Theme

"Improvement usually means doing something that we have never done before." - Shigeo Shingo

STEM Innovation Academy Unit 3

Subject: Introduction to Engineering Design Unit Title: Thoughtful Product Design Grade: 9th	Teacher: Mrs. Braizer-Martin Duration: 9 weeks; January - March

Summary of Unit

In this unit, students reverse engineer a multi-material consumer product. Then they identify and research the component materials and the material properties that contribute to their selection for use in the product. Students are introduced to life cycle analysis, systems thinking, and ethical considerations in design, and they compare the life cycle of common competing products (such as plastic versus paper shopping bags). This lesson emphasizes the importance of identifying measurable design criteria that define a successful solution and that can be used to evaluate a potential solution. The concept of human-centered design is introduced as students are led through a design experience focused on user needs, perceptions and behaviors, and the design trade-offs necessary in every design process. Students also apply systems thinking to engineering design and consider the ethical implications of engineering decisions. A modern CAD feature, generative design is introduced as a tool to optimize design solutions. Students use the output from a generative design algorithm to explore and select a potential design alternative. In teams, students identify a problem worth solving and apply human-centered design principles and systems thinking to design a gadget to solve the problem as they practice collaboration and communication skills. In teams, students act as an engineering consulting group to solve a problem from a list of problems gathered from school and/or community stakeholders. As part of the design process, the team applies the engineering design process to develop a sustainable solution that includes consideration of material choices and the life cycle of the design. Students meet with the client to understand user needs, develop effective design criteria to inform the design, and create a project design brief. Students also practice important project management skills including developing a task and delivery schedule to manage and monitor project work and facilitating project meetings to report project progress.

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 are the steps of a product life cycle and how can we use the product lifecycle to compare the environmental impact of products?
2. What is sustainable design and how does the choice of material used for a product affect sustainable design?
3. How do you create measurable criteria and constraints?
4. What role does empathy play in human centered design?
5. What can a systems model tell us about how a product interacts with its surroundings?
6. What is generative design and how can we use generative design to determine the effectiveness of our solutions?
7. How can we use statistics to optimize solutions?
8. What behaviors lead to a successful team?
9. What are the roles of a project manager and how can we use a Gantt Chart to schedule projects?

Enduring Understandings: *Students will understand that…*

- All products have a life cycle.
- Analysis, systems thinking, and ethical considerations in design is conducted to compare the life cycle of common competing products (such as plastic versus paper shopping bags).
- The importance of identifying measurable design criteria that defines a successful solution and that can be used to evaluate a potential solution.
- 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:

- Reverse Engineer a Product
- Application of the Design Process
- Identification of criteria and constraints
- CAD- Part models and Assembly models
- Engineering Notebook Documentation
- Quizzes and Tests
- Unit Test

Presentation:

- Students will present their findings about the product they reverse engineered
- Students will formally present all design challenge work by documenting their work in their engineering notebooks
- Students will present their gadget designs as if they were trying to sell their product to consumers
- Students will conduct a gallery walk to present their solutions to their engineering consultant design work

Performance Task(s):

Activity 3.1.1: Reverse Engineer a Product: Students will analyze a consumer product using reverse engineering techniques to document visual, functional, and structural aspects of the design as well as consider material properties. Students will present their findings, appropriately using digital media to enhance understanding of findings, reasoning, and evidence and to add interest.

Activity 3.1.2: Product Lifecycle: Students will learn about the steps of a product's lifecycle. They will conduct research to conduct a life cycle assessment for at least two products that serve the same function and then you compare the findings. Students will devise a way to quantitatively compare the impact of the products and brainstorm ways to repurpose or recycle their products.

Activity 3.1.3: Sustainable Design: Students will research sustainability and sustainability engineers. They will reflect on material properties that affect the sustainability of products. They will research carbon fiber reinforced plastic and justify whether or not they would use the product.

Activity 3.1.4: Design Criteria and Constraints: Students will create a list of criteria and constraints for a product of their choice. Students will review a partner's list, receive feedback and revise based on feedback.

Activity 3.1.5: Consider the Impact: Students will choose a product and brainstorm ways to reduce the environmental impact of the product, while maintaining its performance and quality. Students will conduct an inventory analysis to consider the environmental impact at each stage of the product's lifecycle. Students will create a written proposal to present their improved product idea.

Activity 3.2.1: Human-Centered Design: Students will create interviews or surveys to determine the seating needs of people in different classrooms around the school. They will then conduct those interviews/surveys and make observations. Students will use the information gathered to design a chair that meets user's criteria and constraints. They will sketch the idea and create a scaled prototype.

Activity 3.2.2: Whole-Systems Thinking: Students will create a systems model to tell the story of how a chosen consumer product interfaces with surrounding systems. Then, the students will think about the product's interactions more broadly, considering marketing, materials, environment and manufacturing. Students will analyze a design problem from a systems thinking perspective.

Activity 3.2.3: Generative Design: Students will learn how to consider stress and strain factors in their design by using generative design software on Inventor. They will consider the needs of their chair designs and try to narrow potential solutions using generative design software.

Activity 3.2.4: When is "Good" Good Enough?: Students will apply optimization skills and inferential statistics to optimize product quality. They will review provided data from manufacturing production runs and determine whether investment should be made in the equipment based on how closely the data meets the customer's specifications.

Activity 3.2.5: Gadget Design: Students will go through every step of the design process to design a useful gadget. They will conduct consumer interviews, create a systems model, construct a model, collect data and recommend improvements to optimize their design. They will present their design in the style of a 30 sec commercial.

Activity 3.3.1: Establishing a Team: Students will create a list of team norms and methods of effective collaboration to guide their group work on their current project.

Activity 3.3.2: Project Scheduling: Students will use a Gantt Chart to organize the tasks they will have to complete for this project. They will organize them and roughly decide how long each task will take, and consider who will be responsible for each task.

Activity 3.2.3: The Engineering Consultant: Students will work as engineers hired by a consultant to solve a problem. They will go through every step of the design process, including following their project schedule, create CAD models, conduct a life cycle assessment (with an Inventory Analysis). Students will conduct a gallery walk to present their solutions.

Black History Month: February 1st - March 1st

1) Design a Poster on Canva

Students will research Black Engineers or STEM contributors to create a poster on Canva to portray the life and accomplishments of the person of their choice. Poster should include historical information and pictures.

2) The Intellectual Property of Eli Whitney

Students will analyze Eli Whitney's patent for invention and the petition he filed with Congress concerning his invention. Students will summarize the documents and respond to the following questions;

What was the loophole in the 1793 patent law? Why did Eli Whitney write the petition to Congress? What evidence did Eli Whitney have to support his petition?

3) Scavenger Hunt

Students will take part in a Black History Scavenger Hunt. Students will be placed in groups. Each group will be provided with the Black History 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.

4) Virtual Museum Tour

Students will take part in a virtual visit of The Black Inventor Online Museum to explore the ingenuity and accomplishments of Black Inventors over the last 300 years. Students will also choose one Black Inventor to write a biography on.

Extensions (Tier I):	Differentiation (Tiers II and III)
• Additional criteria and/or constraints in design challenges • Product Lifecycle- compare more items that have the same function • Interview more people- get more criteria and constraints • 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

Anthropometric / Carbon footprint / Collaboration / Commercial / Consensus / Constraint / Constructive Criticism / Criteria / Critical Path / Gantt Chart / Generative Design / Human-centered Design / Internet of Things / Life cycle assessment / Optimization / Planned Obsolescence / Product Life / Product Lifecycle / Project / Project Charter / Project Management / Project Risk Management / Project scope / Raw materials / Recycle / Renewable / Runoff / Safety Factor / Service life / Stakeholder / Stormwater runoff / Sustainable / Sustainable design / Systems Thinking / Team / Team Norms

Expert/Field Experience(s)

- Field Trips: Assembly Company, Material Company
- Potential Guest Speakers: CAD Drafter, Product Designer, Environmental Engineer

Literacy Connections/Research

- Students will research the components of a product's lifecycle
- Students will research about sustainability, sustainability engineers and sustainable materials
- 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

Special Education/ 504:	**English Language Learners:**
-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)	- 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)

Gifted and Talented:	Students at Risk for Failure:
- 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)	- 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. -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.

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/

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.

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.

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.	