of the characteristics and scope of technology. 2. Students will develop an understanding of the core concepts of technology. 3. Students will develop and understanding of the relationships among technologies and the connections between technology and other fields of study.	All robotics activities provide excellent hands-on exposure to technology in use and development. • Robotics activities feature linkages to advanced technology that allow students to connect their designs to real-world needs and solutions • Successful robot operation revolves around the application of systems concepts to make sensors, actuators, and other components work together • Design processes take into account goals, resources, and trade-off factors to achieve optimal results • Technology exists in proper context alongside applications in science, math, and engineering • Several different technologies (e.g. desktop computer, USB/Bluetooth peripheral interface, mobile robotics controller, electromechanical sensors and actuators) are routinely used together in the operation of the VEX robot system, and all are necessary for it to work

Technology and Society

6. Students will develop an understanding of the role of society in the development and use of technology.	Robotics Engineering Design Challenges are linked to real world problems that use similar technologies to accomplish tasks that fulfill a social and/or economic need in the real world. For example: • For instance the orchard project and the automated workcell simulate problems that are being worked on in today's world. Some robot activities focus specifically on Human-Robot Interaction (HRI), an emerging field dealing specifically with psychological and design issues relating to the use of robots in human environments.

Design

8. Students will develop an understanding of the attributes of design 9. Students will develop and understanding of engineering design 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem-solving.	Students gain first-hand experience with developing a functional robotic system in many activities, including: • The Orchard Project • The Hot Dog Maker • Automated Work Cell

Abilities for a Technological World

11. Students will develop the ability to apply the design process 12. Students will develop the ability to use and maintain technological products and systems	Students will apply design processes continually while working with and developing the robot. Here are some basic examples: • VEX competitions In the course of working with the robot, students will be responsible for the maintenance of their robots: • Mechanical soundness (the robot needs to be kept in good enough condition to perform its tasks daily) • Organizing information (students must keep good enough records to know how to use systems they initially designed days or weeks earlier) • Troubleshooting (robots have problems–often–and students must be able to identify and solve these issues as they arise) Students will work with many important technologies as part of the operation of the VEX system: • VEX electronic microcontrollers • Desktop/laptop computer and software (VEX Programming Software, word processor for write ups, spreadsheets for data graphs) • Peripheral interfaces (USB or Bluetooth wireless) • Electromechanical systems (touch, light, rotation, sound, ultrasonic sensors) • Electromechanical actuators (Interactive Servo Motors)

The Designed World

16. Students will develop an understanding of and be able to select and use energy and power technologies 17. Students will develop an understanding of and be able to select and use information and communications technologies 18. Students will develop an understanding of and be able to select and use transportation technologies 19. Students will develop an understanding of and be able to select and use manufacturing technologies	The VEX robot itself is an excellent example and integrator of many different designed technologies working together as a coordinated system. • Power sources (battery technologies – rechargeable Lithium-Ion vs. disposable alkaline) • Vehicle systems (all the robot's systems must work together in order to make it mobile, a viable platform for transportation of goods or as a platform to perform other work) • Manufacturing and prototyping (robot must be built and modified using appropriate materials, plans and tools) • Structural soundness and stability concepts are integral to the design of the robot's physical form. • Communication between system components (desktop to VEX, sensors to VEX, VEX to motors) • Communication technologies (USB vs. Bluetooth)

Reading, Writing, Listening, Presenting Connections

Academic Concept Integration Opportunities While Working with Robots

Communications skills applied when working with Robots

Engineering does not exist in a vacuum; it is highly interdisciplinary and highly social. Teamwork is a central foundation of Engineering, and communication is essential to smooth functioning of any engineering team. Students will find that highly developed communication skills are an absolute necessity for success.

Situation or Activity	Communications Concepts Applied
Maintain Engineering Design Notebook	Organization of information
Reach consensus on which of several student-proposed designs the team will build	Teamwork and group communication skills • Running and participating in meetings • Building consensus
Compose a compelling proposal to convince a (virtual) sponsor that their robot's development is worth funding	Formal persuasive composition Integrate self-conducted research into a piece that is not purely expositive Technical writing • Explaining technical decisions and implementations to an audience that is not necessarily technically inclined
Document the team's progress and accomplishments daily	Documentation and accounting for time, resources, and progress
Undergo review and integrate feedback from experts	Review and feedback processes Learning to accept and respond to criticism
Choose from a variety of representations to best illustrate and communicate a point	Use many different formats of both technical and nontechnical information, across different media: • Graphs • Charts • Tables/Matrices • Photographs • Sketches • Timelines • PERT and Gantt Charts • Multimedia presentation • Text

Communications Continued

Various interim deliverables intended for either internal or external use	Examples • Descriptive/Explanatory Composition: Describe behaviors, verbalize the functionality of parts of the program • Expository writing: How the machine works • Persuasive/Explanatory Composition: Justify a design choice • Record data in a table, evaluation of methods, predictions, describing robot behavior, describing a proportional relationship • Verbalize troubleshooting processes, analyzing and describing an unexpected situation or observation • Describe a design concept • Compare/contrast design choices, document and record steps, explain why the group took a certain approach • Research, examine and evaluate real-world robot applications • Describe a complex programming concept • Develop a marketing plan for a robot technology
Programming the robot	Communicate instructions explicitly to a robot using a “foreign” language

Curriculum Organization

The next four pages are designed to give you a quick overview of what is included in the curriculum. This section includes quick links designed to quickly allow you to find a particular section. The curriculum is divided into seven sections:

Introduction to Robotics
Safety
Project Management
Planning Your Project
Robotics Lessons
Programming Lessons
Engineering Activities
And Resources

Intro to Safety, Project Management, and Project Planning are common threads that will be revisited in every lesson.

- Safety is the first lesson presented in the curriculum and needs to be emphasized by the teacher every day of class.
- Project Management - Every major industry needs project managers; the skill sets developed by these lessons are fundamental skills that all future workers will need. Students will get better at managing projects if they are given the responsibility to lead a project and held responsible to produce the documentation that demonstrates that they managed the project in an orderly manner.
- The Planning Your Project section is designed to give students an introduction to technical sketching, drawing conventions, the importance of precision, suggestions on how to make things move, and a library of VEX parametric solid modeling parts that can be used by students using SolidWorks or Autodesk.

Intro to Robotic Lessons - The Robotics Lessons units are designed as science-like labs where students apply investigative procedures to find the answers to questions that roboticist need to have answered in many robotic projects.

- How are signals sent? – Students learn the behaviors of radio transmitters and receivers in a teleoperated system.
- How much current will my robot draw? – Students gain an understanding of the relationship between robot work and the current that the motors draw.
- How much will a motor lift? – Students learn how to measure stall torque for motors and determine the point where the clutch will disengage without causing damage to the motors.
- How do gear ratios affect speed and torque? – Students learn the relationships between gear ratios, torque and speed.
- Does wheel size matter? – Students quickly find that even simple choices like wheel size have significant consequences on robot performance.
- Can I make my own sensor? - Students explore how potentiometers work and how they can be integrated into a robotic system.
- Does wheel size matter using encoders? - Students will need the programming kit as well as a set of encoders for this investigation.
- Mechanics – The mechanics lessons are new in the VEX 2.0 curriculum. These lessons were developed in a partnership with California University of Pennsylvania.

They include lessons on: force, torque, center of mass, statics, inertia, kinematics, dynamics, and machines. These lessons have a very high level of mathematics and will require academic rigor.

Intro to Programming Lessons - The Programming Lessons section of the curriculum consists of two parts: Programming the Radio Controller, and Programming the VEX Controller Using ROBOTC.

Note: students can have a very successful experience using the VEX Radio Controller without any customization of the radio control; the purpose of this set of labs is to teach the student how to optimize their robot's performance.

Programming the Radio Controller – In this section student will learn that the VEX Radio Controller is a very sophisticated electronic device that allows many opportunities to optimize control of the robot through the remote control unit. Each of the lessons comes with a video that explains the function the students will explore and a worksheet that they will complete, written in a lab format. The student will learn how to:

- Program the configuration menu on the transmitter
- Program the motor direction via the remote control
- Program the scale menu to control the relationship between the joystick position and motor control
- Program the edit points menu to fine-tune the joystick control
- Program the trim menu of the radio controller and the trim channel buttons to gain greater control with the transmitter
- Program the P Mix feature of the radio to control multiple motors with one joystick
- Program the drive menu of the radio controller to enable new control modes
- Use the jumpers to alter the behavior of the robot

Programming the VEX Controller Using ROBOTC – This section of the curriculum is designed to take new programmers and lead them step by step into the world of C-programming. ROBOTC gives the roboticist the largest amount of control of any language available to the VEX controller. ROBOTC uses an industry standard C programming language and is the language that *all* teachers should use in their classrooms. The programming training tool is divided into five sections:

- Setup – In this section students will learn how to build their robot, what firmware is, and how to download the firmware.
- Fundamentals – In this section students will learn how to think about programming as well as the fundamentals of programming in ROBOTC.
- Movement – In this section students will begin to program their robots to solve the Labyrinth Robotics Engineering Challenge. They will learn how to control their robot's direction and speed autonomously.
- Radio Control – In the radio control section students will learn how to map their radio control buttons and joysticks using the ROBOTC software to solve the Minefield Engineering Design Problem using radio control; they will also learn how timers work in ROBOTC.
- Sensing In the sensing section the students will learn how to use feedback from sensors to develop an autonomous program that will enable them to solve the Minefield Engineering Design Problem.

Click Index of the lessons in the ROBOTC for a complete index of programming resources.

Each section of the curriculum consists of a series of videos, which are designed to introduce the topic studied, as well as a complementary PDF which aligns with the videos. The PDFs are in both a unit format which can be found on each unit page, or the whole document can be printed and used as a text. Each lesson contains a set of robotic programming challenges as well as extension activities designed to challenge students to apply their newfound programming skill. This portion of the curriculum is between 9 -12 weeks long moving at a good pace.

Intro to Engineering Activities - The Engineering Activities portion of the curriculum is divided into five engineering activities:

- The Rube Goldberg Challenge - This design challenge has two parts: a typical Rube Goldberg Challenge and then a variation of the challenge which allows students to use a combination of remote control and autonomy to create a perpetual motion machine.
- The Orchard Challenge – The Orchard challenge consists of multiple parts:
    - Introduction – students take the role of consultant developers at an automation company who are investigating whether their client in the agricultural business should invest in developing automated systems to spray pesticides.
    - Phase one – Students will develop a robot in four different iterations that will be able to navigate the orchard successfully. Phase one is remote control.
    - Phase two – Basic autonomy driving straight and turning
    - Phase three – Sensor autonomy using feedback loops
    - Phase four – Enhanced Autonomy demonstrating obstacle detection as well as shared control.
- The Hot Dog Maker Design Challenge - In this challenge students are challenged to develop an automated system using the VEX Design System to automate a hot dog shop.
- The Automated Work Cell – The automated work cell combines the advanced features of the VEX system to complete a system that incorporates relays, PWMs, pneumatics, and other technologies available to the team. This is an advanced engineering design challenge.
- VEX Competitions – provides a link to Carnegie Mellon's Robotics Academy where there are links to many VEX robotics competitions, some that can be implemented by teachers in their classroom and others that are both regional and national in nature.

Intro to the VEX Resources Section - And last, but certainly not least, is the VEX Resources section. This section is divided into four areas: electronics, mechanics, basic electricity, and advanced. Each section consists of multiple resources that teachers new to VEX will find very helpful if they are using VEX in competitions or using VEX to make cross discipline connections.

Electronics

- Crimping – In this lesson the student will learn the general process of crimping by following a step by step procedure to crimp leads to a touch sensor.

- Soldering – In this lesson the student will learn how to solder by soldering leads to a touch sensor.
- Multimeter – In this lesson the student will learn to use a multimeter to test for continuity and voltage.
- Home Brew Sensors – In this set of lessons students will learn how to build an analog sensor (potentiometer) and a digital sensor (touch sensor).

Mechanics
- Fasteners – In this lesson the student will learn how to identify the different types of fasteners: screws, nuts, bolts, and washers.
- Tapping – In this lesson the student will learn how to tap. They will be able to identify and select the proper tap and drill, and to drill and tap a hole.
- Hand Tool Recognition – In this lesson students will learn the names of 40 basic hand tools.

Basic Electricity
- Lemon Battery – In this lesson students will explore the nature of batteries by constructing their own battery out of lemons and metal strips.
- DC Circuits – Consists of three electrical concepts:
    - Kirchhoff's Voltage Law
    - Ohm's Law
    - Current Flow
- Simple Schematics – A student handout that explains what a schematic is, gives rules on drawing schematics, and provides common electronic schematic symbols
- Electromagnetic Solenoid – In this lesson student will build a working solenoid using wire, a battery, a straw, and an iron core nail.
- Relays – In this lesson students will build a working relay designed to reinforce what relays are and how they control current flow in circuits.
- DC Motor – In this lesson students build a simple DC motor using wire, a Styrofoam cup, a battery and a magnet.

Advanced Applications

Extended Testbed – The VEX controller can be used to control other electromechanical actuators using relays and PWMs. The extended testbed lesson shows students how to connect the relays and PWMs to the VEX controller.

Pneumatics – This lesson will show students how pneumatic systems are used with the VEX system.

Pulse Width Modulation – This is a short video designed to show students how they will connect a PWM to the VEX controller enabling students to build robots with motors other than the standard motor that comes with the VEX Design System.

Relays and PWMs – In this lesson students will be introduced to all of the components that they need to learn in order to use PWMs and relays to control other electromechanical systems.

VEX Teaching & Assessment Tools

Rubrics for Assessment

Assessment is such an important part of education today. Students will meet teacher's expectations if they know what they are. We've included the following rubrics for assessment that are designed to help students and teachers assess the quality of their work:

- Writing Criteria
- Rubric for Presentations
- Work Habit Evaluation
- Work Place Competencies Evaluation
- Engineering Journal Rubric
- Internal Design Review Rubric
- External Design Review Rubric
- Request for Proposal Rubric

The Engineering Journal

The Engineering Journal will be to tool that the students will use throughout the course to keep their projects organized. One of the goals of this course is to teach students how engineers' problem solve and manage projects. A good engineer/project manager schedules the project, documents the project's milestones, and documents the design process. Each student is required to keep an "Engineering Journal" for each problem worked on in this class. This will help the student to organize their class work and help the teacher to assess their work.

Each teacher will have their own expectations of what should be included in the Engineering Journal. This handout is for reference only.

Engineering Journal PDF

Glossary of Robotic Terms

Vocabulary and terminology are important parts of a student's robotics education. The VEX curriculum contains 11 pages of terms that are used in science, technology, and engineering fields.

Robotic Engineering Glossary PDF

Introduction to Robotics

Introduction Teacher Expectations

Course overview/Why study ROBOTICS *Suggested Time: two periods*

Note to the teacher: It is important for the student to know what the expectations are for the course. Appendix "A" includes introductory handouts that each student should become familiar with. These handouts cover all parts of the course from grading through course content.

Resource Materials

Engineering Journal plus **Engineering Journal Rubric**

Lockers for each student

Course Outline (to be developed by teacher)

Work Habit Evaluation Rubric

Workplace Competencies Evaluation Tool

Writing Criteria Rubric

Robotics Text (if available)

Learning Objectives

Students will be able to:

- Describe the class rules**.**
- Review the course syllabus
- Describe how grades are earned in this class.
- Describe how the **engineering design journal** will be used in this class**.**
- Describe the engineering projects that students will work on this year in class.
- Describe how **student work habits** will be evaluated.
- Describe the types of **workplace competencies** that they should strive to perfect.

Learning Activities

Students will:

- Be required to secure an engineering design journal and participate in a class discussion on how the engineering design journal will be evaluated.
- Receive a copy of:
    1. The course syllabus
    2. Intro to ROBOTICS class - how grades are earned
    3. The class rules
    4. The workplace competencies Evaluation
    5. The work habits evaluation rubric
    6. The writing criteria rubric

- Discuss how grades will be earned in this course
- Assigned a locker or some other method of storage for their projects

Procedures for Assessment

Teacher observation/classroom discussion

Check to see if students have and engineering design journal

The assessment rubrics which can be found in the **VEX curriculum**

Plan of Study

Note: Each teacher will have a different set of resources available as well as experience. This plan of study is designed as a place to begin. Teaching is a craft that takes years of practice to become an expert. You will need to modify this plan to fit your needs.

Day 1

- Welcome to robotics class
- Class rules, regulations, and expectations
  - Describe your specific class rule
    - **Work Habit Evaluation**
    - **Career Competencies**
    - Where students sit
    - Where students store their projects
    - How grades are earned
  - Describe the Student Engineering Journal
- Discuss robotic interests of students
  - Movies (iRobot, Star Wars, etc)
  - Personal Robots
  - List as many robots as the class can think of.
- Describe that this is an Engineering class, discuss what engineering is.
  - Show the '**Engineering Process**' video
- Assign students to obtain an engineering design journal for class tomorrow.

Day 2

- Review Classroom Expectations and grading.
- Check to see if students brought their engineering design journal to class.
- Handout **Definitions of Engineering** and have students pick one of the definitions and defend it.
- Have students write a description of what engineering is and give examples. Pass out the **writing rubric** so that students know how they will be evaluated.

Introduction to STEM Related Career Paths; (science, technology, engineering, mathematics) Jobs Available/Education required *Suggested Time: 2- 3 days introduction, then ongoing throughout the course*

Resource Materials

Video, "**Powering Industry**", produced by The Robotics Academy

Carnegie Mellon Robotics Institute project pages website

The **National Robotic Engineering Center** website

The **Robotics Academy** website

Learning Objectives

Students will be able to:

- Identify the ubiquitous nature of robotics and embedded systems
- Describe what a robot is.
- Describe what an embedded system is.
- Discuss the education needed for specific career choices.
- List jobs related to robotics, automation, embedded systems, and manufacturing.
- Describe various career paths for STEM careers

Learning Activities

Students will:

- Watch the introductory video "Powering Industry, rethinking training today"
- Discuss what embedded systems are, identify examples of embedded systems, and then write a student developed definition of an embedded system.
- List technologies on the board that use embedded systems
- Visit either **Carnegie Mellon's Robotics Institute** or **National Robotics Engineering Center** website and choose a robot to present to the class. Student's presentations will be evaluated according to the **presentation rubric**.
- Use the writing process to write an essay on one of the following topics:
    - Embedded systems
    - Ubiquitous nature of automation
    - STEM related careers or some other teacher selected topic

Procedures for Assessment

The Writing Criteria Rubric

Work Habit Evaluation Rubric

Engineering Journal Rubric

The Presentation Rubric

Plan of Study

Day 1

- Begin a discussion about what a robot is.
- Show the video "**Powering Industry**"
- Discuss what a system is: A system is a group of parts that work together to accomplish a task.
- Ask students to help identify what an "embedded system" is.
- Show examples of embedded systems.
- Assign students research a variety of robots. Places to go to find robotic examples include: **Carnegie Mellon's Robotics Institute** or **National Robotics Engineering Center's** website. There are many other places to look!
- Assign student to pick one robot and prepare a presentation, handout the **presentation rubric** so that students know how they will be evaluated.

Day 2-3

- Review Classroom Expectations and grading.
- Review what a robot is and how robots are made up of subsystems.
- Assign students to continue their robotic research and prepare for their presentations. These presentations can be done individually or as a team.
- Monitor student progress and offer resources as needed.

Introduction to the Software and Hardware in the lab

Suggested Time: 1 period and then ongoing

Note to the teacher: One of the goals of a quality STEM education program is to introduce students to current hardware and software applications. Achieving technological literacy is a lifelong endeavor; as soon as you think you are caught up things change! The list below may not be relevant a couple of years from now, and will require your ongoing attention.

- Parametric Solid Modeling Software
- Documentation software:
  - Word processing software
  - Photo Editing software
  - Homepage, blog, or web software
  - Video production software
  - Scheduling/project management software
- Programming software
- Classroom printing options
- Various robot hardware that demonstrates:
  - Robot autonomy
  - Robot communications
  - Embedded systems
  - Vision systems
  - Sensing systems
  - A variety of different communication channels; Bluetooth, Ethernet, Crystals…

Resource Materials

Parametric Solid Modeling Software plus tutorials

Digital/ Video Cameras

Photo/Video editing software

Microsoft Office Suite (or something compatible)

Robot Systems

Project management handouts as deemed appropriate by the instructor

Printer

Learning Objectives

Students will be able to:

Describe which software applications are available to document and manage their engineering projects.

Describe teacher expectations of engineering documentation.

By the end of the course, students should be able to competently use the software and hardware available in the class with minimal supervision from the teacher to document and manage their projects.

Read the documentation and accompanying manuals to learn how to use software and hardware that they are unfamiliar with.

Complete tasks in a timely manner.

Learning Activities

Students will:

Discuss project management and the importance of documentation in an engineering project.

Discuss what **PERT Charts** and **Gantt Charts** are.

Describe how **design reviews** work and the difference between a preliminary and detail design review.

As appropriate and in context with the project observe demonstrations of the use of the various software and hardware in the lab.

Manage projects using various hardware and software available in the lab

Take pictures using the digital/video cameras and use them in project documentation.

Use the hardware and software in the lab to complete assignments.

Procedures for Assessment

The Writing Criteria Rubric

Work Habit Evaluation Rubric

Engineering Journal Rubric

The Presentation Rubric

Plan of Study

Day 1

- Demonstrate the capabilities of the various hardware and software available in your lab either through teacher demonstration of by showcasing various student developed documents that demonstrate exceptional work.

- Prepare a demonstration of the types of robots that you will use in this class. If this is the first time that you've taught this course the then create some excitement, distribute Vex kits (or show area where students will retrieve all of the Vex parts needed) to complete a Squarebot. *Note: If you choose to do this, you need to cover safety (the very next lesson) at a high level before you begin building your robots*.

- Show students where the will store their robot, partially completed robotic items and other parts. **Suggestion:** Give students a small storage container (tray, Tupperware, bag, etc) to keep screws, washers, bolts, etc in one place in the main storage area.

- Before construction, discuss the importance of organization of parts, nuts, bolts and cleanliness of the work area. Explain there will be some sort of teacher assigned penalty assigned (point loss, loss of privileges, etc) for things left out after the period.

- As a group, explain to the class, by opening each main area on the **Overview** page, the function of each group. Provide a brief explanation of each of these areas**((Remote Control, Motor Actuators, Computer, Sensors, Structural Components, and Pneumatic Actuators)**

Safety – 5 day intro - Ongoing

Introduce during the first week of school

Safety is a concern in all industries; safe practices will be emphasized and will be a common thread throughout this curriculum.

The safety lessons that are included in the VEX curriculum set an attitude that the students will take with them for the rest of their lives. These are very important lessons.

Resources

- Safety Module taken from the VEX Curriculum

Learning Objectives

The student will be able to:

- Define what “Safety is an Attitude” means.
- Complete the “Robotics Lab Safety Inspection Sheet”.
- Identify unsafe situations in the lab, fix them, or bring them to the attention of the teacher.
- Demonstrate safe and conscientious habits when working with Robotics and Intelligent Systems.
- Pass a Safety Unit Quiz with 100% accuracy.

Learning Activities

The student will:

- Participate in a general lecture on General Lab Safety.
- Turn in completed teacher-assigned worksheets on safety.
- Participate in the lecture on Electrical Safety.

- Identify potential hazards in the lab. The class may break into groups and begin the Robotics Lab Safety Inspection Sheet.
- Participate in the lecture on Power Tools safety.
- Participate in the lecture on the safe use and handling of power tools, proper use of personal protective equipment: eye protection, ear protection, aprons, etc...
- Participate in the lecture on MSDS and chemical materials.
- Observe a soldering demonstration and participate in the lecture on Soldering safety (if applicable).
- Pass the Safety Unit Quiz with 100% accuracy.
- Present findings (as a team) about the Robotics Lab Safety Inspection Sheet.

Procedures for Assessment

- Safety Unit Quiz
- Robotics Lab Safety Inspection Sheet presentation and documentation
- Teacher observation
- Class participation
- Engineering Journal
- Work Habit Evaluation
- Work Place Competencies Evaluation

Plan of Study

Safety is a common thread that needs to be continually reinforced and woven into every lesson. The plan of study listed below is for teacher reference only. Teachers will have their own specific situations that may require a modification of the safety resources supplied with this curriculum.

Day 1

- General Lab Safety – provide a tour of the lab/facility and provide the students with a general lecture on lab procedures, lab organization, and general safety.
- Copy and distribute the General Lab Safety handout and assign students to read the handout and place it in their Engineering Journals. Students may complete additional teacher-assigned worksheets on safety.
- Break the students into groups and begin the Robotics Lab Safety Inspection Sheet. This safety survey may take students several days and their idea of what

is safe will be influenced by the remaining safety lessons that will be covered in subsequent safety lessons.

- Assign students to inspect the lab and complete the Robotics Lab Safety Inspection Sheet.

Day 2

- Discuss what “Safety is an Attitude” means to you.
- Assign safety glasses to students.
- Copy and distribute the Electrical Safety Handout and assign students to read the handout and place it into their Engineering Journals. Identify potential electrical related hazards in the lab.
- Students will continue to work on the Robotics Lab Safety Inspection Sheet due at the end of this unit.

Day 3

- Introduce students to general Power Tool Safety. Copy and distribute the Power Tool Safety Handout and assign students to read the handout and place it into their Engineering Journals. Identify potential power tool safety hazards in the lab.
- Provide a lecture on the safe use and handling of power tools, proper wear and use of safety glasses.
- Students will continue to work on the Robotics Lab Safety Inspection Sheet report due at the end of this unit.

Day 4

- Discuss Material Safety Data Sheets (MSDS) and chemical materials. Have students go to the Internet and lookup examples of material safety data sheets.
- Students will continue to work on the Robotics Lab Safety Inspection Sheet report due at the end of this unit.

Day 5

If your students will be soldering, this lesson will be appropriate.

- Copy and distribute the Soldering Safety handout and assign students to read the handout and place it into their Engineering Journals. Identify potential soldering safety hazards in the lab.

- Soldering – The class will be required to wear their safety glasses during the soldering demonstration.
- Provide a lecture/demonstration to the students about soldering.
- Students will continue to work on the Robotics Lab Safety Inspection Sheet report due at the end of this unit.

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End of Unit Culminating Activity

- Safety Unit Quiz
- Complete a one page essay describing what a “safe attitude” is.
- Present findings from the Robotics Lab Safety Inspection Sheet in whatever format the teacher assigns. Discuss the survey as a group and make safety modifications as needed.

Introduction to VEX Systems – 3 - 5 days

A system is a group of parts which accomplishes a task. Students need to learn to think in terms of systems in order to understand how complex systems and technologies work. The VEX robotics system provide a great opportunity to demonstrate systems.

Resources

VEX Robot Design System

Learning Objectives

The student will be able to:

- Identify the basic components of the VEX kit and generally describe their role in the overall robotics system; Remote Control, Motor Actuators, Computer, Sensors, Structural Components, and Pneumatic Actuators.
- Unpack the Vex kit (if required)
- Build a Testbed to test the operation of the Vex kit, or
- Build a Squarebot 2.0
- Test Squarebot to ensure that it operates correctly.

Learning Activities

The student will:

- Provide the class with an overview explanation of the VEX system using the Overview helper page.
- Participate in a lecture designed to help with component identification.
- Use the VEX helper page: What's inside the kit to help identify VEX parts.
- Unpack the VEX kit and place the parts in the proper storage containers.
- Participate in a classroom discussion on systems. Describe the VEX robot in terms of systems. Remote Control, Motor Actuators, Computer, Sensors, Structural Components, and Pneumatic Actuators.
- Build and test the hardware by building a testbed or by building Squarebot 2.0. Identify the importance of tightening the nuts and bolts on the Squarebot so it will not fall apart when it is running. Direct the class to build Squarebot 2.0; point out the possible confusion between servo motors and DC motors.

- Once construction is complete, provide an area where they may test and run their newly constructed Squarebots, and review parts and components identification.

- Homework – Have students find a complex piece of machinery and identify the sub-systems that make the machine. Students are responsible to present their findings to the class.

Procedures for Assessment

- Successfully built testbed or Squarebot 2.0
- Work habit evaluation rubric
- Classroom Observation

Plan of Study

Day 1

- Discuss general laboratory safety that pertains to your specific lab. The length of the safety discussion is relative to the amount of tools, machinery, etc you plan to use in the class. In this Scope and Sequence, there are only hand tools used…. Hack saw, hammer, pliers, shears, vices, screwdriver, Allen wrenches

- Demonstrate a pre-built **test bed** of Vex Electronics.

- Discuss the **components of the VEX electronics system** and how they work.

- Explain and demonstrate the use of the **remote control**, and use of all of the channels.

- Explain what **frequency crystals** are, and how they transmit signals between the radio and the controller. More information as well as a lab can be found at the **Remote Control Operation.**

- Instruct the class on where you keep your frequency crystals.

- Demonstrate how to insert the crystals into the **radio** and the **receiver**.
  Note: You will want to have a policy for the crystals because they are small and easy for students to misplace.

- Have students begin to learn the parts of the radio and controller.

- Explain to students classroom procedures around batteries.
  Note: You will want to have a policy for the batteries because they typically are used by multiple classes and will need to be kept charged.

- Explain where tools are kept.

Note: You will want to have a policy for the tools because students have varying degrees of responsibility and tools will be shared by multiple classes. Have a place for everything and have students place everything in its place when they finish each day.

- Assign class to begin constructing the **Squarebot**. It will take approximately 3-5 days to complete their robots.

- Begin with a warm up safety quiz relative to your lab.

Days 2 - 5

- Have students continue to construct and then test their **squarebot**.

Programming the VEX remote control – 9 to 18 days

This learning activity provides two sets of parallel lessons on remote control. The first set of lessons utilizes a simple remote control test bed, while the second set uses the Squarebot that is used throughout the programming material. Since the lesson sets are almost exactly the same, it would not be appropriate for students to complete each one. Instead, the teachers must select the set that best fits their schedule and classroom goals.

The test bed was designed to be assembled quickly. Therefore, this lesson set is best suited for teachers who have limited class time. This lesson set is also favorable for students who are less interested in construction; it gets to the material on remote control as quickly as possible. The first lesson deals with four functions on the transmitter options menu: Config, Reverse, Scale, and Drive. The second lesson deals with the remaining transmitter options: Edit Pt, Trim, and P. Mix. The third lesson deals with jumpers and manipulating the Vex controller through hardware changes. It is important to complete the lessons in the correct order, because the concepts and questions in each lesson build on those in the ones that preceded it.

Squarebot, on the other hand, takes class time to build. The Squarebot lesson set would be preferable for instructors who have more class time available. The structure of these lessons mirrors that of the test bed lessons, so it remains important to move through the lessons in the appropriate order.

There are two benefits to teaching remote control with Squarebot rather than with the test bed. First, many of the control options taught in the lesson were created specifically for a vehicular robot. At times, these options are not equally useful or engaging when applied to the test bed. Second, the Squarebot is used in many of the programming lessons, which means that the investment of time will prove useful beyond the scope of this particular lesson.

Resources

- VEX Robot Controller and Radio Transmitter.
- Batteries or rechargeable batteries plus the remote control
- Sets of individual crystals for multiple robots in the room
- Programming the Vex Remote Control Lessons

Learning Objectives

The student will be able to:

- Describe the transmitter menu options
- Restore the transmitter's default settings
- Use the VEX radio transmitter to control a robot
- Describe the relationship between transmitter channels and joystick axes

- Switch between transmitter configurations
- Use the transmitter menu to alter the Squarebot's response to joystick control
- Write a technical paper that describes how to edit the transmitter's reverse option
- Explain the difference between linear and exponential scaling
- Explain the function of the edit points option
- Explain how the edit points option can be used to correct for inherent hardware errors
- Explain how to use the transmitter's trim option
- Use the trim option to establish optimum control settings for a variety of purposes
- Use the P. Mix option to set a master channel, slave channel, and describe their relationship to each other
- Enable "arcade style" joystick controls
- Discuss the pros and cons of both drive modes
- Describe a jumper and its functions
- Use jumpers to enable code stored in the microprocessor
- Coordinate control between jumpers and the transmitter
- Gain a deeper understanding of robotic control

Learning Activities

The student will:

- Turn in the completed worksheets for Config for the Squarebot or for the testbed
- Participate in the lecture on **Maximizing the Default Code**.
- Participate in the lecture on the **Radio (Transmitter)** helper link, the **Controller** , the **Crystals**, and the **Receiver.**
- Participate in the lecture on **Transmitter Menus**
- Complete the worksheets on Test Bed Reverse or Squarebot Reverse
- Complete the worksheets on Squarebot Scale or the Test Bed Scale
- Complete the worksheets on Squarebot Edit Pt or the Test Bed Edit Pt.
- Complete the worksheets on Test Bed Trim or Squarebot Trim.
- Complete the worksheets on Squarebot P. Mix or Test Bed P. Mix.
- Complete the worksheets on Squarebot Jumpers, or Test Bed Jumpers.
- Complete the Programming the Remote Control Quiz.

Procedures for Assessment

- Programming the Remote Control Quiz.
- Daily written assignments
- Classroom Observation
- Writing Criteria
- Work Habit Evaluation

Plan of Study

In the examples provided for the plan of study we will use the plan using Squarebot, but it could be applied to the testbed also.

Day 1-3

- Demonstrate to the class the way an operational Remote Control Car is set up. Organize the class into groups of 2 or 3 and (if not already done) have them complete the assembly of the VEX Squarebot by adding the radio receiver and the microcontroller.

- Hand out the Maximizing the Default Code Resource for student reference. Instruct the class to complete the assembly including 2 bumper switches and motors to the microcontroller (as shown in the Resource).

- Print the Transmitter Menus handout for the class or show them where to access it from the VEX curriculum.
- Review the Radio (Transmitter), the Controller, Crystals, and the Receiver.

- Discuss how the Logic Subsystem interacts with the Structure Subsystem, the Motion Subsystem, the Sensor Subsystem, and the Power Subsystem.

- Watch the video on Remote Control Config.
- Provide a brief lecture on how to access the Remote Control Config system on the radio transmitter.
- Handout the remote control Config menu worksheet designed for the Squarebot and have students complete the worksheet.

Day 4-5

- Discuss the Reverse Menu and watch the Reverse video.
- Hand out the remote control Reverse Menu worksheet designed for Squarebot and assign the students to complete these reverse menu lab.

Day 6-7

- Discuss the Scale Menu option and watch the Scale Video. Answer students questions about what scale is.
- Hand out the Scale Menu worksheet designed for Squarebot and assign students to complete the scale menu lab.

Day 8-9

- Discuss the Edit Point option and watch the Edit Point Video. Answer students questions about what scale is.
- Hand out the Edit Point worksheet designed for Squarebot and assign students to complete the scale menu lab.

Day 10 - 18

- Continue with the same pattern for Trim, P.Mix, Drive, and Jumpers. It will be determined by the instructor and the emphasis of the course whether these are valid lessons. Another option is to assign student teams the responsibility to teach the rest of the class how to use the menu systems.

End of Unit Culminating Activity

Programming the Remote Control Quiz.

Introduction to Robotics Engineering
Planning Your Project – 10 days - Ongoing

The first part of the curriculum was intended to allow students to become comfortable with the hardware and software that are part of the VEX system. Starting here we begin to offer students investigations and engineering design problems intended to teach them about engineering.

Students are required to share ideas as they develop solutions to their engineering design problems. Technical sketching is the universal language of engineers. The resources available in the "Planning Your Project" section of the VEX curriculum assume that the teacher has experience teaching technical sketching and requires some level of teacher expertise and/or other resources for a teacher to implement this section of the curriculum well. The Planning Your Project section is designed to support teachers who are interested in incorporating technical sketching and design, and/or parametric solid modeling. (the parametric solid modeling section include parts only and assumes that SolidWorks or Autodesk is already installed on the computers) These materials are designed as VEX specific supplemental materials that can used by an experienced teacher.

It will depend on the teacher's point of emphasis, but this section will take several days. Since engineering design is emphasized throughout the course, it is a good choice to introduce these lessons early in the course so that students understand what a good sketch/drawing looks like and so that they know how to interpret drawings. One method is to introduce students to sketching early, challenge them with a design problem that involves building a working model, and then review sketching, dimensioning, engineering process, and design reviews. This gives students the opportunity to work on sketches for designs that have meaning to them.

Project planning resources are divided into the following sections:

- Introduction to Technical Sketching - consists of a PowerPoint presentation that the teacher can modify to introduce the topic, three short videos that demonstrate sketching technique, a set of handouts that explains sketching technique, and four sketching exercises involving common hand tools that may be used in the class.
- Drawing Conventions - consists of two printable PDFs illustrating technical sketching standard line conventions and general dimensioning rules. These PDFs should be printed, reviewed for understanding, and given to students to keep in their Engineering Journal.
- Pattern Developments – is a PDF handout that introduces the topic of pattern development and provides an example of a student-designed manipulator as well as examples of joints commonly used in sheet metal fabrication.
- Pictorial Sketching - consists of a one page handout that shows the difference between isometric and oblique pictorial sketches, a PowerPoint presentation that reinforces "crating technique" when sketching pictorial drawings and a pictorial sketching step-by-step video, which illustrates isometric drawing, oblique drawing, and the crating technique.

- Precision Measurement - consists of a PowerPoint presentation that explains how to read a dial caliper, micrometer, and engineering rule, a worksheet that involves accurately measuring VEX components, and a handout on units of measurement.
- How to Make Things Move - consists of two PowerPoint presentations that demonstrate pictorially how common moveable parts work. These presentations can be use as a kickoff activity when challenging student to design moveable parts for various applications.
- Vex Solid Models - consists of a printable PDF Vex parts library, and both SolidWorks and Autodesk Inventor models of these parts. Note that your computer must have either or both of these programs to use these models.

The Printable Lessons are sketching exercises designed to allow students the opportunity to practice what they have just learned in context. Some of the exercises include PowerPoint examples that demonstrate how to sketch the particular part step-by-step.

- Sketching the Plus Gusset – Consists of a PDF worksheet designed to check for understanding of orthographic projections (multiview drawings). The worksheet also reinforces sketching technique and proportionality. This is a good assessment tool.
- Sketching the Gusset – Consists of a PowerPoint presentation that shows the method to sketch the Gusset as well as a PDF worksheet for students to complete. This sketch is a little bit harder than the Plus Gusset.
- Sketching Fasteners – This lesson consists of two PowerPoint presentations. The first presentation is on types of fasteners, their properties, and how to identify them. The second presentation is to be used with the accompanying PDF as an organizer that allows the teacher to review the types of fasteners available. Students can be assigned to sketch and label the fasteners.
- Sketching the Bearing Block – Is an exercise designed to have students take a pictorial drawing that has some rounded surfaces and convert it into an orthographic projection. The PowerPoint is designed as a tool that the teacher can modify and use to demonstrate how to sketch the orthographic projection. The PDF is the worksheet.
- Dimensioning the Bearing Block – Dimensioning objects is difficult for students. This worksheet will give students practice dimensioning objects.
- Dimensioning the Plus Gusset – Consists of both a PowerPoint presentation and the worksheet. The PowerPoint presentation is designed as a teacher aid that begins to demonstrate how dimensions are applied to drawings.
- Dimensioning the Pivot – Is a worksheet that includes both straight and round parts to dimension.

Resources

- Planning Your Project taken from the VEX Curriculum
- Paper, pencils
- Engineering projects

Learning Objectives

The student will be able to:

- Use proper line technique when sketching.
- Sketch single view drawings.
- Sketch orthographic drawings (multiview drawings).
- Sketch pictorial drawings
- Dimension parts.
- Interpret technical drawings at a novice level.
- Measure accurately.

Learning Activities

The student will:

- Sketch teacher assigned parts.
- Turn in completed teacher assigned worksheets.
- Participate in the lecture on technical sketching.
- Describe and apply common drawing conventions.
- Describe and apply common dimensioning rules.
- Describe the difference between a multiview drawing and a pictorial drawing.
- Design parts to solve teacher assigned engineering problems using standard sketching practices.

Procedures for Assessment

- Teacher observation
- Class participation
- Engineering Journal
- Work Habit Evaluation
- Sketching Evaluations
- Work Place Competencies Evaluation

Plan of Study

This is for reference only and will be modified to suit the needs of the individual student.

Day 1

- Pass out Introduction to Sketching PDF, review why sketching is an important skill, how technical sketching is the universal language of engineers, and have students place the handout into their Engineering Journals.

- Demonstrate proper sketching technique or show the sketching technique videos as appropriate to demonstrate technical sketching technique; exercise 1, exercise 2, exercise 3. Have students complete the worksheet sketches at the bottom of the Introduction to Sketching PDF and place the completed exercises into their Engineering Journal.

Day 2 - 4

- Have students complete the Tool Sketching Worksheets to improve their technical sketching competency. Place the completed sketches in their Engineering Journal.

- Introduce the students to proper drawing conventions. Give students the Standard Line Conventions handout, review it, and have the students place it into their Engineering Journal.

- Introduce the concept of an orthographic projection drawing, also called a multiview drawing, to students. Show the PowerPoint presentation of How to Sketch the Gusset. Have the students sketch the Plus Gusset and the Gusset and place the completed sketches in their Engineering Journal.

Days 5 - 7

- Introduce students to the concept of dimensioning. Give the students the General Dimensioning Rules handout. Review the rules with them and then have them place the handout in their Engineering Journals.

- Show the PowerPoint presentation of Dimensioning the Bearing Block, and assign students the sketch to complete.

- Assign students the Dimensioning the Pivot and Dimensioning the Plus Gusset sketches to complete.

Days 8 -10

- Introduce students to the concept of sketching pictorial drawings. Print the Pictorial Sketching handouts and give them to students. Discuss the difference between isometric and oblique pictorial sketches.

- Show the Pictorial Sketching PowerPoint which demonstrates how to layout a pictorial sketch using the crating method.

- Show the Pictorial Sketching Video which shows sketching technique used to sketch pictorial sketches.

- Assign students pictorial sketches to complete of VEX parts.

Introduction to Engineering – 10 day intro – phase 1

The goal of the Engineering section of the course is to help students understand engineering: what engineers do, the processes they use, their problem solving methodologies, and how they work together in teams. When you type “define: engineering” into an Internet search engine you will get approximately 20 different definitions for engineering. At the end of the Introduction to Engineering unit students should be able to define what the study of engineering is.

Learning engineering, like problem solving, is an iterative process. In this curriculum students will be challenged to solve a series of engineering design problems where they will be asked to research, design, problem solve, lead, and actively participate in developing the solution to gradually more complex design challenges.

To contextualize the learning experience we will be using a Rube Goldberg type of challenge. There are many other types of engineering challenges that a teacher may want to select; bridge building, egg drop, trebuchet building, mouse trap car, paper plane contest… The engineering challenge will be determined by the teacher. We choose the Rube Goldberg challenge for several reasons: students can use recycled materials, most of the robotic engineering design challenges will involve motion and the Rube Goldberg challenge demonstrates motion, and there are many examples of Rube Goldberg mechanisms available for students to research and potentially take ideas from. Another added value of the Rube Goldberg challenge is that students can quickly move into the VEX Goldberg Challenge, where they are able to use remote control and/or programming to develop a perpetual motion machine out of VEX parts.

Resources

What is Engineering PowerPoint

Engineering Process Video

Definitions of Engineering PDF

Engineering Processes PDF

Rube Goldberg Engineering Challenge Activities

Learning Objectives

The student will be able to:

- Describe what engineering is.
- Describe engineering processes.
- Function on multi-disciplinary teams
- Communicate effectively using all forms of verbal and non-verbal communications.

- Describe various methods used to manage and schedule projects.
- Participate in and conduct a design review.
- Identify and formulate solutions for an engineering problem using engineering design processes.

Learning Activities

The student will:

- Solve a teacher assigned Rube Goldberg challenge. Note: the goal in this lesson is to expose students to an engineering design problem and have them work in engineering teams to solve the problem. Other engineering problems include: model bridge building, mouse trap cars, trebuchet design, paper airplanes, and an egg drop; the engineering design topic chosen is at the teacher's discretion.

- Read the Rube Goldberg Challenge Handout and be prepared to discuss the problem as a class. Place the handout into their Engineering Journal.

- Read the Brainstorming Primer Handout and be prepared to discuss proper etiquette when working on teams, discuss positive as well as negative experiences students had when participating on teams. Place the handout into their Engineering Journal.

- Describe the attributes of a good team member.

- Read the Problem Solving Strategies Handout and be prepared to discuss how to problem solve as a team. Place the handout into their Engineering Journal.

- Participate in a class discussion on how to conduct your first team meeting.

- Read and discuss the Team Building Handout. Place the handout into their Engineering Journal.

- Watch the Engineering Process video and discuss how engineering processes can be applied to the engineering design challenge that they are working on.

- Read the Definitions of Engineering Handout, select their definition of what engineering is, and be prepared to defend that definition during a class discussion. Place the handout into their Engineering Journal.

- Read the Robotics Teams Handout and be prepared to discuss the roles needed to solve their engineering design problem. Students will place the handout into their Engineering Journal.

- Discuss how to divide responsibilities using a Master Schedule, the Group Matrix, or the Planning Organizer Handouts and then divide into teams and begin to brainstorm potential ideas and assign individual responsibilities to team members as they solve their engineering design challenge. Students can pick whichever responsibility matrix that they like to assign individual and team responsibilities.

- Read the Using GANTT Charts Handout and/or the Using PERT Charts Handout and be prepared to discuss time management and how it relates to project management. Students will place the handout into their Engineering Journal. (It will be at the teacher's discretion to determine which scheduling tool is appropriate. Younger students will begin with GANTT charts.)
- Discuss individual responsibility to the project. Complete the Daily Log Handout which will document their daily contributions to the project. Students will keep their completed Daily Log in their Engineering Journals.
- Read the Design Review Handout and be prepared to discuss the concept of design reviews in class. Students will place the copy of the Design Review Handout into their Engineering Journals.
- Students will schedule design reviews as needed.
- Turn in individual teacher assignments related to the design challenge including proof of project management; a Master Schedule, Group Matrix, and Planning Organizer for their team.
- Participate in a team directed Design Review.
- Present the solution to their design challenge.

Procedures for Assessment

- Teacher observation
- Classroom/team participation
- Daily Log Entries
- Design Review
- Project Rubric
- Rubric for Presentations
- Work Habit Evaluation
- Work Place Competencies Evaluation
- Engineering Journal Rubric

Plan of Study

Note: Determine the resources that you will make available to the students before you assign them a challenge. Set the project end date before you begin the project. For the Rube Goldberg Challenge, for example you might allocate 10 days, this includes:

- Four days to introduce engineering, working in teams, project management, and project scheduling.
- Two days for students to brainstorm, plan, and prototype engineering solutions and conduct design reviews.
- Two days for students to test and iteratively improve.
- One day for the project demonstration.
- And one day for a debriefing at the end of the challenge.

Day 1

- Give students the Definitions of Engineering handout and assign them to read the definitions for homework and be prepared to present their favorite definition of engineering to the class.
- Show the video" Engineering Process".
- Engage students in a lecture with the PowerPoint presentation "What is Engineering?"

Day 2

- Pass out Rube Goldberg Challenge handout (or whatever engineering challenge that you've selected for this project: model bridge building, mouse trap cars, trebuchet design, paper airplanes, egg drop, etc.; the engineering design topic chosen is at the teacher's discretion.)
- Discuss "What is Engineering?" and have students help to define their favorite definition of engineering.
- Discuss the assigned engineering challenge and begin to identify the project requirements as well as how they will be assessed.
- Have the students begin to consider and develop their solutions to the problem individually and explain that teams for the challenge will be developed tomorrow.
- Hand out Brainstorming Primer (PDF) and Problem Solving Strategies (PDF) and have students place them in their Engineering Journal and assign them to read the handouts for homework.

Day 3

- Provide students with a copy of the Competition Schedule handout to provide discussion points for breaking a project into parts. Students should place the handout into their Engineering Journal.
- Pass out the Team Building and First Team Meeting PDFs and discuss what it means to work together on a team project. Have students share their experiences working on teams. Encourage students to discuss both good and bad experiences and how they handled them in the past.
- Discuss the Brainstorming Primer and Problem Solving Strategies PDFs and how they would incorporate these strategies on an actual team.
- Break the groups into teams and allow them to begin to brainstorm solutions to the engineering design problem.
- Assign the students to select a project management/scheduling tool that will allow their teams to assign deliverables to individuals for homework from the Master Schedule, Group Matrix, and Planning Organizer handouts.
- Hand out GANNT Chart/PERT Chart PDFs. Have students place their handouts into their Engineering Journals, read the handout for homework and be prepared to discuss time management tomorrow in class.

Day 4

- Engage students in a discussion on Project Management and the responsibilities of the project manager. Discuss GANNT Charts and PERT Charts and the advantages and disadvantages of these scheduling tools.
- Assign the students to plan a schedule with due dates that align with both the responsibility matrix and the project completion date. Handout the Design Review PDF and have students place it into their Engineering Journal.

Day 5 - 6

- Discuss what Design Reviews are.
- Assign students to begin to prototype and test potential solutions for their Rube Goldberg Mechanism.
- Conduct an internal design review, checking project status as well as the responsibility matrix.
- Students are responsible to document what they completed on the project into their individual Daily Logs.

Day 7 – 8

- Build and iteratively test the teams' Rube Goldberg Mechanism.

Day 9

- Students demonstrate their solutions to the class.
- Pass out the Writing Rubric and discuss your expectations.
- Students are required to write a one page description of how their Rube Goldberg Mechanism works.

Day 10

- Collect student's writing assignment
- Debrief about the following topics:
    - What is engineering?
    - What is project management?
    - Why is it important to schedule?
    - What considerations do you need to make when working as a team?
- Complete the Work Habit Evaluation Rubric and turn it in for a grade.

Engineering Activities Include with this Curriculum

Orchard Project 4-5 weeks

The **Orchard Project** is composed of two major parts:
In Lesson 1, students will research the role of automation technology in one sector of agriculture (pesticide spraying), and put together a presentation to a prospective client to secure funding to begin development.

Lesson 2 is an introduction to radio control, programming and sensors through a series of increasingly sophisticated prototypes of a mobile robot platform that can navigate the tight spaces between rows of trees in an apple orchard.

Automated Hot Dog Maker Project

In the **Hot Dog Maker Project** your team's objective is to develop an automated system for delivering cooked hot dogs once they are ordered. A single person, working from the point of sale, will initiate each order and place the hot dog bun into the system.

The Automated WorkCell

The **Automated Work Cell** is an advance project that is student designed and incorporates all aspects of hardware, software, and engineering.

How are Signals Sent? – 7 days

This is a great lesson that teaches students how crystals work. It also teaches scientific process, graphing, and teamwork. Read the Note to the Teacher to learn more about the lesson.

Resources Required

How are Signal Sent Lesson
Radio Transmitter, crystals, battery, VEX microcontroller, receiver
Pencils, paper, graph paper
Yard stick/tape measure
Data sheets from How Signals Are Sent lesson

Learning Objectives

The student will be able to:

- Explain the relationship between remote control transmitters, crystals, the receiver, and the VEX microcontroller.
- Define resonance (both mechanical and electrical).
- Define both engineering and scientific notation.
- Define both frequency and period.
- Conduct scientific inquiry-based experiments to determine the effect of radio control transmitter antenna length and position on signal strength relative to the receiver.
- Explain how to apply engineering notation to frequency and time period calculation.
- Demonstrate how to use a calculator programmed for engineering notation to determine the appropriate units.

Learning Activities

The student will:

- Construct a basic model of a working system that includes a radio control transmitter, a receiver, a microcontroller and motor driven output.
- Apply scientific process as they complete their resonance investigation.
- Identify and measure the maximum distance from the radio control transmitter antenna to receiver at various antenna heights.

- Apply a fixed transmitter antenna height and fixed transmitter distance from the receiver to discover the optimal angle of the transmitter antenna.
- Determine the effect of an obstructed receiver on the signal strength of the radio control transmitter.
- Use a calculator with engineering exponential notation to determine the frequency and time period of a sinusoidal wave form.
- Collect data from their investigation.
- Apply and describe the various points of experimental procedure:
  1. Experimental hypothesis
  2. Measurement technique
  3. Multiple trials
  4. Systematic error
  5. Random error
- Write the vocabulary words and definitions in their Engineering Journals.
- Summarize what they learned in each investigation.

Procedures for Assessment

- Quiz on 'How Signals are Sent".
- Classroom Observation
- Writing Criteria Rubric
- Work Habit Evaluation

Plan of Study

Day 1

- Introduce this lesson set with a teacher led lecture, or by using the How Signals are Sent Video Overview.
- Open the Lesson Guide PowerPoint presentation and review with students what they will learn, the importance of establishing a scientific method when conducting these labs, and your requirements of them in this set of labs.
- Handout and discuss the Introduction for Students Handout. After the class discussion, students will place the handout into their Engineering Journals.

- Review important vocabulary words with students: Resonance, Oscillate, Oscillator, Amplify, Amplifier, Frequency, Period, Sinusoid.
- Show students what the signal platform will look like. Either use the Signal Platform Construction Show or use a VEX robot with the labs.

Days 2-5

- Review the scope of the lesson with the class. If needed, review how the remote control transmitter works; Radio Remote Transmitter guide.
- Describe the difference between Scientific Notation and Engineering Notation. Print the Scientific and Engineering Notation handout for students and assign the students to use either scientific or engineering notation as they work on the "How Signals are Sent" investigations.
- Discuss with the Horizontal Antenna Test Procedure (Lesson 1), Vertical Antenna Test (Lesson 2), and the Obstruction Test (Lesson3) with the class. Describe how the How Are Signals Sent (Worksheet) will be used to collect and analyze data during these labs. Students will place the completed worksheets into their Engineering Journals.
- Discuss/Lecture on the Sinusoids, Frequency and Period (Lesson 4) handout. Students will place the worksheet along with any teacher assigned problems in their Engineering Journals

Day 6

- Review all relevant materials that you plan to test the students on with the class and provide them with a worksheet on Scientific and Engineering Notations and Sinusoids, Frequency and Period.
- Have students complete any remaining parts of the labs.

End of Lesson

- Students will complete the How Signals are Sent Quiz..
- Ask student to use the writing process to summarize what they learned in the "How Signals are Sent" lesson.

How Much Current Will My Robot Draw – 3 – 4 days

In this investigation, students will learn the relationship between current and work. Students will use the Vex Robotics System in a laboratory setting and conduct scientific inquiry-based experiments to determine how current draw is affected by traversing increasing inclines. Students will construct a modified Squarebot, which will require attaching a multimeter in series with the battery, crimping wires, and mounting the multimeter on the robot.

Students will gain an understanding of math and science concepts including work, power, and force. In addition, students will learn the definitions of voltage, current (including direct and alternating), and resistance, and how these concepts relate. Students will also learn how to use a multimeter to check for continuity and DC voltage. Students will learn how to crimp their own Vex connectors and what a series circuit is. Also, they will learn the factors that affect current draw in their robot, and the relationship between voltage, current, work, and time. Additionally, students will graph their experimental results and draw conclusions about the relationship of scientific concepts.

Read the Note to the Teacher to learn more about this lesson.

Resources Required

How Much Current Will My Robot Draw Lesson
Lesson Current Draw Procedures
Current Draw Worksheet
Current Draw Excel Spreadsheet
Modified battery
Multimeter
Wire stripper

Learning Objectives

The student will be able to:

- Describe the relationship between current draw and work.
- Apply the scientific process and collect data from their investigation.
- Modify a battery and place it in series with a multimeter.
- Use a protractor to layout a test bed for their robot current investigation.
- Measure current output while the robot climbs inclines of increasing angles.
- Graph their experimental data and explain the results.
- Describe how a multimeter works
- Use a multimeter to test continuity and check DC voltage.

Learning Activities

The student will:

- Preview the overview video to begin to understand the purpose of the lesson.

- Read the Introduction to the Student to learn about the lesson, key concepts, and reference materials available for student use during this lesson.
- Learn the following vocabulary: force, power, work, current , voltage, resistance, direct current, alternating current, series circuit, parallel circuit.
- Measure voltage using a multimeter.
- Build a testbed to conduct the experiment.
- Cut and strip wire, then crimp electrical connections correctly.
- Apply and describe the various points of experimental procedure:
    6. Experimental hypothesis
    7. Measurement technique
    8. Multiple trials
    9. Systematic error
    10. Random error
- Write the vocabulary words and definitions in their Engineering Journals.
- Summarize what they learned in each investigation.

Procedures for Assessment

- How Much Current Will my Robot Draw Quiz
- Classroom Observation
- Writing Criteria Rubric
- Work Habit Evaluation

Plan of Study

Days 1

- Introduce this lesson set with a teacher led lecture, or by using the How Much Current Will my Robot Draw Video Overview.
- Open the Lesson Guide PowerPoint presentation and review with students what they will learn, the importance of establishing a scientific method when conducting these labs, and your requirements of them in this set of labs.
- Handout and discuss the Introduction for Students Handout. After the class discussion, students will place the handout into their Engineering Journals.

- Review important vocabulary words with students: Force, Power, Work, Current, Voltage, Resistance, Direct Current, Alternating Current, Series & Parallel Circuits
- Use the Current Draw Lesson Setup Video and the Current Draw Lesson Procedures Video to show the students what the investigation will look like.
- Check students for understanding of concepts. Review the following helper links with students: Current, Voltage, and Resistance.

Days 2-3

- Hand out Current Draw Lesson Setup worksheet and the Current Draw Lesson Procedure worksheet for students to review and place in their Engineering Journal.
- Either handout or point students to the Current Worksheet PDF or the Current Worksheet excel spreadsheet and discuss how data will be collected and assessed for this investigation.
- Demonstrate to students how to use the multimeter and how to prepare their battery for the investigation.
- Have students collect the data from the investigation.
- Discuss the data and have students write a short description that demonstrates their understanding of the relationship between current draw and work. Students are required to describe how this investigation will affect their future robot designs.
- Check student's understanding and review for the quiz.

End of Lesson

- Students will complete the How Much Current Will my Robot Draw Quiz.
- Ask student to use the writing process to summarize what they learned in the "How much current will my robot draw" lesson.

How Much Can a Motor Lift – 3 – 4 days

When students compete in robotic competitions they often have to make decisions on which motor to use for each application. This lesson begins to introduce students to some of the features of small electronic motors.

Things the robotic designer needs to know:

- What is the motor rating?
- How much the motor will lift?
- How fast will the motor lift?
- How can I control the speed and the strength? (there are tradeoffs)
- How much current will the motor will draw?
- What can cause my motor to burn up?

In this investigation students will learn to measure stall torque for the VEX motors. They will learn about the VEX clutch. In the ideal test system the experimenter would be able to count on the slip-clutch to disengage before the motor was damaged. In our investigation we found that the slip-clutch disengaged after the motor had already reached its limit. In other words, the motor would be damaged with the slip-clutches that we experimented with. This is important for you to note to your students.

Students will be measuring the amount of torque the motor is able to exert before it stalls. This will be accomplished by building a test bed that enables the experimenter to vary the amount of weight the motor is able to lift. Students will also learn a lesson about leverage; the further the weight moves from the fulcrum the larger the torque.

Read the Note to the Teacher to learn more about this lesson.

Resources Required

How Much Can a Motor Lift Lesson
Stall Torque Procedures
Stall Torque Lesson Procedures PDF
Light weights
Scale

Learning Objectives

The student will be able to:

- Describe the relationship between torque, the distance from the fulcrum, and weight.
- Define what a clutch it and its importance in the VEX system.
- Apply and clarify various points of an experimental procedure:
    - Experimental hypothesis
    - Measurement Technique
    - Multiple trials
    - Systematic error
    - Random error
- Collect data from the investigation

- Graph results
- Calculate averages
- Measure accurately using a ruler/meter stick or tape.
- Measure accurately using a scale or student developed measuring device in ounces or grams.
- Convert between various units of measure.
- Extrapolate new information from the data collected.
- Write a conclusion that summarizes the lessons learned in the investigation.

Learning Activities

The student will:

- Discuss the importance of selecting appropriate motors.
- Identify how motors are rated.
- Identify key terms in the unit.
- Apply scientific process.
- Write a program that will be used to control the motor.
- Build a test bed.
- Move a weight along the lever to test varying conditions.
- Calculate TORQUE = distance times weight (TORQUE = D x W).
- Run their investigation at least three times with each condition.
- Accurately measure the results in each condition and record them.
- Convert mass between English and metric units.
- Learn relationship of weight to distance from the fulcrum.
- Describe torque in terms relating to weight times distance.
- Write a conclusion describing what was learned.

Procedures for Assessment

- How Much Can My Robot Lift Quiz
- Classroom Observation
- Writing Criteria Rubric
- Work Habit Evaluation

Plan of Study

Days 1

- Discuss the Lever Law and its effect on mechanics.
- Discuss the clutch that is built into the VEX system and have the students try to determine a good way to measure the clutch's ability to protect the motor.

- Introduce this lesson set with a teacher led lecture, by using the How Much Can my Motor Lift? Video Overview or by using the Stall Torque Lesson Procedures slideshow.
- Open the Lesson Guide Power Point presentation and review with students what they will learn, the importance of establishing a scientific method when conducting these labs, and your requirements of them in this set of labs.
- Handout and discuss the Stall Torque Lesson Procedures handout. After the class discussion, students will place the handout into their Engineering Journals.
- Assign students to build the Stall Torque Test Bed.
- Check students for understanding of conversion of units by reviewing the Factor Label Method handout. Students will place the handout into their Engineering Journals for future reference.

Days 2-3

- Assign students to conduct the investigation by following the Stall Torque Lesson Procedures.
- Check students understanding and review for the quiz.

End of Lesson

- Students will complete the How Much Can My Robot Lift Quiz
- Ask student to use the writing process to summarize what they learned in the "How much can my robot lift" lesson.

How Do Gear Ratios Affect Speed and Torque – 3 – 4 days

In this investigation, students will learn the relationship between gear ratio, torque, and speed. Students will use the Vex Robotics System in a laboratory setting and conduct scientific inquiry-based experiments to determine the effect that changing a gear ratio has on torque and axle speed. Students will begin with the construction of a gearbox. They will then measure axle speed and lifting capability at a 1:1 gear ratio. Next, they will measure axle speeds and calculate theoretical lifting capabilities at gear ratios of 1:3, 1:9, and 1:45. They will calculate actual lifting capabilities for all gear ratios for which they have sufficient weights.

Please note: we designed a crate and used rolls of pennies because we thought they're easily available. Feel free to substitute whatever lifting apparatus and/or weights you prefer. An especially good solution is a strong spring scale (20 - 60 lb. maximum). By anchoring the spring scale, then tying it to the string, you do not need to use a crate or weights. If you wish to use weights, standard barbell weights with a hole in the center will work well. You will probably need to be able to use 60 pounds of weights to test the maximum gear ratio. Tie a string securely through the hole and around the weight, and then tie the string securely to the gearbox, according to instructions. Note also that care should be taken during lifting. The string should be strong enough to hold up to 60 pounds and be double or triple knotted securely. Students must not stand with their feed directly under the weights.

Safety: Test the system to see if it is capable of lifting the load. Make sure the load is reasonably well balanced. Make sure you set the wheel perpendicular to the table edge. Make sure you align the string parallel to the wheel, so it will spool correctly onto it. Make sure you grasp the platform firmly. Make sure your fingers do not touch the gears. Make sure people and objects are well clear of the area below the crate and weights.

After completing the experimental procedure, students will chart and analyze their data.

Read the Note to the Teacher to learn more about this lesson.

Resources Required

- How Do Gear Ratios Affect Speed and Torque Lesson
- The gearbox
- The lifting crate
- 40 Rolls ($20.00) of pennies (Feel free to substitute different weights or holding devices, as mentioned earlier.)
- Timer
- String
- Tape (any)
- Vex remote control (with frequency crystal matching the crystal in the Vex controller in the testbed
- Programming Dongle
- ROBOTC software

Learning Objectives

The student will be able to:

- Describe the inversely proportional relationship between gear ratios and the robots speed.
- Describe the relationship between gear ratios and torque.
- Define torque
- Describe the difference between a gear ratio and a compound gear ratio
- Calculate a compound gear ratio
- Apply the scientific process
- Construct and manipulate a gearbox
- Measure axle speed and relative strength as the gear ratio varies
- Collect data from the investigation
- Apply and describe the various points of experimental procedure:
    - Experimental hypothesis
    - Measurement technique
    - Multiple trials
    - Systematic Error
    - Random Error
- Summarize in writing what they learned in the investigation.

Learning Activities

The student will:

- Discuss the relationship between gears and speed
- Discuss the relationship between gears and torque and give real world examples where engineers have applied this relationship in today's technology
- Discuss torque
- Construct a gearbox to complete this investigation
- Read and follow the directions from the Mechanical Advantage Lesson Procedure slideshow
- Write a conclusion describing what they learned.

Procedures for Assessment

- Mechanical Advantage Quiz
- Classroom Observation
- Writing Criteria Rubric
- Work Habit Evaluation

Plan of Study

Days 1

- Discuss torque and how gears can be used to affect the mechanics of an object.
- Discuss how an engineer can use gears in the VEX system to change speed and torque of a mechanical system.
- Introduce this lesson set with a teacher led lecture, by using the How Do Gear Ratios Affect Speed and Torque? Video Overview, or by using the Mechanical Advantage Lesson Guide.
- Print the Introduction for Students handout for the mechanical advantage lesson. Have students place the handout into their Engineering Journals for future reference.
- Handout and discuss the Mechanical Advantage Lesson Procedures handout. After the class discussion, students will place the handout into their Engineering Journals.
- Assign students to build the Gear Box Test Bed.

Days 2-3

- Assign students to conduct the investigation by following the Mechanical Advantage Lesson Procedures handout.
- Check students understanding and review for the quiz.

End of Lesson

- Students will complete the Mechanical Advantage Quiz
- Ask student to use the writing process to summarize what they learned in the "How do gear ratios affect speed and torque" lesson.

Does Wheel Size Matter – 3 – 4 days

In this investigation students will identify the relationship between the diameter of the wheel and the speed the robot travels. This investigation gives the teacher an excellent opportunity to:

1. Teach scientific process
2. Give students opportunities to apply measurement
3. Talk about and use mathematical terms such as “plot (or graph) data”, and “extrapolate”. In mathematics, extrapolate means to estimate a value of a variable outside a known range from values within a known range by assuming that the estimated value follows logically from the known values.

Students will construct a robot that can be modified to incorporate three different driving wheel conditions: the small wheel, the medium wheel, and the large wheel. Students will be given a robot, a stop watch, and a specific distance to travel. The distance will be marked by a piece of tape at the beginning and the end of the testing area. The robot will use the default code on the VEX controller and the VEX radio to complete this investigation. Students are required to calculate the speed the robot travels in condition one, estimate the speed for condition two, and extrapolate the speed for the third condition from the plot of the first two conditions.

When the lesson is completed, the students will write a conclusion about what they learned.

Read the Note to the Teacher to learn more about this lesson.

Resources Required

- Does Wheel Size Matter Lesson
- Robot plans
- Stop watch
- Measuring tape
- Wheel size worksheet

Learning Objectives

The student will be able to:

- Build a test bed
- Setup independent, dependent, and control variables to conduct a scientific investigation
- Apply and clarify various points of experimental procedure:
    - Experimental hypothesis
    - Measurement technique
    - Multiple trials
    - Systematic error
    - Random error
- Analyze data and draw conclusions

- Run the investigation under three different conditions
- Collect data, record it on a data table, and graph the data
- Convert between centimeters and inches
- Extrapolate the new distance traveled based on prior testing
- Write up a summary of lessons learned in the investigation

Learning Activities

The student will:

- Conduct a scientific investigation that allows them to determine the relationship between wheel size and the distance a robot travels.
- Extrapolate new distances the robot will travel as the wheel size changes based on collected data,
- Follow procedures
- Write a conclusion describing what they learned.

Procedures for Assessment

- Wheel Size Matters Quiz
- Classroom Observation
- Writing Criteria Rubric
- Work Habit Evaluation

Plan of Study

Days 1

- Introduce this lesson set with a teacher led lecture, by using the Does Wheel Size Matter? Video Overview, by using the Wheel Size Matters Lesson Guide or by using the Wheel Size Starter Kit Lesson Procedures.
- Print the Wheel Size Starter Kit Lesson Procedures handout for the wheel size lesson. Have students place the handout into their Engineering Journals for future reference.
- Open the Extrapolation helper page and discuss it with students. Have the students write down a definition for extrapolation as well as graph an example and place it into their Engineering Journals.
- Review circle geometry for students and how it relates to wheel geometry.

Days 2-3

- Assign students to conduct the investigation by following the Wheel Size Matters Lesson Procedures handout.
- Check student's understanding and review for the quiz.

End of Lesson

- Students will complete the Wheel Size Matters Quiz.
- Ask student to use the writing process to summarize what they learned in the "Wheel Size Matters" lesson.