Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2013 Volume III: Sustainability: Means or Ends?

Robotic Construction Using Sustainable Energy and Design

Curriculum Unit 13.03.02
by Jonathan Cap

Introduction

In Robotics class, students learn about six simple machines: lever, pulley, inclined plane, wedge, screw, and wheel and axle. This knowledge is necessary to teach the following unit, and students will need to understand these systems in order to construct their robots for the course. Robotic Construction Using Sustainable Energy and Design will cover the following engineering and robotic principles: gear ratio, torque, momentum, center of gravity, acceleration, gear train, stall torque, subsystem, traction, structure and materials. Along with learning what these principles are, and the proper definitions of each, students will learn how different system layouts will affect the vehicle, the sustainability of the vehicle, and the energy the vehicle consumes. By producing robots with a well thought out gear train and design, students will determine the amount of power needed to accelerate their robot. Students must use their prior knowledge, along with newly learned knowledge, to design their robot in the following unit.

Teaching strategies will include cooperative learning, interdisciplinary teaching (pairing with math), daily reviews of previously learned material, teaching vocabulary throughout the unit, graphic organizers, hands on/ active participation, visual graphs, problem solving instruction, and gamification (replacing traditional unit evaluation, such as tests and quizzes, with a game/competition to evaluate their created robot). Classroom activities include brainstorming, tug of war, and a power vs. efficiency testing.

The unit will align to each of New Haven Public Schools 21 st Century Competencies: problem solving and critical thinking, creativity and innovation, communication and collaboration, initiative, self-direction and accountability, citizenship and responsibility, and accessing and analyzing information.

Problem solving and critical thinking, accessing and analyzing information, creativity and innovation, and communication and collaboration will be used throughout the unit. It will be seen in all the activities in order for the students to create their own design and make modifications throughout the planning process.

Initiative, self-direction, and accountability, and citizenship and responsibility will be seen more in the group work sessions. Students will have to meet deadlines, give their peers feedback, and reflect on their own experiences.

Standard for Technological Literacy

Standards:

The Nature of Technology

3. Students will develop an understanding of the relationship among technologies and the connections between technology and other fields of study.

Technology and Society

5. Students will develop an understanding of the effects of technology on the environment.

6. Student will develop an understanding of the role of society in the development and use of technology.

Design

8. Students will develop an understanding of the attributes of design.

9. Students will develop an 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.

Abilities for a Technological World

11. Students will develop the abilities to apply the design process.

13. Students will develop the abilities to assess the impact of products and systems.

The Designed World

16. Students will develop an understanding of and be able to select and use energy and power technologies. [1]

Background Knowledge

Robots and machines are often mistaken for one another. A robot is a series of machines that is able to carry out complex actions it is programmed to do. Our society is relying more and more on robot to carry out tasks or services. The robotics field is growing very rapidly, and there will be projected job openings in the near future. These jobs include the development and design of robots, as well as the construction and maintenance of these systems. By introducing students to this field at a high school level, it will give them a better understanding of how the world works around them. They will get hands on experience in physics, mathematics, engineering, and design principles. These skills are essential in the robotics field, these skills can be applied to almost any area of study, and they will improve students' motor skills as they construct the robots in the classroom.

Metropolitan Business Academy is a magnet school with a business focus. Our school currently has 400 students enrolled; however, each grade is not made up of 100 students at this time because the program is still growing. There are roughly 80 students in the senior class and 125 students in the freshmen class. Because we are a magnet school, half of our students are supposed to come from urban districts (in this case, New Haven), and half are supposed to come from surrounding suburban districts (like Branford, North Haven, and Wallingford). Currently, sixty percent of our students are from New Haven and forty percent are from suburban districts within a thirty-mile radius. Our school is made up of forty percent Hispanic/Latino students, forty percent African American students, and twenty percent Caucasian or other (mostly Asian) students. Every year our school becomes a little more diverse.

In our school, there are four pathways that students can choose from at the end of their ninth grade year. The pathways include: allied health & science, law & political science, technology, and finance. Every student must enroll in one pathway, but students can take courses outside of their pathway as an elective if there is room in the class. In robotics, there are mostly students who are in the technology pathway, but I also have students who are taking it as an elective. This particular robotics course is for juniors and seniors who have already taken Algebra 1 and Geometry, and students who have or are currently enrolled in Algebra 2.

Previously before this unit, time was spent learning the six simple machines, what they are, and how they provide mechanical advantage. Students also learned vocabulary words and robotic terminology. Students have already built Rube Goldberg Machines, as well as Lego and Vex robots, giving students a working understanding of the six simple machines, as well as an understanding of robotics construction and design. Details are included below.

The six simple machines provide mechanical advantage, which makes different tasks easier to complete. These six simple machines can be used in conjunction with each other to create a more complex machine. This can be best and most obviously seen in Rube Goldberg Machines. Rube Goldberg Machines are complex machines that are made up of combinations of simple machines where one action and/or movement triggers a series of movements. By studying and creating Rube Goldberg machines prior to this unit, it will provide students with a better understanding of simple machines and how they can be combined to create a more complex system.

Six Simple Machine Definitions

A lever is a beam that is hinged on a fulcrum. It is used to provide great force to lift an object at one end by applying a smaller force over a larger distance, such as a bottle opener. (See Figure 1.)

A pulley is a wheel on an axle that is used to change the direction of a force on an object. If multiple pulleys are combined, it will create a mechanical advantage. Two pulleys combined will allow one to lift an object with only half of the weight of that object. It does this by moving the object over a longer distance. (See Figure 1.)

An inclined plane is a flat surface that is higher on one end. It is commonly seen in ramps; it allows for an easier way to move things. It provides mechanical advantage by moving an object over a longer distance but using less force. (See Figure 2.)

A wedge is two inclined planes joined back to back. It is used to split objects. This is seen in an axe or a knife. The mechanical advantage can by calculated by dividing the length of either slope by the thickness of the large end. (See Figure 2.)

A screw is an inclined plane that is spiraled across a central cylinder. The mechanical advantage is calculated by dividing the circumference by the pith of the screw. (See Figure 3.)

A wheel and axle are fixed to each other, so they will rotate together. The mechanical advantage is the ratio of the wheel to the ratio of the axle of their radius. (See Figure 3.)

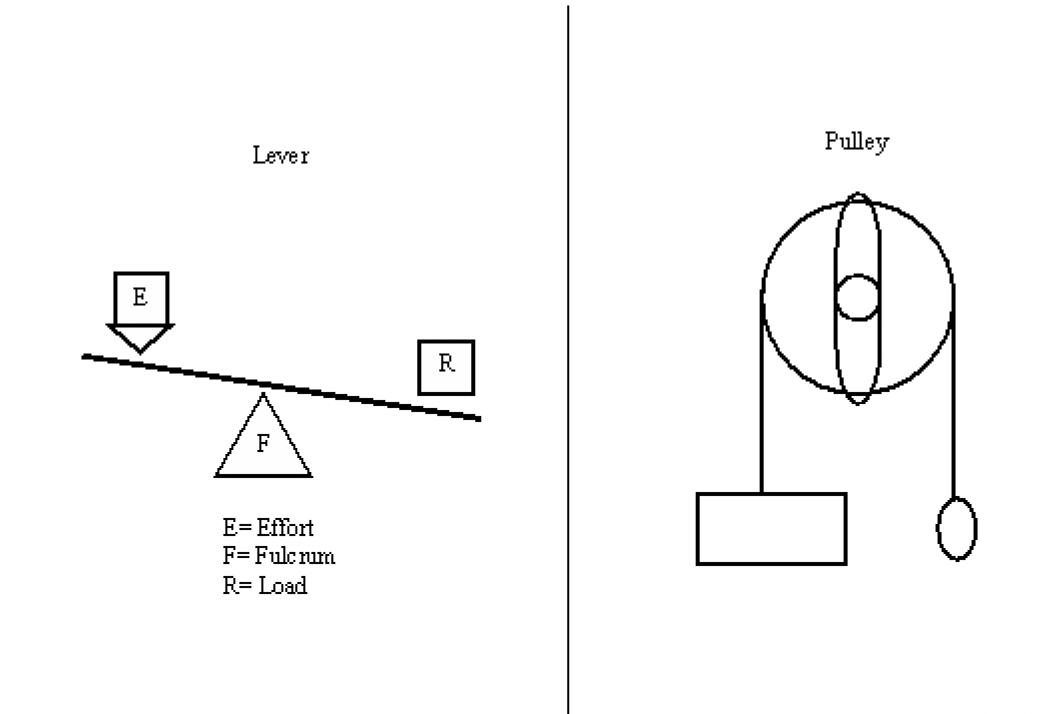

Figure 1.

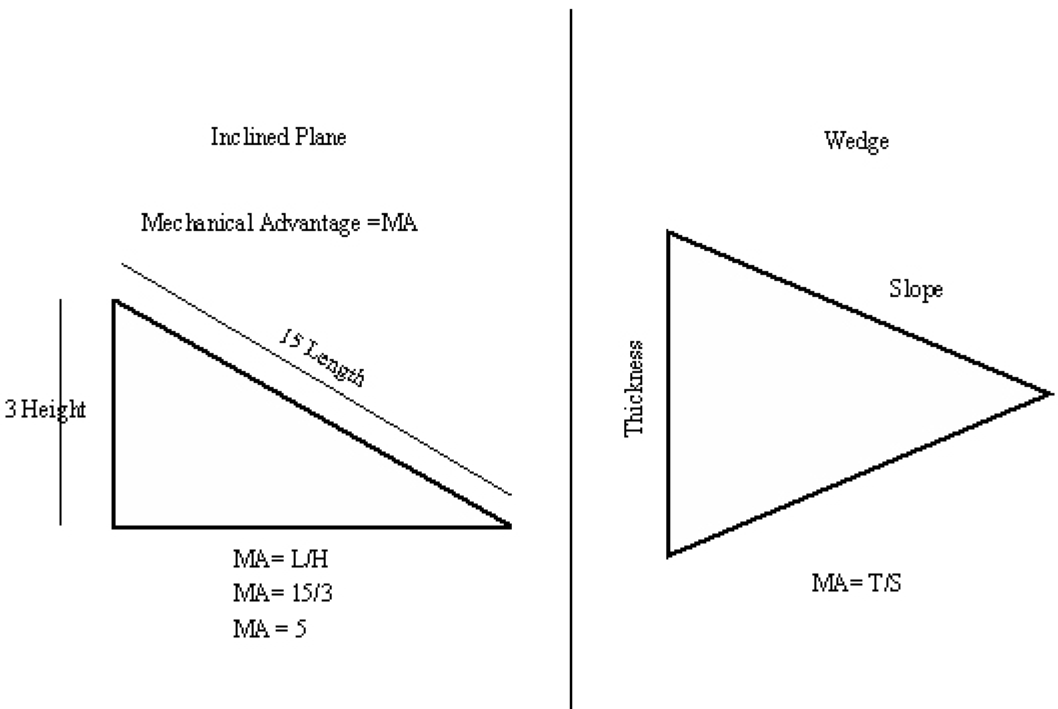

Figure 2.

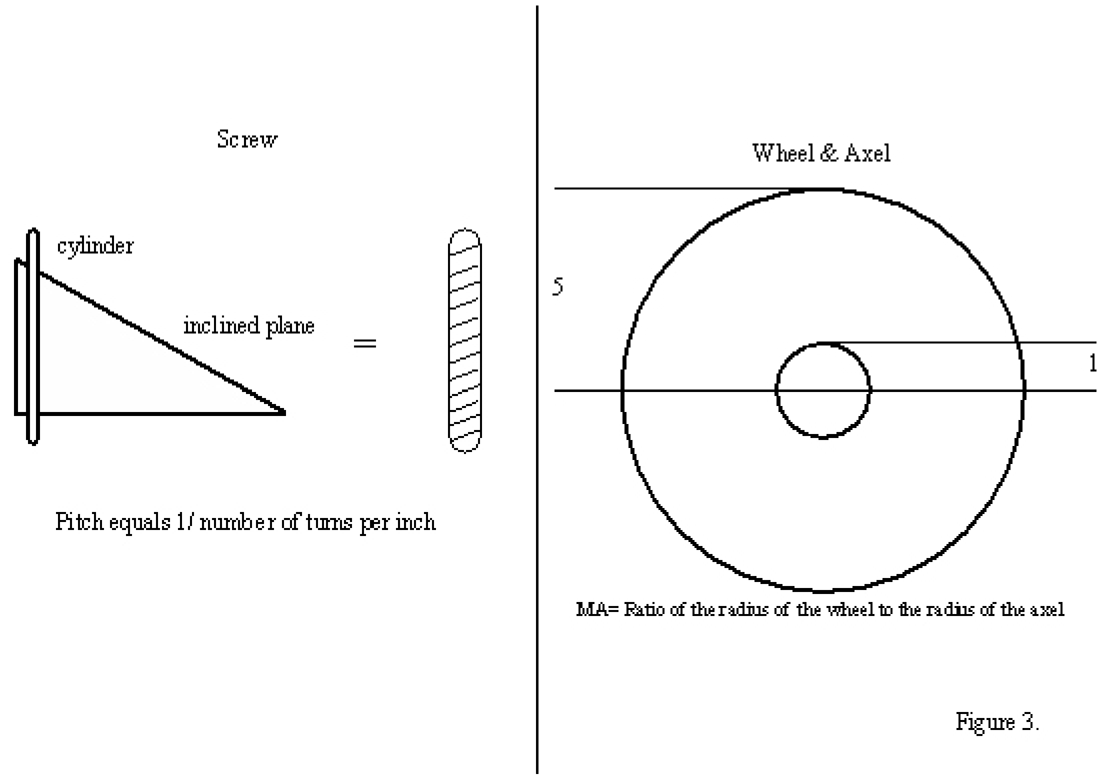

Figure 3.

Robotic terminology:

Gear Ratio- (in a gearbox, transmission, etc.) the ratio between the rates at which the last and first gears rotate. By altering the gears and creating different gear ration the students will be able to adjust whether their robot is fast or powerful.

Torque- A measure of force about a rotating axis; "How hard something is rotating."

Momentum - heavier objects have more momentum; it takes more force to get them moving and also takes more force to stop them.

Center of gravity - If the center of gravity is too high, it can cause the object to tip over.

Acceleration- A change in speed over time. Depending on the gear ratio along with the traction will affect the acceleration of the object.

Geartrain - Represents the part of the drivetrain, which transmits power from the motor to the ground.

Subsystem - the weight and strength of the subsystem can affect the object; a lighter subsystem will be more energy efficient.

Traction- The friction between a drive member (wheel) and the surface it moves upon. The amount of force a wheel can apply to a surface before it slips. A wheel or surface must have traction in order to create motion. If there is too little traction, the wheel will slip on the surface. If there is too much traction, there will be too much friction to move. This could also affect the efficiency of the object. This is seen in everyday life of tires. Tires that are rated for snow or off- roading are great for their purpose; however, using them on a highway will affect the gasmileage, as opposed to changing the tires for the season. [2]

Unit Overview

The purpose of this unit is to show how design can impact the amount of energy and resources that are used. Part of green design and construction is not always about the materials themselves. This does play an important role, but it is about the amount of energy that is used to complete the construction and how the object will sustain once it is built. We need to consider what the carbon footprint will be after construction.

For this unit, we will be working with Vex robotic kits. If one is just starting a robotics course, the Swept Away Classroom Bundle is a great starting point. This unit can be done with almost any type of robotic kits. I prefer Vex; they are very versatile and simple, and advance robots can be built from these kits. There is no need for any type of specialized equipment, such as a workshop, when using the Swept Away Classroom Bundle. Almost anything can be built with the hex wrenches that are included in the kit. If one wanted to cut any of the metal pieces, it can be done with simple hand tools. The vex kits are also reusable, they will last for several years, and replacement parts can also be purchased when necessary. Vex kits can be purchased directly from Vex at www.vex.com. Any robotic kits can be used if vex is not available or if the program is using another brand.

This unit will be a total of nine, 87 minute class periods. There will be three topics that will be cover with accompanying activities/ projects:Brainstorming, Tug of War, and Power vs. Efficiency. Brainstorming will be done in one class period, and students will learn about recycling vs. repurposing and the cradle to grave/cradle to cradle concept. The brainstorming students do will be about these newly learned topics. The Tug of War lessons will take four class periods and will focus on gear ratios, so students understand power and efficiency. The Power vs. Efficiency test will take four class periods, and students will use the knowledge gained so far in this unit, as well as background knowledge from previous units, to build a sustainable robot that is capable of accomplishing several tasks. When the unit is over, students will be able to organize their thoughts/ideas, work collaboratively, and they will understand that design plays an important role in an object's efficiency and sustainability.

Lessons/Classroom Activities

Grouping

Groups will be different throughout each lesson. This will allow students to work with a variety of people, which will help them learn from each other and be closer as a class. I've learned that groups of two work the best. It allows each student to be part of the project. It will also allow the teacher to interject into groups if they are struggling or not understanding. When groups are larger, some group members might feel left out or their ideas are not included. Evidence that partners work more efficiently and students are more engaged than when working in larger groups can be found in *Focus: Elevating the Essentials to Radically Improve Student Learning* by Mike Schmoker. The teacher will assign groups for the brainstorming activity, students will pick one partner for the "Tug of War" and a different partner for the "Power vs. Efficiency Test". Groups should be different for each activity.

Class Openings

Throughout the unit, most class periods will begin with students using their exit ticket from the previous class with teacher feedback. Students will have time to review the comments from the teacher and apply those comments to the construction of their robots. Students will also have time ask the teacher questions during the class openings.

Brainstorming Lesson

Objective: Students will be able to use graphic organizers to generate and organize their ideas about recycling and repurposing materials.

Rationale: A large majority of this unit is problem solving. Throughout this unit, students will be given problems or objectives to complete. For much of this, there is no one right answer or one formula that will give the correct answer. Students will need to come up with their own ideas with little or no guidance or information from the teacher. This, in turn, can create frustration or stress. It is important to let the students know that even if their idea does not work out they are not a failure. By organizing one's thoughts, collaborating with their peers, and applying past knowledge and principles, almost any problem can be solved and any situation can be overcome. This lesson is to help students learn to brainstorm in an organized fashion. It will also help students who may think they are not creative or not good at planning out their work come up with ideas.

The following problem will be posted on the board prior to class: What can glass, aluminum, and plastic bottles be recycled into? Some of their ideas could be things that are already being done; others can be their own ideas/ inventions. Brainstorming techniques, such as web organizers (See Figure 4.) and brainstorming charts (See Figure 5.), have been used in previous units. We will briefly review each, and students will choose what they feel is best for their learning style. Their organizer will include the list of materials and the product it can be recycled into. After the students record their ideas down on paper, they will explain the recycling process for each object in writing; for example, a plastic bottle can be recycled into a plastic storage bin by shredding the plastic bottles, washing them, melting them down, and using injection molding to form the new product. It is important for students to understand that their explanation may or may not be right, so they will need to justify their reasoning. After the students complete this individually, they will meet in groups to share, discuss, defend their ideas, and come up with new ideas. This is similar to a Think, Pair, Share activity. This will allow students to then come up with a master list of outcomes and procedures using everyone's input. The groups will create T-charts with explanations of outcomes and procedures to keep their ideas organized.

After the opening, the teacher will give direct instruction on the difference between recycled and repurposed materials. To explain these two ideas, the teacher will use the cradle to grave, cradle to cradle concept. While the teacher gives direct instruction, students will take notes in their class notebooks, so they can refer to this information later in this lesson and other lessons to follow.

Example of Web Organizer

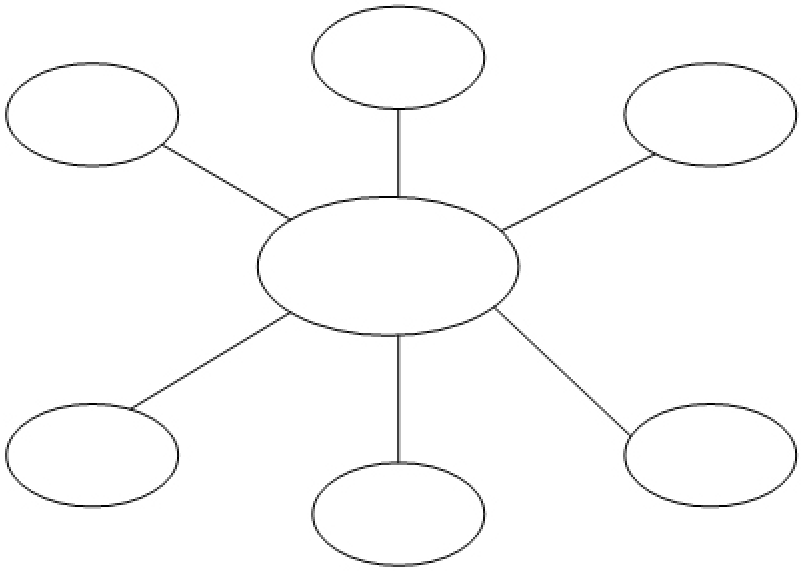

Figure 4.

Example of a Brainstorming Chart

Materials	Recycled	Repurposed
Plastic		
Glass		
Aluminum		

Figure 5.

Cradle to Grave Concept vs. Cradle to Cradle Concept

Cradle to grave is a phrase used to describe a product's lifespan. Each object humans create will have a lifespan; some are shorter than others. In the design field, it is important to think about this to help make products more sustainable for the environment, but it can also help make products cheaper to manufacture. One example of this would be bottled water; a bottled water is purchased, consumed, and then the bottle is discarded. This is an example of a short lifespan. To be better for the environment, a little more and different materials could be used to manufacture a reusable bottle, which would be used over until it is damaged or lost. This is the ideal product, but there will always be a need for disposable water bottles. This is where the design process can come in because someone could design a bottle that uses less plastic. This will make the bottle cheaper to produce and will create less waste. Another concept is cradle to cradle. This is where a product is not disposed of or recycled, but instead it is repurposed. This means that after its intended use, the product is used in a new way. One example of this would be if you took a tin coffee can or glass food jar, removed the contents, and used it as a pencil holder or to store small hardware (screws, nuts, bolts etc.). Recycling products is very important, and everyone should do their best to practice this concept at work and home; however, it is not the best solution. Recycling takes energy; a bottle, for example, needs to be shredded then the bottle is melted to produce the recycled goods. This is done in factories that will require lots of energy to operate. In the end, recycling is good, repurposing is better, but overall, using fewer materials will help to conserve energy, be more sustainable, and also be green for the environment.

After this instruction, students will remain in their groups. They must take the same objects, glass, aluminum, and plastic bottles, and they must think of ways to repurpose these objects. The groups will record their ideas on another organizer. Once done, the groups will share their thoughts and ideas with the class. In the last five minutes of class, students will answer the following question: Why is repurposing more green and sustainable than recycling in some situations? Give me one example of this to support your thinking.

Tug of War

Objective: Students will be able to create an efficient robot that will be able to pull the counter weight and opposite directional force of another group's robot.

Rationale: Tug of war is a game in which two teams line up grabbing a section of rope and facing each other. The objective is to pull the center section of rope across a given mark with your team. Winning the contest shows that your team was stronger and/or more powerful because you were able to pull the other team and the center section of rope closer to your side. This can be done in robotics using principles and concepts covered in previous classes to develop a robot that has more strength and power. This will be a hands on exercise where the students must come up with a design that they feel will beat the competition. Taking into account the gear ratios will allow students to decide on the amount of torque their robot will produce. They will also take into account the robot's acceleration, center of gravity, momentum, and traction.

The students will be placed in groups of two and will use brainstorming techniques from the brainstorming lesson to design and build a robot. The teacher will have the groups calculate these concepts to create statistics for their robot using equations that were taught in a previous unit, such as the torque and gear ratio. With the statistics, students can make predictions about which team their robot will win or lose against. After this is all complete, the students will run competitions against other groups and record their results. After the competition, a follow up discussion will take place as a class to talk about why certain robots performed better than others. We will record the information discussed on the board or on chart paper for students to refer to later if needed. This will give the students a visual of the concepts and terms that were previously learned to better understand and use in future projects.

Materials needed: Rope or cord to attach to each robot (carbineers also work well) and tape to use as the centerline. The teacher will place the two attached robots on either side of the centerline marked on the floor. No slack should be in the rope or cord. Students will have four (87 minute) class periods to complete this. The fourth class period will be used to test their designs. After the tests are complete, a 20 minute class discussion will take place focusing on different robot designs. The remainder of the class period will be used to disassemble the robots and put away supplies.

Principles/ Key Concepts: Gear Ratio, Torque, Momentum, Center of Gravity, Acceleration, Geartain, Subsystem, and Traction. Students learned all these principles and concepts in a previous unit.

Class Period 1: Students will enter the room and be given a word sheet with a list of the principles and key concepts list above. They will have five minutes to define them in their own words. After, a class review will take place in which the students volunteer to share their definitions with the class. The teacher records the information on the board, and when necessary, adds to or alters the definition to make it correct. Students are adding to and correcting their own definitions when necessary. Students will choose a partner to work with for this project. They will be given the briefing along with the constraints of the tug of war assignment. The class will go through the briefing and constraints together. Questions and clarifications will be made during this time.

After the briefing, the students will begin to brainstorm their design ideas using principles and key concepts from the opening, and students will explain how each concept will be applied to their robot. They will also research tug of war strategies for the remainder of the class period. The last five minutes of class students write two to three sentences briefly explaining their robot design and why it will work. They will also be encouraged to write any questions they have about this assignment.

Class Period 2: Students will receive their exit ticket from the previous class. They will be given five to ten minutes to alter their design based on the teacher feedback; they can also ask the teacher one-on-one questions about their design at this time. Students will then take out their notebooks, and with direct instruction from the teacher, they will learn about power and efficiency.

The teacher will explain that a sustainable design does not need to lack power. For example, a tow truck is designed for power; it tows objects that can be the same weight or heavier than itself. The engine and gear train is designed for this. A racecar is designed for speed; it would not be able to tow like a tow truck, just as a tow truck would not be able to accelerate like a racecar. These are two examples of items designed for specific tasks. In order to design something that will be successful and efficient, one needs to know what it will be used for. In the game of tug of war, a design can make or break the competition. If gears are correctly put together, the robot does not have to completely sacrifice speed, power, or efficiency. When designing the robot, it is important to think about what design will make it the most efficient by using less materials and by allowing the energy, in this case, the battery, to be able to get the most power out of one charge. The teacher will write power and efficiency on the board with their definitions, and students will copy them into their notebooks. Power is energy that is produced by a mechanical device, and it is also a physics term to measure work. "Efficient: (of a system or machine) achieving maximum productivity with minimum wasted effort or expense." [3] Students will look at the principles and key concepts, and they will decide how to design their robot, how it will be geared together, the traction on the wheels, and the amount of materials that will be need to make this robot.

After the direct instructions/note taking period, students will begin to construct their robot and do that for the remainder of the class period. Because there is no need to construct arms or lifts, the construction will be much quicker. The time will be used trying out their design and re-working the gears and other factors to produce a better vehicle for this assignment. Batteries should be placed in chargers before leaving.

In the last five minutes of class, students will work with their partner to evaluate their progress from today's class by answering the following question: In two to three sentences, explain why you believe your robot will win the tug of war by being the most efficient without sacrificing power. Use evidence to support your thinking. Students will also make a to-do list of things they need to complete during the next class.

Class Period 3: Partners will receive their exit ticket from the previous class. They will be given five to ten minutes to review the to-do list they created for themselves and re-evaluate their robot based on teacher feedback. Students will also be able to ask one-on-one questions at this time. The remainder of the class period will be used to complete the construction of their robot. The teacher will circulate the classroom offering assistance when needed and answering any questions a group has.

In the last five minutes of class, students will work with their partners to evaluate their robot and answer the following questions in two to three sentences each: Based on your group's design, what are the strengths and weaknesses of your robot? Did you feel you lost power while trying to be more efficient? What is your prediction for your robot during the competition? Use evidence to support your thinking when answering each question.

Class Period 4: Partners will receive their exit ticket from the previous class with teacher feedback. Partners will have five to ten minutes to meet, to get batteries, and to make last minute repairs or assembles based on teacher feedback. Students will be able to ask final one-on-one questions at this time about their robots. Groups will be placed opposite each other, the rope/cord will be attached to one end of each robot, and the tug of war will begin. There will be three rounds per match, and each group is responsible for recording all the results. After three rounds, groups will rotate until they have competed against every other group. If there is an uneven number of groups, the groups not competing for that round will observe, cheer on, and/or help with the competition set up. A group should not wait to compete for longer than one match.

Once all the groups have competed against each other, a class discussion will take place to reflect on the assignment. The teacher will ask groups to think about and discuss their results with the class. Did these results match the predictions made during the previous class? Did the efficient design hinder your group's success? While the class discussion is taking place, students will also write down their own answers to the questions asked.

In the last five minutes of class, students will work on individual reflections for this project and the competition in their own words. They will explain if their prediction was correct or not. They will also explain how they believe the tug of war relates to or is an example of power and efficiency. Students will hand this in while exiting the classroom.

Power vs. Efficiency Test

Objective: Students will be able to create an efficient robot with a partner that will be able to pull a load, push a load, lift a load, maneuver through obstacles, and also drive at the fastest speed possible down a straight away.

Rationale: In the previous lesson, students learned that just because a robot is heavy because of more material used does not mean it will be more powerful. The students learned that the design of their robot, traction, and forward force played an important role in the design and success of the robot. A well thought out design for a specific task, and taking into account the restraints given, will give students the knowledge to create efficient, well thought out robots. In this lesson, students will be required to design a robot that will complete the tasks while also achieving high efficiency. The students will be given a briefing in class with the necessary details.

Principles/ Key Concepts: Gear Ratio, Torque, Momentum, Center of Gravity, Acceleration, Gear Train, Subsystem, Traction, Power, Energy, and Efficiency. Students learned all these principles and concepts in a previous unit.

Briefing

The Red Cross building is located in New England, which is known for its extreme winters. The building is snowed in with no way of escape, there is a disaster that has just occurred, and we must get the building ready to provide help. Students, your mission, should you choose to accept, will be to create a vehicle which will be able to move up to a three pound snow bank, drag a five pound supply crate, maneuver through an obstacle course, lift a boulder and place it in a receptacle, and race a straight way to save a victim. If you choose not to accept, the Red Cross will be at risk of failure, along with your grade. Here are the constraints:

Construct and program a robot that will complete the tasks previously stated. These tasks will be demonstrated in one class period (87 minutes) on a single battery charge. Each task completed will earn points. Points will vary depending on how difficult the task is. Each task will also be timed; time will be a factor for specific tasks, such as racing the straight way to save the victim or to decide on ties. Your grade will be based on the completion of this task. Good luck, and may the odds be forever in your favor!

The first class period will be used to brainstorm ideas for the construction of the robot; the next two class periods will be used to design/build the robot. The fourth class period will be used to test the robots.

Class Period 1: Students will be given a word sheet with a list of the principles and key concepts from above. They will have five minutes to define them in their own words. After, a class review will take place in which the students volunteer to share their definitions with the class. The teacher records the information on the board, and when necessary, adds to or alters the definition to make it correct. Students are adding to and correcting their own definitions when necessary.

The teacher will then give direct instruction around design, sustainability, energy and efficiency, and will review recycling versus repurposing. Students will take notes in their class notebooks, so they can refer to this information while brainstorming and building their robot with their partner. It is important for students to understand that by simply altering the design an object can become more energy efficient. When gearing their robot, a student can allow their robot to travel farther if the gear ratio is thought out before building it, and also if the robot is designed for the task it will perform. When constructing the framing, students can use engineering principles to still have a strong frame but with less material, making it more sustainable. Students need to understand that when a product can last longer and use less energy in the process that is being green/sustainable. They need to incorporate this idea into their own robot design. Students need to think about what a product will be used for and what its cradle to grave or cradle to cradle life expectancy is, especially when creating a greener and more sustainable robot for this mission; for example, students need to think about how their robot could be repurposed or recycled after this mission is complete. This lesson will also help students understand how to make greener and more sustainable decisions in their own lives.

Students will pick a partner to work with. They will be given the briefing along with the constraints of the Power vs. Efficiency assignment. The class will go through the briefing and constraints together. Questions and clarifications will be made during this time.

After the briefing, the students will begin to brainstorm their design ideas using principles and key concepts from the opening and explain how they will be applied to their robot using graphic organizers of their choice. They will also research design ideas and strategies for the remainder of the class period. During the last five minutes of class, students write two to three sentences briefly explaining their robot design and why it will work. They will also be encouraged to write any questions they have about this assignment.

Class Period 2: Students will receive their exit ticket from the previous class. They will be given five to ten minutes to alter their design based on the teacher feedback; they can also ask the teacher one-on-one questions about their design at this time.

After the questions are answered, students will begin to construct their robots. They will work on this with their partner for the remainder of the class period. The teacher will be circulating the room during this time to answer questions the groups may have and offer assistance when necessary.

In the last five minutes of class, students will work with their partner to evaluate their progress from today's class by answering the following question: In two to three sentences, explain why you believe your robot will be successful for each specific task: (1) moving up to a three pound snow bank, (2) dragging a five pound supply crate, (3) maneuvering through an obstacle course, (4) lifting a boulder and placing it in a receptacle, and (5) racing a straight way to save a victim. Is your group sacrificing power from one task to be more efficient at another task? Use evidence to support your thinking when answering each question. Students will also make a to-do list of things they need to complete during the next class.

Class Period 3: Partners will receive their exit tickets from the previous class. They will be given five to ten minutes to review the to-do list they created for themselves and re-evaluate their robot based on teacher feedback. Students will also be able to ask one-on-one questions at this time. The remainder of the class period will be used to complete the construction of their robot. Again, the teacher will circulate the room to answer one-on-one questions and offer assistance when necessary.

In the last five minutes of class, students will work with their partners to evaluate their robot and answer the following questions: Based on your group's design, what are the strengths and weaknesses of your robot? Did you feel you lost power while trying to be more efficient for any of the tasks? What is your prediction for your robot during the competition? Use evidence to support your thinking when answering each question. Batteries should be placed in chargers before leaving.

Class Period 4: Students will be given their exit tickets with teacher feedback. Students will be given 15 minutes to meet in their groups to get batteries and make last minute repairs or assembles based on teacher feedback. During this time, the teacher will be available to answer any last minute one-on-one questions before the competition begins.

The teacher will hand out slips of paper with a number on it to each group. This will tell the students which obstacle to start at. In order for the obstacle course to be completed in the most efficient time, groups will all start at different stations and move through in a clockwise fashion. This will allow most, if not all, of the groups to be working throughout the entire class period. Students will run through the obstacle course and record their own progress and points.

Once all the groups complete each obstacle station, approximately thirty minutes, a class discussion will take place to reflect on the assignment. It is important that the instructor emphasize that just because a group had difficulty, or was unable to complete a task, does not mean students failed; the teacher should encourage students to recognize what could have been done to make the robot more successful if they were to complete this task again. The teacher will ask groups to think about and discuss their results with the class. Did these results match the predictions made last class? Did the efficient design hinder your group's success? While the class discussion is taking place, students will also write down their own answers to the questions asked.

In the last twenty-five minute of class, students will write a short open response to the following questions: What did you learn about sustainable design by completing this assignment? How did your use of sustainability help or hinder your robot design? Now that you have competed, what changes would you make to your robot to make it more efficient and/or sustainable if you were to do this over again? Now that your mission is complete, come up with one way to recycle and one way to repurpose your robot to make sure that your design really was green. Come up with at least one example explaining where a more sustainable design could be used in our everyday lives. Use evidence to support your thinking.

Points Per Obstacle

Built Vehicle- 1 point

Program- 1 point

Snow Bank 1- 2 points

Boulder - 1 point for each boulder placed in receptacle with in one minute

Supply cart- 4 points

Drag race - 2 points

Obstacle course - 1 point for each cone or object not touched (Total 4 points)

Works Cited

Booth, Wayne C., Gregory G. Colomb, and Joseph M. Williams. *The craft of research* . Chicago: University of Chicago Press, 1995.

DuVall, John Barry, and David R. Hillis. *Manufacturing processes: automation, materials, and packaging* . 2nd ed. Tinley Park, Ill.: Goodheart-Willcox, 2008.

Dyson, Freeman J.. *Imagined worlds* . Cambridge, Mass.: Harvard University Press, 1997.

Floyd, Thomas L. . *Principles of Electric Circuits Conventional Current Version* . Upper Saddle River, NJ: Pearson Prentice Hall, 1981.

Horath, Larry. *Fundamentals of materials science for technologists: properties, testing, and laboratory exercises* . Englewood Cliffs, N.J.: Prentice Hall, 1995.

Morrow , H.W. , and Robert P. Kokernak. *Statics and Strength of Materials* . Upper Saddle River, NJ: Pearson Prentice Hall, 1991.

[3] "Oxford Dictionary," Oxford University Press, last modified 2013, http://oxforddictionaries.com/definition/english/efficient?q=efficient. This is the best definition that pertains to our subject.

Ristinen, Robert A., and Jack J. Kraushaar. *Energy and the environment* . New York: Wiley, 2006.

[1] *Standards for Technological Literacy* : Content for the Study of Technology. Edited by International Technology Education Association, 210. Reston, Virginia: 2007. This is the International Standards for Technology and Engineering Education.

[2] "Vex Inventor's Guide," Vex Robotics Design System, last modify May 2008, www.vex.com. This is the manual that comes with the products we are using throughout this course.

Vieweg, Fried., and Sohn Verlasgesellschaft. *Handbook of Automotive Engineering* . Warrendal,PA: SAE International, 2005.