Theme

"Anything that works against you can also work for you once you understand the Principle of Reverse." - Maya Angelou

STEM Innovation Academy Unit 2

Subject: Introduction to Engineering Design Unit Title: Assembly Design Grade: 9th	Teacher: Mrs. Allison Braizer-Martin Duration: 9 weeks; November - January

Summary of Unit

In this unit, students learn methods to physically join parts in an assembly, including mechanical fasteners, adhesives, press fits, and hinges. They learn about different types of fit and how to specify tolerances to achieve desired fits between interacting parts. Students then learn how to assemble parts using CAD and create simple bottom-up assemblies that realistically simulate physical mechanical systems. Assemblies are documented in CAD with assembly drawings. Students apply engineering principles and practices to reverse engineer and improve a consumer product by disassembling and analyzing a product or system to understand and document the visual, functional, and/or structural aspects of its design. Students will also conduct a case study of a common consumer product to identify potential ways to improve the manufacturability and ease of assembly of the product. Students will also use top-down modeling to model the consumer product students have reverse engineered. They will apply the design process again to design and prototype (3D print) an integrated accessory for the reverse engineered product and present the design. Finally, in this unit students investigate a variety of materials through experimentation and are tasked with selecting materials to serve a specific purpose. The types of materials investigated include wood, metals, ceramics, plastics, and composites to identify properties that may impact material selection. Properties investigated can include density, conductivity, strength, flexibility, hardness, and so on. Students learn how to assign specific materials to CAD models and to differentiate between assigning the physical properties of a material to a part and only changing the visual appearance of the part. Students work within a team to imagine the future through research of innovative materials and the redesign of a product using advanced materials. Lastly, students work collaboratively to reverse engineer and troubleshoot a non-working, multi-component mechanical device. Then, team members work together to redesign the device, produce working drawings, and produce new parts to correct the design and manufacture a working physical model.

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.

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

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).

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 different types of tolerance and how can I use tolerance to achieve desired fits between interacting parts?
2. What are the different types of joining techniques?
3. What are assembly joints and how can I use them to create assembled product on CAD?

4. How can we appropriately document design intent using exploded views and parts lists?
5. What is reverse engineering?
6. What is visual analysis and how can I use it to better understand a product?
7. What is functional analysis and how can I use it to better understand a product?
8. What is structural analysis and how can I use it to better understand a product?
9. What is the difference between top down and bottom up modeling and what is it advantageous to use each?
10. What are the principles of design for manufacturing and how can they be used to improve products?
11. What are the different properties materials can have and how can they be used to identify materials, and to recommend the best materials for certain uses.

Enduring Understandings: *Students will understand that…*

- CAD skills are built upon.
- There are several methods used to physically join parts into an assembly (including mechanical fasteners and adhesives as well as press fits and hinges).
- It is important to learn Interference and clearance fits and to specify tolerances to achieve desired fits between interacting parts.
- CAD assembly modeling is used to create simple bottom-up assemblies that realistically simulate physical assemblies and document assemblies with CAD drawings.
- Iteration is applied to earlier design projects to incorporate new skills and knowledge learned
- Applying appropriate engineering tolerances will specify the allowable variation, size of individual features, and orientation and location between features of an object.
- Using the mean and standard deviation of a data set will fit it to a normal distribution and using the Empirical Rule estimates population percentages.
- Applying engineering principles and practices to reverse engineer and improve a consumer product is also a part of the design process.
- The process of Reverse Engineering involves analyzing the product's function, structure, and visual elements.
- It is necessary to conduct a case study of a common consumer product to identify potential ways to improve the manufacturability and ease of assembly of the product.
- You'll learn a second method of CAD assembly modeling, top-down modeling, to help you more efficiently model mechanical systems. And finally, you'll have an opportunity to design and prototype (3D print) an integrated accessory for a product that you have reverse engineered and present the design.
- Investigating a variety of materials through experimentation and selecting materials to serve a specific purpose is part of the engineering design process.
- Types of materials investigated include wood, metals, ceramics, plastics, and composites and that identifying properties may impact material selection.
- There are different properties investigated that may include density, conductivity, strength, flexibility, hardness, and so on.
- Assigning specific materials to CAD models differentiates between assigning the physical properties of a material to a part and only changing the visual appearance of the part.
- Listing material properties are important to design, including mechanical, chemical, electrical, and magnetic properties.
- Performing an experimental protocol investigates a phenomenon and/or helps to gain knowledge.
- Conducting non-destructive tests (hardness, flexure, conductivity) on different material types investigates material properties.

- Creating and interpreting a computer model or simulation of simple objects, assemblies, or systems to inform engineering decisions solve problems.
- Creating technical drawings using 3D computer-aided design (CAD) software documents a design according to standard engineering practices.
- Communicating effectively with an audience is based on audience characteristics.

Stage 2 – Assessment Evidence

Formative, Summative and Authentic Assessments:

- Design Process
- Engineering Notebook Documentation
- Modelling of 3D Objects with CAD software
- CAD Part files
- How to plug in numbers for variables in formulas
- Quizzes and Tests
- Unit Test
- Protective Case Project
- Assemble It! Project

Presentation:

- Students will formally present all design challenge work by documenting their work in their engineering notebooks
- Students will present on their assigned type of joining technique to inform the class
- Students will orally present their accessory for their reverse engineered product, acting as though they are pitching the idea to a client
- Students will orally present their design for an application of their chosen material
- Students will orally present their improvement to the trammel toy flaws, acting as though they are pitching the idea to a client

Performance Task(s):

Activity 2.1.1: Tolerate This: Students will apply appropriate tolerances to specify the allowable variation, size of individual features, and orientation and location between features of an object. They will then use the mean and standard deviation of a data set to fit it to a normal distribution and use the Empirical Rule to estimate population percentages.

Activity 2.1.2: Hold it Together: Students will research an assigned type of joining technique and present their findings to the class. Together, the class will have compiled a database of information about many different joining techniques.

Activity 2.1.3: Putting it Together: Students will apply assembly joint constraints to create assembled files in CAD.

Activity 2.1.4: Document the Assembly: Students will document assemblies appropriately by creating exploded multiview drawings with descriptive annotations.

Activity 2.2.1: What is Reverse Engineering?: Students will closely analyze the inner and outer workings of a video game controller to learn the processes involved in reverse engineering.

Activity 2.2.2: Visual Analysis: Students will perform a visual analysis of an object of their choosing by describing how the elements and principles of design are at work in the product.

Activity 2.2.3: Functional Analysis and the Black Box: Students will perform a functional analysis of an object of their choosing by describing how it works, and describing the system's inputs and outputs.

Activity 2.2.4: Structural Analysis and Product Disassembly: Students will perform a structural analysis of an object of their choosing by taking it apart and noting details of each component through a Product Disassembly Chart. Students will create 3D CAD models of each component of their product.

Activity 2.2.5: CAD Design Tools: Students will apply more advanced CAD commands, such as the sweep, revolve and construction features, to 3D model a simplified version of a water heating tube for a coffee maker, which students have been looking at as an example during each step of the reverse engineering process.

Activity 2.2.6: Top down or bottom up?: Each member of a group will be assigned a subassembly, which they will create using top down modeling. Students will create assembly drawings for their subassemblies, including multiview drawings, exploded views, parts lists, and title blocks. Then, the group will assemble their subassemblies to create their full assembly model, using bottom up modeling.

Activity 2.2.7: Design for Manufacturability and Assembly: Students will apply the principles of design for manufacturability and assembly of mechanical products by analyzing a jaw style staple remover, conducting a functional analysis, product disassembly and calculating the complexity factor. Students will analyze manufacturing processes to brainstorm what parts of the stapler remover could be adapted to improve its manufacturability, taking DFMA guidelines into account.

Activity 2.3.1: Material Properties: Students explore material properties, starting with mass, weight, volume and density and then getting into more complicated properties, such as chemical, magnetic, thermal and mechanical properties. Students will conduct non-destructive tests (hardness, flexure, conductivity) on different material types to investigate material properties.

Activity 2.3.2: Evaluating Materials: Students will select and justify the use of materials for prototyping and manufacturing products. Students will design a Martian Habitat, focusing on justifying why they chose certain materials to use for different parts of the habitat.

Activity 2.3.3: Students will change the material and appearance of their CAD models. Students will create new materials in CAD that they can assign properties to. Students will run interference testing on CAD assemblies to observe and fix overlap among part files in an assembly.

Authentic Assessments

Activity 2.1.5: Students will redesign their protective cases from the prior unit while including a specific hinge design for the cover and model the assembly on CAD.

Activity 2.2.8: Design an Integrated Assembly: Students will use what they learned while reverse engineering the product of their choosing throughout the unit to brainstorm an accessory that could improve the product. Students will create CAD assemblies of their products, document their assemblies and present their design processes using a project portfolio.

Activity 2.3.4: Students will choose a material and conduct research to understand the properties and uses of the material. Then students will imagine a future application for the material. They will design their new product and create a model of it using CAD.

Activity 2.4.1: Troubleshoot an Assembly: Students will use what they learned throughout the unit to design and model improvements to a toy that has been manufactured with design flaws. They must consider the type of fit needed between interfacing parts to provide proper function to the system. They must also consider both bottom up and top down assembly and apply assembly constraints to the object. Lastly, they must consider the choice of material for the components.

Extensions (Tier I):	Differentiation (Tiers II and III)
• Additional criteria and/or constraints in design challenges • Give students opportunities to research more types of joining techniques • Give students opportunities to research more types of materials • 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

Abstraction / Aesthetic / Allowance / Assembly / Balance / Bilateral Tolerance / Black Box / Bottom Up Modeling / Color/ Degree of Freedom / Design for Assembly / Design for Manufacturability / Elasticity / Form / Functional Analysis / Joint / Limit Dimensions / Manufacture / Mass / Mass Density / Material / Physical Properties / Polymers / Shear Stress / Simple Machines / Strain / Stress / Tension Force / Tolerance / Top Down Modeling / Unilateral Tolerance / Volume / Weight / Working Drawings

Expert/Field Experience(s)

- Field Trips: Manufacturing Plant
- Potential Guest Speakers: Manufacturer, Material Scientist, CAD Drafter

Literacy Connections/Research

- Students must research information about joining types and use that information they learned, as well as they information their classmates learned to inform decisions about assembly for their own designs
- Students must research information about material properties and uses to inform their choices for materials for their own designs
- 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.	