Unit Overview – Socially Responsible Engineering & Technology (POS)
Course: Y1U2
Unit Title: Can I Borrow a Pencil? (**Mechanical / Structural Engineering)**
Approximate Length of Unit: 2-3 Weeks (based on five day weeks; 45 minute periods each day)

Unit Summary

This unit will raise student interest in principles of mechanical and structural engineering. Students will be presented with the following problem:

The designed world thrives on simplifying human responsibilities through the development of efficient systems. Proper application of mechanical advantage can increase speed or torque, change rotational axis, and ensure repeatability and reliability. Working with gears enables designers to apply more speed or torque based upon the desired outcome. Before concepts of mechanical advantage can applied to later units in this course and others, you need a pencil to proceed with your note taking, sketches, and brainstorming. You will a design a system that will get you that pencil from the other side of the table in both the shortest (and longest) period of time, using the exact same materials. This design under constraint will be evaluated on the gap in range between your shortest and longest period of time. You will need to apply core concepts of speed and torque to meet these requirements.

At the beginning of this unit, students will be learning the construction, variety, and application of gears. Specific characteristics of each type will be introduced. The contrasting nature of speed and torque will be applied to gear systems, and students will need to know how to design systems geared towards a specific outcome. They will need to know the math concepts involved in calculating mechanical advantage, and how to design sound, structural systems that overcome outside forces placed on them.

In order to prepare them with the understandings they will need to develop a viable solution to the problem, students will need to understand how existing devices work. Once an understanding is acquired, students can then collaborate as a team to develop a gear system to move a load over a given distance in the shortest and longest period of time using the same core materials. Design teams will submit a final portfolio on the project.

Primary Interdisciplinary Connections: Engineering, Mathematics

21st Century Themes:

Unit Rationale

Mechanical advantage provides widespread, necessary functions to a variety of applications. Gears provide reduction in motorized equipment, reverse the direction of rotation, increase/decrease the speed of rotation, transfer rotational motion to another axis, and keep rotations synchronized.

The designed world requires the movement of people and cargo, and gears are a core component of products ranging from the automobile to a children's toy. Students cannot proceed in a comprehensive study of the designed world without the ability to understand and apply basic mechanical advantage principles.

Through keeping the load, distance, and power source consistent, students will prove how gear ratios can effectively demonstrate speed and torque. Principles of compression, tension, bending, torsion, and shearing will be applied to ensure the unit remains structurally sound when an outside force is placed upon it.

Suggested Materials:

- Modeling systems (e.g. LEGOS) that contain a variety of gears
- Low voltage DC motors

Suggested Tools and Machines:

- Variable power supply
- Analog or digital voltmeter

Unit Assumptions: Student has understanding of how to apply and document steps of engineering design process

Learning Targets

Standards for Technological Literacy (ITEEA)

Standard 2: Students will develop an understanding of the core concepts of technology. **AA**. Requirements involved the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.
N. Power systems must a source of energy, a process, and loads.

Math (NJCCCS 4) –

Standard 4.3 (Patterns and Algebra) – All students will represent and analyze relationships among variable quantities and solve problems involving patterns, functions, and algebraic concepts and processes.

CPI #	Cumulative Progress Indicator (CPI)
4.3.12.B.2	Analyze and explain the general properties and behavior of functions or relations, using algebraic or graphing techniques.

Science (NJCCCS 5)

5.1 Science Practices: All students will understand that science is both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge. The four Science Practices strands encompass the knowledge and reasoning skills that students must acquire to be proficient in science.

5.2 Physical Science: All students will understand that physical science principles, including fundamental ideas about matter, energy, and motion, are powerful conceptual tools for making sense of phenomena in physical, living, and Earth systems science.

CPI #	Cumulative Progress Indicator (CPI)
5.1.12.B.2	Build, refine, and represent evidence-based models using mathematical, physical, and computational tools.
5.2.12.E.4	Measure and describe the relationship between the force acting on an object and the resulting acceleration.

Educational Technology (NJCCCS 8.1)

8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaboratively and to create and communicate knowledge.

CPI #	Cumulative Progress Indicator (CPI)
8.1.12.A.2	Produce and edit a multi-page document for a commercial or professional

	audience using desktop publishing and/or graphics software.

Engineering and Technological Literacy (NJCCCS 8.2)

8.2 Technology Education, Engineering, and Design: All students will develop an understanding of the nature and impact of technology, engineering, technological design, and the designed world, as they relate to the individual, global society, and the environment.

CPI #	Cumulative Progress Indicator (CPI)
8.2.12.C.3	Evaluate the positive and negative impacts in a design by providing a digital overview of a chosen product and suggest potential modifications to address the negative impacts.
8.2.12.F.1	Determine and use the appropriate application of resources in the design, development, and creation of a technological product or system.

21st Century Skills (NJCCCS 9.1)

9.1 21st-Century Life & Career Skills: All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures.

CPI #	Cumulative Progress Indicator (CPI)
9.1.12.A.1	Apply critical thinking and problem-solving strategies during structured learning experiences.
9.1.12.B.1	Present resources and data in a format that effectively communicates the meaning of the data and its implications for solving problems, using multiple perspectives.

Standards 9.4 Career and Technical Education All students who complete a career and technical education program will acquire academic and technical skills for careers in emerging and established professions that lead to technical skill proficiency, credentials, certificates, licenses, and/or degrees.

CPI #	Cumulative Progress Indicator (CPI)
9.4.12.M.15	Employ critical thinking skills (e.g., analyze, synthesize, and evaluate) independently and in teams to solve problems and make decisions.
9.4.12.O.22	Employ technological tools to expedite workflow.
9.4.12.O.33	Evaluate and demonstrate skill with a range of technological tools designed to manipulate, report, or operate with data acquisition.
9.4.12.O.(1).1	Apply the concepts, processes, guiding principles, and standards of school mathematics to solve science, technology, engineering, and mathematics problems.
9.4.12.O.(1).2	Apply and use algebraic, geometric, and trigonometric relationships, characteristics, and properties to solve problems.
9.4.12.O.(1).7	Use mathematics, science, and technology concepts and processes to solve problems in projects involving design and/or production (e.g., medical, agricultural, biotechnological, energy and power, information and communication, transportation, manufacturing, and construction).
9.4.12.O.(1).8	Select and use a range of communication technologies, including word processing, spreadsheet, database, presentation, email, and Internet applications, to locate and display information.
9.4.12.O.(1).9	Employ concepts and processes for the application of technology to

	engineering.
9.4.12.O.(1).12	Model technical competence by developing and applying processes and concepts in the design process.
9.4.12.O.(2).4	Use scientific and mathematical problem-solving skills and abilities to develop realistic solutions to assigned projects, and illustrate how science and mathematics impact problem-solving in modern society.

English Language Arts Writing (Common Core)

- RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
- RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Mathematics (Common Core)

- S-IC.5. Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.

Industry Standards

NOCDI

- STEM – Pre-Engineering, Engineering Technology

Design Brief

Background/Scenario:

The designed world thrives on simplifying human responsibilities through the development of efficient systems. Proper application of mechanical advantage can increase speed or torque, change rotational axis, and ensure repeatability and reliability. Before concepts of mechanical advantage can applied to later units in this course and others, you need a pencil to proceed with your note taking, sketches, and brainstorming.

Problem/Opportunity Statement:

Using the following components in a team of two, design and develop a gear system that will move a pencil in both a short and extended period of time over the span of six inches. The difference in time between the two tests will be the determining factor between groups.

In a team of two, design and develop two working prototypes of powered gear system that will move a pencil over the distance of six inches in both the fastest and slowest period of time.

Specifications/Criteria:

The students will design two working systems:

- One system will move a pencil six inches in the shortest period of time.
- The second system will move a pencil six inches in the longest period of time.
- The difference in times will be testing measure used to determine success.
- Use only modeling system parts.
- The base of the system cannot exceed one foot in any direction. A piece of tape will be placed on the testing platform (tabletop) to accurately measure 6 inches.

- Be operable by one person.
- Students will be responsible for two pages of documentation; one highlighting the mechanical advantage for each system and the second with sketches of the anticipated system appearance.
- Two page documentation portfolio:
  - Page 1: Highlight the mechanical advantage and construction of system (with photos)
  - Page 2: Test results

Constraints:

Time –
  - Both systems will be timed by instructor or another objective party.

Money -
  - Students can use their own modeling system supplies if necessary/needed.

Energy –
  - Power supply set at 4.5 volts.
  - Output will be confirmed before each test to ensure fairness.

Tools/Machines
  - Use safety as needed.
  - stopwatch, voltmeter, power supply

People
  - Maximum of two people per design team.
  - No human interaction with the system during testing.

Information
  - Students must have gear ratio determined prior to assembly.

Materials
  - Use only modeling system parts.
  - Includes 3 worm gears, 9 spur gears (no more than 3 of one size), a crank no more than 2" inches long.

Stakeholders:
- All students who will advance in course outline.
- All students who are looking to pursue career in engineering or technical field.

Student Grouping Notes:
Groups of two will allow both parties to be involved in brainstorming, design, and documentation. Larger groups will garner a less efficient distribution of tasks.

Material Notes: Teacher can change gear requirements based upon availability and budget. Primary requirement rests with ensuring same number are used by all groups and with both systems. If LEGO motors are not available, teacher can provide motors to each group that has the same voltage/amperage properties.

Unit Essential Questions	**Unit Enduring Understandings**
• How has mechanical advantage impacted the designed world? • When is the proper time to design a system output for speed? • When is the proper time to design a system output for torque? • How are mechanical and structural engineering	• The application of mechanical advantage to different systems is essential to a highly functioning designed world. • Speed and torque are inversely related to one another. • Materials that cannot be glued together present unique challenges.

related? • How do different department personnel function together on a design project? • How can using the same materials for two different prototypes garner different results? • How does a design team member work effectively to be a productive person of the team?	• Structural failure can compromise mechanical function. • Proper classroom organization facilitates efficient time management.

Unit Learning Targets

Throughout the unit, students will contrast the function, construction, and components of gear systems designed for both speed and torque to complete a specific goal.

Students will . . .

1. Research the history and application of modeling systems. (9.4.12.O.22)
2. Recognize the challenges of design under constraint. (9.1.12.A.1)
3. Communicate evidence of the design principles and necessary content in portfolio development. (8.1.12.A.2, 9.4.12.O.(1).8, 9.1.12.B.1, 8.2.12.C.3)
4. Identify the various types and functions of gear systems. (8.2.12.F.1, 9.4.12.O.(1).9)
5. Differentiate between systems designed for speed and torque. (9.4.12.O.(1).12, 5.2.12.E.4, S-IC.5)
6. Demonstrate the ability to calculate mechanical advantage. (9.4.12.O.(2).4, 9.4.12.O.(1).7, 9.4.12.O.(1).1, 9.4.12.O.(1).2, 4.3.12.B.2)
7. Demonstrate the ability to construct structurally sound prototypes. (9.4.12.O.(1).12, 8.2.12.F.1)
8. Demonstrate effective use a voltmeter and power supply effectively. (9.4.12.O.33, 9.4.12.O.(2).4, 5.2.12.E.4, 5.1.12.B.2)
9. Demonstrate how to achieve different results using the same materials. (9.4.12.O.(1).12, 5.2.12.E.4, S-IC.5)
10. Execute structured learning experiences to maximize efficient use of time and material. (9.4.12.M.15, 9.1.12.A.1)
11. Present evidence of project detail to classmates and instructor. (8.1.12.A.2, 9.4.12.O.(1).8, 9.1.12.B.1, 8.2.12.C.3, RST.11-12.9)

Project-Based Learning Plan:
Engineering Design Process (Sequence and Assessments)

Teacher Instruction	Student Evaluation
Step One: Identify the Problem	
Lesson 1: Inefficiency in the Designed World: Impacts of Modeling System Durability and Reusability.	**Formative Assessments: (must have feedback)** ○ Student design teams will assess modern and pressing inefficiencies in the designed world. Teacher and peer groups will provide feedback on relevance and suggest potential improvements. **Summative Assessments:** • Written reflection with rubric: Students will identify the most pressing inefficiency in the designed world and suggest improvement.

Notes: • Discuss impact of modeling system durability and reusability.	**Notes:**
Step Two: Frame the Design Brief	
Lesson 2: Framing the design brief for the mechanical advantage project • Review of design brief requirements • Review of specifications • Review of constraints • Review of engineering design process Lesson 3: Classroom Organization/Citizenship & Tool Usage	**Formative Assessments:** • Using teacher prepared rating scale, students will rate themselves on clean up and organization. • Teacher will conference with each two person design team to review and provide feedback on specifications of the design brief. **Summative Assessments:** • Quiz - summarizing primary constraints and specifications of design brief. (ULT#2) • Performance assessment with rating scale: Students will demonstrate proper clean up procedure. (ULT #10)
Notes: Lesson #2: Teacher will provide examples of portfolios from former students who properly documented the engineering design process.	**Notes:** Teacher will actively inspect student work stations, storage bins, and tool cabinets to ensure all items were returned properly. Floor will continuously be inspected for small, modeling system parts. Misplacement or loss of small parts is a common problem.
Step Three: Research & Brainstorming	
Lesson 4 – Introduction to Gears Lesson 5 – Calculating Mechanical Advantage Lesson 6 – Forces on Structures	**Formative Assessments:** ▪ Teacher will critique initial sketches of gear systems and provide feedback for students in order to make changes. ▪ Teacher will conference with each two student design team on portfolio development quality and content and provide feedback for improvement. **Summative Assessments:** • Mechanical advantage Quiz (UTL#5) • Gears Test (UTL # 4,5,6) • Structures Stress Quiz (ULT#7)
Notes: These brief lessons on structures are necessary to ensure the forces on structures do not prohibit accurate system testing. Concepts will provide enduring impact over multiple units.	

<table>
<tr><td>Teacher will provide background information on gear uses, types, and how to calculate mechanical advantage.</td><td></td></tr>
<tr><td colspan="2">Step Four: Generation Alternate Solutions</td></tr>
<tr><td>Lesson 7
• Communicating Possible Solutions</td><td><u>Formative Assessments:</u>
▪ Teacher will critique sketches of gear systems and encourage more detailed annotations.
▪ Teacher will question structural integrity in regard to design with modeling systems.

<u>Summative Assessments:</u>
• Portfolio Assessment: Examples of Gear System Designs (add to portfolio as evidence of possible solutions for both speed and torque system) (ULT#3)</td></tr>
<tr><td>Notes:
Lesson #7: Teacher should encourage students to sketch and design systems with necessary parts prior to assembly. Using the formulas to calculate mechanical advantage, students should brainstorm various ways to create multiple gears designed for both speed and torque.</td><td>Notes:
Students will be required to have at least three different gear designs with annotations and mechanical advantage calculations for the summative assessment. Final portfolio will then contain at least three possible solutions for a speed system and three for a torque system.

Students should be consistently working on their documentation portfolio throughout the design process. Remaining current with the portfolio should ensure an authentic, sequential record of events. Periodic grading is encouraged to relay the importance of remaining current with their documentation.</td></tr>
<tr><td colspan="2">Step Five: Chosen Solution with Rationale</td></tr>
<tr><td>Lesson 8:
• Explaining and Defending the Best Solution</td><td><u>Formative Assessments:</u>
▪ Teacher will continue to critique sketches of gear systems and return them to design teams if more detailed sketches are required.
▪ Teacher will conference with design teams to ensure portfolios are current with the proper step of the design process.

<u>Summative Assessments:</u>
▪ Presentation w/rubric – Students share best solution (ULT#3)</td></tr>
<tr><td>Notes:
Lesson #8: Teacher should present previous examples of student work and encourage dialogue with students on how to defend decisions. Using a</td><td>Notes:
This portfolio progress check under formative assessment is designed to ensure that documentation includes all steps up to and including Step 5.</td></tr>
</table>

rubric, students will review previous student work and determine strengths and areas for improvement.	Teacher should not allow students to proceed to developmental work unless all steps are properly documented. A presentation should be given by each design team to explain why they chose the best solution. Teacher will encourage students to defend their solution using knowledge acquired in Step 3. (Research and Brainstorming) Teacher will review final drawing to confirm required materials are used.
Step Six: Developmental Work	
Lesson 9: • Using Pictures as a Form of Documentation Development.	**<u>Formative Assessments:</u>** ○ Teacher will critique pictures to ensure right perspective is captured. **<u>Summative Assessments:</u>** **None**
Notes: Ensure students have all the proper materials from modeling system.	**Notes:**
Step Seven: Prototype	
Lesson 10: • Conducting the Testing Procedure using the Power Supply and Voltmeter Safely and Accurately	**<u>Formative Assessments:</u>** ○ Teacher will critique construction and fastening techniques and provide feedback if potential problems exist. **<u>Summative Assessments:</u>** **None**
Notes: Lesson #10: Students will collaborate to construct the first mechanical system. They will decide if their first system will be designed for speed or torque.	
Step Eight: Testing and Evaluation	
	<u>Formative Assessments:</u> ○ Teacher conferences with each design team for frequent safety and function tests of equipment. Based on feedback, students will move forward with testing or re-evaluate testing procedure to ensure safety. **<u>Summative Assessment:</u>**

	▪ Portfolio Assessment: (ULT#3) • Written Record of Test Results using Rating Chart (add to portfolio) • Written Analysis with evidence of possible solutions, and photos capturing mechanical advantage and performance of final system. (add to portfolio)
Notes: Teacher will establish testing location with voltmeter and power supply. Teachers will review testing procedure for design teams. After formal testing and collection of data/photos, teacher will approve breakdown of first gear system and the design of the second system. Testing procedures will then be repeated for a second system, designed for speed if the first one was designed for torque, or designed for torque if the first one was designed for speed.	**Notes:** One member of design team will initiate test, the other will keep time. Teacher can assign another student to take pictures. Portfolio expectations and assessment will be the same for the second test.
Step Nine: Redesign and Reflect	
Lesson 11: • How to write a technical reflection paper?	**<u>Formative Assessments:</u>** ○ Teacher will conference with each design team to evaluate and provide feedback on their mechanical and structural performance of first system. **<u>Summative Assessments:</u>** *At the end of steps eight and nine, as measured by a rubric, designated team members will be responsible for:* • Reflection Paper: How different results can be achieved using the same materials (ULT #9).
Notes: After providing time for both formal tests, instructor will provide time to share their written reflection within each group and within the class.	**Notes:**
Step Ten: Communicate	
Lesson 12:	**<u>Formative Assessments:</u>** ○ Students will practice using presentation

Delivering Effective Presentations	software/equipment delivery; including pacing, presence, and readability. Using the rubric they will be evaluated on, peers and instructor will provide feedback on what to improve. **<u>Summative Assessments:</u>** ○ Performance activity w/ rubric: Presentation of project portfolio to peers. (ULT# 9)
Notes: Teacher will discuss with students qualities of strong presentations and provide examples of effective presentations submitted by former students.	**Notes:** Students will present results of both systems and discuss structural and mechanical engineering principles.

Corresponding Technology Student Association (TSA) Activities
Animatronics **Engineering Design**
Curriculum Development Resources

Lesson Plans	
Lesson	**Timeframe**
Lesson 1 Inefficiency in the Designed World: Impacts of Modeling System Durability and Reusability.	45 minutes / 1 day
Lesson 2 Framing the Design Brief	25 minutes / ½ day
Lesson 3 Classroom Organization / Citizenship & Tool Usage	20 minutes / ½ day
Lesson 4 Introduction to Gears	45 minutes / 1 day
Lesson 5 Calculating Mechanical Advantage	45 Minutes / 1 day
Lesson 6 Forces on Structures	45 Minutes / 1 day
Lesson 7 Communicating Possible Solutions	45 minutes / 2 days
Lesson 8 Explaining and Defending the Best Solution	45 minutes / 5 days Includes design, development, and testing of both systems
Lesson 9 Using Pictures as a Form of Portfolio Development	10 minutes / ¼ day
Lesson 10 Conducting the Testing Procedure using the Power Supply and Voltmeter Safely and Accurately	10 minutes / ¼ day
Lesson 11 How to write a technical reflection paper?	20 minutes / ½ day
Lesson 12 Delivering Effective Presentations	45 minutes / 1 day
Teacher Notes:	

Curriculum Development Resources