Theme

"Never mistake motion for action." - Ernest Hemingway

STEM Innovation Academy Unit 4

Subject: Introduction to Engineering Design Unit Title: Making Things Move Grade: 9th	Teacher: Mrs. Braizer-Martin Duration: 9 weeks; March - June

Summary of Unit

This unit focuses on familiarizing students with basic engineering knowledge related to simple mechanical and electrical systems and the use of mathematical models to represent design ideas and to inform design decisions. Students begin by reverse engineering a mechanical device to identify simple machines and mechanisms that influence motion and contribute to the function of the device. Students identify different types of motion (rotary, oscillating, linear, and reciprocating) and investigate mechanisms that cause motion (including cams, gears, pulleys, chain and sprockets) and later use these mechanisms to create, transform, and control motion to solve a problem. Students practice CAD skills by developing assembly models of the mechanisms they investigate and simulating motion in the CAD environment. To support efficient CAD modeling, students will also learn to use mathematical functions to represent dimensional relationships in a 3D solid model. Students investigate forces that resist motion. First students study spring forces and develop a mathematical model to determine the relationship between spring displacement and force for a given spring. Students also learn about simple electrical circuits and how to transform electrical power to motion using a motor. Students design and install a circuit to run a hobby motor that powers their previously designed automaton. As part of the electrical circuit, students develop a mathematical model to inform the design of a simple potentiometer to control the speed of the motor. As an end of course project, students design and build a toy that includes an electro-mechanical system that will produce realistic motion of a figure(s) or object(s) resulting from the rotation of an axle powered by a motor with minimal frictional resistance. As part of the automaton design process, each student creates a CAD assembly model and creates a computer simulation of automata motion, CAD technical drawings, and a physical working model of their design.

Stage 1 – Essential Questions

Standards/Outcomes:

New Jersey Student Learning Standards for English Language Arts

AS.W.2 - Writing
Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 - Writing
Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.7 - Writing
Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

SL.1 - Speaking and Listening Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

Science and Engineering Practice - Developing and Using Models

Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

New Jersey Student Learning Standards for Mathematics

N.Q.2 - Quantities
Define appropriate quantities for the purpose of descriptive modeling.

G.MG.1 - Modeling with Geometry
Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.2 - Modeling with Geometry
Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).

S.ID.1 - Interpreting Categorical and Quantitative Data
Represent data with plots on the real number line (dot plots, histograms, and box plots).

S.ID.4 - Interpreting Categorical and Quantitative Data
Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators,
spreadsheets, and tables to estimate areas under the normal curve.

2020 New Jersey Student Learning Standards for Science

HS-PS2-1- Forces and Motion
Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

2020 New Jersey Student Learning Standards for Computer Science and Design Thinking

8.2.12.ED.2: Create scaled engineering drawings for a new product or system and make modification to increase optimization based on feedback..

8.2.12.ED.5: Evaluate the effectiveness of a product or system based on factors that are related to its requirements, specifications, and constraints (e.g., safety, reliability, economic considerations, quality control, environmental concerns, manufacturability, maintenance and repair, ergonomics).

2020 New Jersey Student Learning Standards – Career Readiness, Life Literacies, and Key Skills

9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas

9.4.12.CI.2: Identify career pathways that highlight personal talents, skills, and abilities

9.4.12.CI.3: Investigate new challenges and opportunities for personal growth, advancement, and transition

Essential Questions:

1. What is a mechanical system? How can we effectively model mechanical systems?
2. How can we use mathematical models to model linear motion?
3. What is Hooke's Law? What are spring characteristics and how can they be modeled mathematically?
4. What is friction? How does an object's coefficient of friction affect it motion?
5. How can simple machines be used to transfer motion?
6. How can friction be reduced using a bushing?
7. What is a circuit and how can we use circuits to create motion?
8. What is a variable resistor?

Enduring Understandings: *Students will understand that…*

- There are different types of motion.
- Separating a complex process into multiple subprocesses is implemented in an organized way to complete a larger process.
- To create relationships among part features and dimensions, parametric formulas are used.
- Performing a functional analysis of a product or system to determine the purpose, inputs, outputs and operation of a product system.
- Correctly applying constraints to a multi-component model simulates realistic relative motion of the component parts.
- Making strategic use of digital media in presentations enhances understanding of findings, reasoning, and evidence and to add interest.
- Analyzing a consumer product using reverse engineering techniques document visual, functional, and structural aspects of the design.
- Explaining the benefits of human-centered design and apply principles aligns to product design with intended use.

- Design quality concepts such as performance, usability, accessibility, reliability, and safety impact product development.

Stage 2 – Assessment Evidence

Formative, Summative and Authentic Assessments:

- Creating an Automaton
- Application of the Design Process
- Reverse Engineer a Product
- CAD- Cam Drawings
- Engineering Notebook Documentation
- Quizzes and Tests
- Unit Test

Presentation:

- Students will formally present all design challenge work by documenting their work in their engineering notebooks
- Students will conduct informal presentations (gallery walk style) of their automata designs, to make sure their designs are as good as possible before adding in motors
- Students will present their final automata design, focusing on how motion is transferred through the system, as well as the use of springs, friction and circuits within the design

Performance Task(s):

Activity 4.1.1: Reverse Engineer a Mechanism: Students will reverse engineer a wind up toy with the purpose of understanding how motion is transferred through the system.

Activity 4.1.2: Cams Make the World Go Round: Students will use parametric modeling to design a CAD model of a cam. Students will consider the tolerance and allowance of the fit between the hole and the axle of the automata assembly.

Activity 4.1.3: Mechanisms of Motion: Students will build an assigned Mechanical System using Vex. Students will analyze the mechanical systems made by all groups, specifically looking at the necessary inputs and outputs of each system.

Activity 4.1.4: Modeling Mechanical Motion: Students will build and analyze the motion of a pulley and different gear systems. They will model these systems on CAD and use the CAD animations features to analyze the motion of the pulley on the computer.

Activity 4.1.5: Cams in Motion: Students will model linear motion using graphs. Students will use motion graphs to compare the motion of different sized and different shaped cams.
Activity 4.1.6: Design a Cam: Students will design the cam or cams they wish to use in their automata, based on the type of motion that would fit with the story/theme of their automata. They will model the cam in CAD and create a physical model of the cam.
Activity 4.1.7: Simulating Cam Motion: Students will assemble a simple automata box with their cam in CAD.

Activity 4.1.8: Shoebox Automaton: Students will create a rough mock-up of an automata using the cams created in Activity 4.1.6. The cam should transfer motion from one axle to another. Students will test their design, make revisions and create a motion graph to describe the motion of the follower as it travels along the cam.

Activity 4.2.1: Force Springs Eternal: Students will conduct an experiment that will show the relationship between applied force and displacement of a spring. Students will create a mathematical model to show this relationship. Students will identify the slope of the model as the spring constant. Students will learn about Hooke's Law and examine Hooke's Law through the context of the experiment performed. Students will research different types of springs to learn about classification, usage and storage of energy. Students will design and conduct an experiment to test one of the characteristics of a spring. Students will analyze their data and present their experimental process to another team.

Activity 4.2.2: Friction is a Real Drag: Students will use an online simulation to analyze object particles when objects slide together to begin to understand the concept of friction. Students will learn about friction by watching a video. Students will be presented with different materials and will record the object's material, weight, normal force, frictional force and use the formula learned to calculate its coefficient of friction. Students will create a model to represent the coefficients of friction for each object.

Activity 4.2.3: Fighting Friction: Students will analyze their Automata Box Kits to determine how friction will play a role in their final designs. They will brainstorm how to reduce friction using a bushing. They will 3D model their bushing concept.

Activity 4.2.4: Friction: Design Friend of Foe: Students will design and build a cam and follower system that uses friction to translate rotational motion of the cam to rotational motion of the follower in another plane. Students will then design and build a pulley and belt system to efficiently transfer motion from one pulley to another. Lastly, students will design a mechanical system that uses friction in one part of the design and minimizes friction in another part of the design.

Activity 4.2.5: Automata Design Challenge: Students will brainstorm ideas for their automata model, considering types of motion and the role springs and friction will play. Students will create a CAD model of their design and create technical drawings of the design. Students will construct and test their design. Students will peer review the designs of their classmates, providing effective feedback.

Activity 4.3.1: Circuit Basics: Students will design and build a circuit to make a motor run using a battery, wires and a switch. Students will integrate their motor into their automata design to motorize the turning of your automaton's axle.

Activity 4.3.2: Fun with Motors: Students will use a multimeter to create a variable resistor using nichrome wire and add this to their circuit. Students will create a mathematical model that estimates the cycles per second of the follower with respect to the setting of the variable resistor.

Activity 4.3.3: Automata Redesign: Students will automate their automata designs by incorporating what they know about circuits. Students will add to their CAD model of the design and update their technical drawings. Students will take a picture of their working automata and write a short story of their electromechanical system.

Activity 4.4.1 (Alternate): Move with a Purpose: Students will design a Rube Goldberg Machine to be housed in the Museum of Industry and Mechanisms. The purpose of the display is to illustrate a transfer of motion through a physical electromechanical system that solves a simple task. They will create a 3D model of their design and present their concept to the class.

Activity 4.4.2 (Alternate): Engineering for Change: Students will use everything they have learned in the course to define a problem that is worth solving. They will completely define their problem using design briefs with clearly identified criteria and constraints, brainstorm solutions, research the topic and create a 3D model and develop working drawings. Students will write a proposal and prepare a presentation to showcase their ideas.

Women's History Month: March 1st - March 31st

1) Exhibitions and Collections

Students will access the Exhibitions and Collections of various influential women throughout history on the Women's History Month Website. Each student will choose one exhibition or collection to explore and write a summary describing the life, accomplishments and work of the person portrayed in the exhibition or collection of their choice.

2) Scavenger Hunt

Students will take part in a Women's History Month Scavenger Hunt. Students will be placed in groups. Each group will be provided with the Women's History Month Scavenger Hunt Worksheet. Each group will use their researching skills to figure out who each Scavenger Hunt description is describing. Points will be given for each correct answer. Points gained during activity will be used as extra credit.

3) Virtual Museum Tour

Students will take part in a virtual visit to the Smithsonian: Because of HER History to explore the ingenuity and accomplishments of Women in Science & Innovation. Students will choose one of seven Collection Objects to explore. Students will create a short video on Adobe spark to portray what was learned in the collection objects explored.

Juneteenth: June 19th

1) Juneteenth National Freedom Day Poster

Students will work in groups to create and present a poster that explains the history and importance of Juneteenth. Students will understand the significance of Juneteenth and explore present day celebrations and learn about the impact of African American leaders.

Extensions (Tier I):	Differentiation (Tiers II and III):
● Additional Cam designs ● Cam Mechanisms- compare complex cams and their function ● Additional cams and motions in Automata Design ● Office Hour Appointments	● Group work will allow high-tier students to support low-tier students ● Open-ended design challenges will allow students to create solutions appropriate for their design and modeling skills ● CAD Tutorial Videos will be provided to aid struggling students

	• CAD Challenges will be provided to challenge students who are excelling • Peer Tutoring • One on one discussions • Office Hour Appointments

Stage 3 – Learning Plan
Project Lead the Way (PLTW) Introduction to Engineering Design Digital Textbook (password required): https://pltw.read.inkling.com/a/b/c9ddcf5dc84f4dca98e9dda94d41c727/p/c0fc8676465f4e15bd4602a84390092b The IED Digital Textbook linked above includes informational text, videos procedures, project requirements, presentations, and technical drawings used in the design of the learning tasks described in the stage 2 section of this unit plan.

Vocabulary
Applied force / Automaton / Average Speed / Bushing / Cam / Circuit schematic / Coefficient of friction / Compression force / Constant force spring / Current / Displacement / Distance / Effort force / Elasticity / Electric Circuit / Electromechanical / Fixed pulley / Friction / Fulcrum / Gear ratio / Gear train / Involute / Kinematics / Linear Motion / Linear Spring / Mechanical Advantage / Mock up / Motion / Movable pulley / Multimeter / Ohmmeter / Open circuit / Parallel circuit / Resistance / Resistance force / Resistor / Rolling friction / Series circuit / Simple machine / Slide switch / Sliding friction / Speed / Spring constant / Spring force / Static friction / Trend / Variable spring / Velocity / Voltage / Voltmeter / Watt hours / Work
Expert/Field Experience(s) • Field Trips: Mechanical Toy Company • Potential Guest Speakers: CAD Drafter, Product Designer, Electrical Engineer Literacy Connections/Research • Students will research the different types of motion and how it applies to everyday life. • Students will research electricity, usage and storage of energy. • Interesting Engineering articles will give students the opportunity to read about technical engineering advancements and make decisions regarding its ethical implications, which can then be discussed and debated as a class.

<table>
<tr><th>Special Education/ 504:</th><th>English Language Learners:</th></tr>
<tr><td>-Adhere to all modifications and health concerns stated in each IEP.
-Give students a MENU options, allowing students to pick assignments from different levels based on difficulty.
-Accommodate Instructional Strategies: reading aloud text, graphic organizers, one-on-one instruction, class website (Google Classroom), handouts, definition list with visuals, extended time
-Allow students to demonstrate understanding of a problem by drawing the picture of the answer and then explaining the reasoning orally and/or writing , such as Read-Draw-Write
-Provide breaks between tasks, use positive reinforcement, use proximity
-Assure students have experiences that are on the Concrete- Pictorial- Abstract spectrum by using manipulatives
-Implement supports for students with disabilities (click here)
- Make use of strategies imbedded within lessons
-Common Core Approach to Differentiate Instruction: Students with Disabilities (pg 17-18)</td><td>- Use manipulatives to promote conceptual understanding and enhance vocabulary usage
- Provide graphic representations, gestures, drawings, equations, realia, and pictures during all segments of instruction
- During i-Ready lessons, click on “Español” to hear specific words in Spanish
- Utilize graphic organizers which are concrete, pictorial ways of constructing knowledge and organizing information
- Use sentence frames and questioning strategies so that students will explain their thinking/ process of how to solve word problems
- Utilize program translations (if available) for L1/ L2 students
- Reword questions in simpler language
- Make use of the ELL Mathematical Language Routines (click here for additional information)
-Scaffolding instruction for ELL Learners
-Common Core Approach to Differentiate Instruction: Students with Disabilities (pg 16-17)</td></tr>
<tr><th>Gifted and Talented:</th><th>Students at Risk for Failure:</th></tr>
<tr><td>- Elevated contextual complexity
- Inquiry based or open ended assignments and projects
- More time to study concepts with greater depth
- Promote the synthesis of concepts and making real world connections
- Provide students with enrichment practice that are imbedded in the curriculum such as:
● Application / Conceptual Development
● Are you ready for more?
- Provide opportunities for math competitions
- Alternative instruction pathways available
- Common Core Approach to Differentiate Instruction: Students with Disabilities (pg. 20)</td><td>- Assure students have experiences that are on the Concrete- Pictorial- Abstract spectrum
- Modify Instructional Strategies, reading aloud text, graphic organizers, one-on-one instruction, class website (Google Classroom), inclusion of more visuals and manipulatives, Peer Support
- Constant parental/ guardian contact
- Provide academic contracts to students & guardians
- Create an interactive notebook with samples, key vocabulary words, student goals/ objectives.
- Plan to address students at risk in your learning tasks, instructions, and directions. Anticipate where the needs will be, then address them prior to lessons.</td></tr>
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	-Common Core Approach to Differentiate Instruction: Students with Disabilities [(pg 19)]

21st Century Life and Career Skills: Career Ready Practices describe the career-ready skills that all educators in all content areas should seek to develop in their students. They are practices that have been linked to increase college, career, and life success. Career Ready Practices should be taught and reinforced in all career exploration and preparation programs with increasingly higher levels of complexity and expectation as a student advances through a program of study. https://www.state.nj.us/education/cccs/2014/career/9.pdf	
• CRP1. Act as a responsible and contributing citizen and employee. • CRP2. Apply appropriate academic and technical skills. • CRP3. Attend to personal health and financial well-being. • CRP4. Communicate clearly and effectively and with reason. • CRP5. Consider the environmental, social and economic impacts of decisions. • CRP6. Demonstrate creativity and innovation.	• CRP7. Employ valid and reliable research strategies. • CRP8. Utilize critical thinking to make sense of problems and persevere in solving them. • CRP9. Model integrity, ethical leadership and effective management. • CRP10. Plan education and career paths aligned to personal goals. • CRP11. Use technology to enhance productivity. • CRP12. Work productively in teams while using cultural global competence.
Students are given an opportunity to communicate with peers effectively, clearly, and with the use of technical language. They are encouraged to reason through experiences that promote critical thinking and emphasize the importance of perseverance. Students are exposed to various mediums of technology, such as digital learning, calculators, and educational websites.	

<table>
<tr><th colspan="2">Technology Standards:
All students will be prepared to meet the challenge of a dynamic global society in which they participate, contribute, achieve, and flourish through universal access to people, information, and ideas.
https://www.state.nj.us/education/cccs/2014/tech/</th></tr>
<tr><td>8.1 Educational Technology:

All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.

A. Technology Operations and Concepts: Students demonstrate a sound understanding of technology concepts, systems and operations.
B. Creativity and Innovation: Students demonstrate creative thinking, construct knowledge and develop innovative products and process using
C. technology.Communication and Collaboration: Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others.
D. Digital Citizenship: Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.
E. Research and Information Fluency: Students apply digital tools to gather, evaluate, and use of information.
F. Critical thinking, problem solving, and decision making: Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources.</td>
<td>Technology Education, Engineering, Design, and Computational Thinking - Programming:

All students will develop an understanding of the nature and impact of technology, engineering, technological design, computational thinking and the designed world as they relate to the individual, global society, and the environment.

A. The Nature of Technology: Creativity and Innovation- Technology systems impact every aspect of the world in which we live.
B. Technology and Society: Knowledge and understanding of human, cultural, and societal values are fundamental when designing technological systems and products in the global society.
C. Design: The design process is a systematic approach to solving problems.
D. Abilities in a Technological World: The designed world in a product of a design process that provides the means to convert resources into products and systems.
E. Computational Thinking: Programming- Computational thinking builds and enhances problem solving, allowing students to move beyond using knowledge to creating knowledge.</td></tr>
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