Unit 3: Thoughtful Product Design (7 Weeks)

Content Area: **STEM**
Course(s):
Time Period: **Full Year**
Length: **7 Weeks**
Status: **Published**

UNIT RATIONALE

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.

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?

STANDARDS

NEW JERSEY STUDENT LEARNING STANDARDS: CAREER READINESS, LIFE LITERACIES AND KEY SKILLS

TECH.9.4.12.CI.1	Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).
TECH.9.4.12.CI.2	Identify career pathways that highlight personal talents, skills, and abilities (e.g., 1.4.12prof.CR2b, 2.2.12.LF.8).
TECH.9.4.12.CI.3	Investigate new challenges and opportunities for personal growth, advancement, and transition (e.g., 2.1.12.PGD.1).

NEW JERSEY STUDENT LEARNING STANDARDS: COMPUTER SCIENCE AND DESIGN THINKING

CS.9-12.8.2.12.ED.2	Create scaled engineering drawings for a new product or system and make modification to increase optimization based on feedback.
CS.9-12.8.2.12.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).

New Jersey Student Learning Standards: 21st Century

CRP.K-12.CRP1.1	Career-ready individuals understand the obligations and responsibilities of being a member of a community, and they demonstrate this understanding every day through their interactions with others. They are conscientious of the impacts of their decisions on others and the environment around them. They think about the near-term and long-term consequences of their actions and seek to act in ways that contribute to the betterment of their teams, families, community and workplace. They are reliable and consistent in going beyond the minimum expectation and in participating in activities that serve the greater good.
CRP.K-12.CRP2.1	Career-ready individuals readily access and use the knowledge and skills acquired through experience and education to be more productive. They make connections between

	abstract concepts with real-world applications, and they make correct insights about when it is appropriate to apply the use of an academic skill in a workplace situation.
CRP.K-12.CRP4.1	Career-ready individuals communicate thoughts, ideas, and action plans with clarity, whether using written, verbal, and/or visual methods. They communicate in the workplace with clarity and purpose to make maximum use of their own and others' time. They are excellent writers; they master conventions, word choice, and organization, and use effective tone and presentation skills to articulate ideas. They are skilled at interacting with others; they are active listeners and speak clearly and with purpose. Career-ready individuals think about the audience for their communication and prepare accordingly to ensure the desired outcome.
CRP.K-12.CRP5.1	Career-ready individuals understand the interrelated nature of their actions and regularly make decisions that positively impact and/or mitigate negative impact on other people, organization, and the environment. They are aware of and utilize new technologies, understandings, procedures, materials, and regulations affecting the nature of their work as it relates to the impact on the social condition, the environment and the profitability of the organization.
CRP.K-12.CRP6.1	Career-ready individuals regularly think of ideas that solve problems in new and different ways, and they contribute those ideas in a useful and productive manner to improve their organization. They can consider unconventional ideas and suggestions as solutions to issues, tasks or problems, and they discern which ideas and suggestions will add greatest value. They seek new methods, practices, and ideas from a variety of sources and seek to apply those ideas to their own workplace. They take action on their ideas and understand how to bring innovation to an organization.
CRP.K-12.CRP7.1	Career-ready individuals are discerning in accepting and using new information to make decisions, change practices or inform strategies. They use reliable research process to search for new information. They evaluate the validity of sources when considering the use and adoption of external information or practices in their workplace situation.
CRP.K-12.CRP10.1	Career-ready individuals take personal ownership of their own education and career goals, and they regularly act on a plan to attain these goals. They understand their own career interests, preferences, goals, and requirements. They have perspective regarding the pathways available to them and the time, effort, experience and other requirements to pursue each, including a path of entrepreneurship. They recognize the value of each step in the education and experiential process, and they recognize that nearly all career paths require ongoing education and experience. They seek counselors, mentors, and other experts to assist in the planning and execution of career and personal goals.
CRP.K-12.CRP12.1	Career-ready individuals positively contribute to every team, whether formal or informal. They apply an awareness of cultural difference to avoid barriers to productive and positive interaction. They find ways to increase the engagement and contribution of all team members. They plan and facilitate effective team meetings.

NEW JERSEY STUDENT LEARNING STANDARDS: Technology

New Jersey Core Curriculum - Grade 9 - Technology

8.1.12.A.2

Produce and edit a multi-page digital document for a commercial or professional audience and present it to peers and/or professionals in that related area for review.

8.1.12.C.1

Develop an innovative solution to a real world problem or issue in collaboration with peers and experts, and present ideas for feedback through social media or in an online community.

8.1.12.D.1

Demonstrate appropriate application of copyright, fair use and/or Creative Commons to an original work.

8.1.12.D.5

Analyze the capabilities and limitations of current and emerging technology resources and assess their potential to address personal, social, lifelong learning, and career needs.

8.2.12.A.1

Propose an innovation to meet future demands supported by an analysis of the potential full costs, benefits, trade-offs and risks, related to the use of the innovation.

8.2.12.A.2

Analyze a current technology and the resources used, to identify the trade-offs in terms of availability, cost, desirability and waste.

8.2.12.A.3

Research and present information on an existing technological product that has been repurposed for a different function.

8.2.12.B.1

Research and analyze the impact of the design constraints (specifications and limits) for a product or technology driven by a cultural, social, economic or political need and publish for review.

8.2.12.C.2

Analyze a product and how it has changed or might change over time to meet human needs and wants.

8.2.12.C.5

Create scaled engineering drawings of products both manually and digitally with materials and measurements labeled.

8.2.12.C.6

Research an existing product, reverse engineer and redesign it to improve form and function.

TECH.8.1.12.A.2	Produce and edit a multi-page digital document for a commercial or professional audience and present it to peers and/or professionals in that related area for review.
TECH.8.1.12.C.1	Develop an innovative solution to a real world problem or issue in collaboration with peers and experts, and present ideas for feedback through social media or in an online community.
TECH.8.1.12.D.1	Demonstrate appropriate application of copyright, fair use and/or Creative Commons to an original work.
TECH.8.1.12.D.5	Analyze the capabilities and limitations of current and emerging technology resources and assess their potential to address personal, social, lifelong learning, and career needs.
TECH.8.2.12.A.1	Propose an innovation to meet future demands supported by an analysis of the potential full costs, benefits, trade-offs and risks, related to the use of the innovation.
TECH.8.2.12.A.2	Analyze a current technology and the resources used, to identify the trade-offs in terms of availability, cost, desirability and waste.
TECH.8.2.12.A.3	Research and present information on an existing technological product that has been repurposed for a different function.
TECH.8.2.12.B.1	Research and analyze the impact of the design constraints (specifications and limits) for a product or technology driven by a cultural, social, economic or political need and publish for review.
TECH.8.2.12.C.2	Analyze a product and how it has changed or might change over time to meet human needs and wants.
TECH.8.2.12.C.5	Create scaled engineering drawings of products both manually and digitally with materials and measurements labeled.

TECH.8.2.12.C.6	Research an existing product, reverse engineer and redesign it to improve form and function.

PRE-ASSESSMENTS

Determining an alternate use for a given worn out product based on its end of life cycle.

INSTRUCTIONAL PLAN

MODULE 1

Activity 3.1.1

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Disassemble more complicated product - Create a Google Slideshow
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Presentation of Information gathered from Analysis
Formative Assessment (drives instructional decisions)	- Google Slide Show
Activities and Resources	- See Above

Suggested Modifications

English Language Learners
Adjusted Speech: The teacher changes speech patterns to increase student comprehension. This could include facing the students, paraphrasing, clearly indicating the most important ideas, and speaking more slowly.

Visuals: The teacher uses graphics, pictures, visuals, and manipulatives. This helps ELL students better understand and comprehend the subjects at hand.

Front-Loading Vocabulary: The teacher front loads vocabulary This means providing students with a list of important vocabulary words they will need to know for a book, lesson, etc. prior to the lesson being taught. Including pictures to go with the vocabulary words is also very beneficial for the students.

Students with Individualized Education Plans/504s
Chunking: The teacher presents information in a way that makes it easy for students to understand and remember. Chunking is based on the presumption that our working memory is easily overloaded by excessive detail. The best way to deliver information is to organize it into meaningful units. Because students with special needs get overloaded easily, chunking is a effective strategy to use with them.

Checking for Understanding: It is important to constantly check for understanding, especially for students who have accommodations. Teachers want to make sure students understand the concepts being covered in a way that makes sense to them.

Extra time: The teacher provides students with special needs extra time to complete work or answer questions. It is important to give students enough time to process their thoughts.

Oral Reading: The teacher will read work orally to students. Class work such as tests and literature circles may need to be read aloud to the student.

Gifted & Talented Strategies
Extensions/Enrichments: Teachers will provide gifted and talented students with extension/enrichment projects. Students will be challenged to further their understanding, to apply acquired knowledge, and/or to produce something in reference t acquired knowledge.

Modify/Change Activities: Teachers will monitor and modify activities to accommodate those students who need to be challenged further. Additional reading, problem-solving, writing, or project work is necessary for those students who are ready to move on at a rate more accelerated than their peers. In this way, G & T students are provided the same opportunity for support as special needs students.

Students at Risk of School Failure
Directions or Instructions: Make sure directions and/or instructions are given in limited numbers. Give directions/instructions verbally and in simple written format. Ask students to repeat the instructions or directions to ensure understanding occurs. Check back with the student to ensure he/she hasn't forgotten.

Peer Support: Peers can help build confidence in other students by assisting in peer learning. Many teachers use the 'ask 3 before me' approach. This is fine, however, a student at risk may have to have a specific student or two to ask. Set this up for the student so he/she knows who to ask for clarification before going

	to you. **Alternate or Modified Assignments:** Always ask yourself, "How can I modify this assignment to ensure the students at risk are able to complete it?" Sometimes you'll simplify the task, reduce the length of the assignment or allow for a different mode of delivery. For instance, many students may hand something in, the at-risk student may jot notes and give you the information verbally. Or, it just may be that you will need to assign an alternate assignment. **Increase One to One Time:** When other students are working, always touch base with your students at risk and find out if they're on track or needing some additional support. A few minutes here and there will go a long way to intervene as the need presents itself. **Contracts:** It helps to have a working contract between you and your students at risk. This helps prioritize the tasks that need to be done and ensure completion happens. Each day write down what needs to be completed, as the tasks are done, provide a checkmark or happy face. The goal of using contracts is to eventually have the student come to you for completion sign-offs **Hands On:** As much as possible, think in concrete terms and provide hands-on tasks. This means a child doing math may require a calculator or counters. The child may need to tape record comprehension activities instead of writing them. A child may have to listen to a story being read instead of reading it him/herself. **Tests/Assessments:** Tests can be done orally if need be. Break tests down in smaller increments by having a portion of the test in the morning, another portion after lunch and the final part the next day. **Seating:** Seat students near a helping peer or with quick access to the teacher. Those with hearing or sight issues need to be close to the instruction which often means near the front.

Activity 3.1.2

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Define and Identify parts of a product Life Cycle - Calculate variables - Create Modifications to products according to data
Student Learning Strategies	Journaling

	Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Properly calculated results - Design Revisions based on data
Formative Assessment (drives instructional decisions)	- Engineering Notebook - Google Sheet
Activities and Resources	- See Above
Suggested Modifications	- See Activity 2.1.1

Activity 3.1.3

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Identify a Sustainability Engineer - Compare abilities of materials based on sustainability - Identify uses of Carbon Fiber in manufacturing
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Correctly filled out worksheet
Formative Assessment (drives instructional decisions)	- PLTW Website Info - Engineering Notebook
Activities and Resources	- See Above

Suggested Modifications	- See Activity 2.1.1

Activity 3.1.4

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Identify Compromises in Design and Material Choice based on Criteria and Constraints
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Decisions on Design and Material of a Product - Communication with partner
Formative Assessment (drives instructional decisions)	- Engineering Notebook
Activities and Resources	- See Above
Suggested Modifications	- See Activity 2.1.1

Activity 3.1.5

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Identify Compromises in Manufacturing and Distribution - Perform Inventory Analysis
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Drop in environmental score of at least 10%
Formative Assessment (drives instructional decisions)	- Engineering Notebook - Google Slide Show
Activities and Resources	- See Above
Suggested Modifications	- See Activity 2.1.1

MODULE 2

Activity 3.2.1

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Define Human Centered Design - Create a questionnaire - Interview a student - Create prototype
Student Learning Strategies	Journaling Collaboration Cooperative Learning

	APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Answers and analysis of interviews - properly scaled prototype driven by analysis data
Formative Assessment (drives instructional decisions)	- Engineering Notebook - 3D CAD file - Google Form Survey
Activities and Resources	- See Above
Suggested Modifications	- See Activity 2.1.1

Activity 3.2.2

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Define and Identify Systems and their Parts
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Inventory Analysis of System
Formative Assessment (drives instructional decisions)	- Engineering Notebook
Activities and Resources	- See Above
Suggested Modifications	- See Activity 2.1.1

Activity 3.2.3

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Define and Identify Generative Design - Use Generative Design Tool - Define and Input Stress/Strain into OnShape
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Properly constrained design - Proper forces applied
Formative Assessment (drives instructional decisions)	- Generative Design Results
Activities and Resources	- See Above
Suggested Modifications	- See Activity 3.1.1

Activity 3.2.4

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.

Student Learning Intentions (SLI) WALT: (We	- Use Optimization in a Design

are learning to…)	- Analyze Data to develop a solution
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Proper use of given data in result
Formative Assessment (drives instructional decisions)	- Engineering Notebook - PLTW Website Input
Activities and Resources	- See Above
Suggested Modifications	- See Activity 3.1.1

Activity 3.2.5

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Create video content and properly share - Utilize entire Design Process
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Video Commercial - 3D Printed Gadget
Formative Assessment (drives instructional decisions)	- Engineering Notebook - 3D CAD File

Activities and Resources	- See Above
Suggested Modifications	- See Activity 3.1.1

MODULE 3

Activity 3.3.1

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.

Student Learning Intentions (SLI) **WALT: (We are learning to…)**	- Identify and Create Team Norms - Identify and Assign Team Roles
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Group Communication - Properly Shared Files
Formative Assessment (drives instructional decisions)	- 3D CAD File
Activities and Resources	- See Above
Suggested Modifications	- See Activity 3.1.1

Activity 3.3.2

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Create and Modify Gantt Chart - Assign Responsibilities
Student Learning Strategies	Journaling Collaboration Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Students adhering to their roles - Team working smoothly
Formative Assessment (drives instructional decisions)	- Shared Gantt chart - 3D CAD File
Activities and Resources	- See Above
Suggested Modifications	- See Activity 3.1.1

Activity 3.3.3

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.

Student Learning Intentions (SLI) WALT: (We are learning to…)	- Develop Product Based on Student Needs - Create Gallery Display of Information
Student Learning Strategies	Journaling Collaboration

	Cooperative Learning APB Approach (Activities, Projects, Problems) Class Discussions
Success Criteria	- Gallery Display - Properly Scaled Prototype
Formative Assessment (drives instructional decisions)	- Gallery Display - 3D CAD File - Prototype
Activities and Resources	- See Above
Suggested Modifications	- See Activity 3.1.1

REFLECTIONS

INTERDISCIPLINARY CONNECTIONS: NEW JERSEY STUDENT LEARNING STANDARDS FOR ELA, SOCIAL STUDIES, SCIENCE AND/OR MATHEMATICS

CCSS.Math.Content.HSS-ID.A.1	Represent data with plots on the real number line (dot plots, histograms, and box plots).
CCSS.Math.Content.HSS-ID.A.2	Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.
CCSS.Math.Content.HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling.
CCSS.Math.Content.HSG-MG.A.1	Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).
CCSS.Math.Content.HSG-MG.A.2	Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).
SCI.HS-PS2	Motion and Stability: Forces and Interactions
SCI.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.
SCI.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.
CCSS.ELA-Literacy.CCRA.W.9	Draw evidence from literary or informational texts to support analysis, reflection, and research.
CCSS.ELA-Literacy.CCRA.SL.2	Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

CCSS.ELA-Literacy.CCRA.SL.4	Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.