UTICA CITY SCHOOL DISTRICT

Rapid Prototyping
Advanced Manufacturing: Project 1
8th grade

Essential Question: How can we translate artistic ideas into a manufactured product?

Project Background

This advanced manufacturing module seeks to give students an experience in various types of manufacturing processes, how designers and manufacturers work together to develop a product for mass production, and how different processes work together to take a product from production to packaging and shipping. This project will focus on additive manufacturing processes such as 3D printing. A product is built layer by layer as a material is melted and then solidified on a flat surface. In the next project, students will explore subtractive manufacturing, where a manufacturer produces a product by systematically cutting away from a block of material to achieve the final result. The final project in this module will give students experience in automating processes along an assembly line.

Project Scenario

You are part of a local trophy and specialty items manufacturing company. You are looking to add to your collection and appeal to potential customers in the greater Utica, NY area. The CEO has asked each team to develop a concept for a coin, pendant or other token to highlight local Social or historical events. Highlights can include tributes to events, people, or organizations. The scenes or images on the token should be recognizable to an appropriate audience.

Your team will develop a design for the front and back of a coin, token or pendant. Your product will need to be able to fit inside a box for shipping and marketing purposes and, therefore, cannot exceed 5.5" x 3.5" x 2.25”. This is the maximum allowable size of material from which the packaging will be made. You will also need to propose the final product's material and determine the final piece's weight.

You will determine a design for the front and back of your product, develop a virtual model of your design using 3D modeling software and then print a prototype of your product using the company’s 3D Printers. Your team will write a spec sheet about the token that includes important 3D model pictures of your design, important dimensions, final material, final mass, package requirements and anything else important to the manufacturing and shipping of your product.

You will present your final prototype to the CEO. To do so, you and your team will prepare a poster presentation detailing the social and/or historical significance of your product’s design and the process used to create the prototype. Your CEO will also need your design portfolio, which documents your work throughout the process.

Deliverables include:

- Prototype coin, pendant, token or trophy
- Design poster that includes your design process, rationale for your design, and proposed material and final weight estimates.
- Design portfolio
- Design spec sheet
- Professional notebook

Preparation Notes

This project will require students to have access to 3D modeling software such as OnShape, Autodesk Inventor, Autodesk Fusion 360 or SolidWorks. Some of these may require permission for students to access or have online accounts and may have specific computer requirements to run properly. Please check these requirements before starting this project and ensure that students will have access to your chosen software. Since each school may use a different 3D modeling software, we have not included software tutorials in this project. You will need to give students tutorials on the software as needed.

You will also need to double-check that the 3D printers you plan to use with this project are running and determine a process for transitioning the student *.stl files to the 3D printer. 3D printing can take a lot of time, so consider how and when you will load student files and print them out to best fit the project's flow.

With every project, students keep a professional notebook that captures their work and process on each project. Below are resources for starting and assessing the professional journal:

- Professional Notebook Presentation
- Professional Notebook Instructions
- Professional Notebook Checklist

This project asks students to design a coin, pendent, or token that can be marketed to people within the Utica community. This gives students something relatively “easy” and quick to design and print on a 3D printer. As you gain comfort with the project or have students ready for a greater challenge, you may choose to change the project's direction. For example, students could partner with a local business or industry to design something that solves a need. This can be a great way to incorporate community partners into the project and give students an authentic client. If you do, remember to update the project scenario. Also, keep in mind the project’s main goal is for students to learn about additive manufacturing, solid modeling, 3D printing, and documenting their design process.

Content Standards

The 8th-grade Advance Manufacturing Module dives students into learning more about possible careers in engineering, design, and manufacturing. As such, this module supports the NYSED CTE Theme Modules of Career and Community Opportunities in the areas of technology education and trade and industrial careers. As students use the design process to solve problems, collaborate, and use various forms of verbal and written communication throughout the project, we are addressing standards in the NYSCE Middle-Level CTE Theme Modules of Communication and Interpersonal Relationships, Problem-Solving, and Innovation.

This project will support addressing the following standards from the NYSED CTE Technology Education modules. Below is a list of the standards this project addresses.

- The Nature of Technology Module
  - Characteristics and Scope of Technology
- Design
  - The Attributes of Design
  - Engineering Design
- Abilities for a Technological World
  - Applying the Design Process
  - Use and Maintain Technological Products and Systems
  - Assess the Impact of Products and Systems
- The Designed World
  - Manufacturing Technologies

The unit overview below connects Utica's CTE Career Ready Practices and NYSE Computer Science and Digital Fluency Standards (CSDF). Throughout the unit of study, students will need their Power Skills to fully engage in the project; these have been indicated on the Map of Student Learning.

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Unit Overview

Unit Phase	Career Ready Practices and Digital Fluency Standards (CSDF)	Skills/Topics	Assessments	Resources and Texts
Ask **10 Days**	**Career Ready Practices** 1. Act as a responsible and contributing citizen and employee. 12. Work productively in teams while using cultural global competence. **7-8.DL.2** Communicate and collaborate with others using a variety of digital tools to create and revise a collaborative product. (used throughout the project)	Project Launch Task Analysis and Team Contract	Rapid Prototyping Project Rubric Know/Need-to-Know Team Contract Professional Notebook	Video: What is 3D Printing and How Does it Work? Project Scenario
	Career Ready Practices 1. Act as a responsible and contributing citizen and employee. 2. Apply appropriate academic and technical skills 12. Work productively in teams while using cultural global competence.	Lesson: Design and the Manufacturing Process ● Diagram the design process ● Explain what information is needed to start the design of their coin. ● Explain how the design process helps the later manufacturing process	Creation vs Design T-chart Notes Design Inspiration Notes Professional Notebook	Lesson PPT Slides Video: Challenge Coin Design Process Design Process Phases Design Process Descriptions

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Unit Phase	Career Ready Practices and Digital Fluency Standards (CSDF)	Skills/Topics	Assessments	Resources and Texts
	Career Ready Practices 1. Act as a responsible and contributing citizen and employee. 2. Apply appropriate academic and technical skills. 4. Communicate clearly and effectively and with reason. 6. Demonstrate creativity and innovation. 8. Utilize critical thinking to make sense of problems and persevere in solving them. 12. Work productively in teams while using cultural global competence. **NYCSDF Standards** 7-8.CT.10 Document the iterative design process of developing a computational artifact that incorporates user feedback and preferences.	Determine project focus Write Problem Statement Design Portfolio Setup	Rapid Prototyping Project Rubric – Design Documentation Design Portfolio Professional Notebook	
Imagine **2 Days**	**Career Ready Practices** 1. Act as a responsible and contributing citizen and employee. 6. Demonstrate creativity and innovation. 8. Utilize critical thinking to make sense of problems and persevere in solving them.	Lesson: Brainstorming • Explain what brainstorming is and how it helps in the design process Individual Brainstorming Collaborative Brainstorming	Brainstorming Lesson Notes Notes and sketches from SCAMPER Technique Notes from 6-3-5 Brainstorming Technique	Lesson PPT Slides Video: IDEO Brainstorming IDEO's Rules for Brainstorming SCAMPER Handout SCAMPER Technique

Unit Phase	Career Ready Practices and Digital Fluency Standards (CSDF)	Skills/Topics	Assessments	Resources and Texts
	12. Work productively in teams while using cultural global competence		Professional Notebook	6-3-5 Brainwriting Technique Read, Set, Design Activity Design Challenge Cards
	Career Ready Practices 1. Act as a responsible and contributing citizen and employee. 2. Apply appropriate academic and technical skills. 4. Communicate clearly and effectively and with reason. 5. Consider the environmental, social, and economic impacts of decisions. 8. Utilize critical thinking to make sense of problems and persevere in solving them. 12. Work productively in teams while using cultural global competence **NYCSDF Standards** 7-8.CT.10 Document the iterative design process of developing a computational artifact that incorporates user feedback and preferences.	Decision Matrix ● Narrow my design ideas down to a design Update Design Portfolio and Know/NTK Chart	Completed Decision Matrix Know/Need-to-Know	7th-grade Lesson on Decision Matrices Resources on Decision Matrices ● What is a Decision Matrix ● 7 Steps for Creating a Decision Matrix
Plan/Create	**Career Ready Practices** 1. Act as a responsible and contributing citizen and employee.	3D Modeling Software Tutorials	Student work from 3D modeling practice	

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Unit Phase	Career Ready Practices and Digital Fluency Standards (CSDF)	Skills/Topics	Assessments	Resources and Texts
5 Days	2. Apply appropriate academic and technical skills. 4. Communicate clearly and effectively and with reason. 8. Utilize critical thinking to make sense of problems and persevere in solving them. 11. Use technology to enhance productivity. **NYCSDF Standards** 7-8.DL.2 Communicate and collaborate with others using a variety of digital tools to create and revise a collaborative product. 7-8.DL.4 Select and use digital tools to create, revise, and publish digital artifacts. 7-8.DL.5 Transfer knowledge of technology in order to explore new technologies.	• Perform basic functions on 3D Modeling Software 3D Modeling of Design • Use 3D modeling software to develop a virtual prototype of my object	3D model of coin, token, pendant or trophy design Rapid Prototyping Project Rubric – 3D Modeling and Printing	
	Career Ready Practices 1. Act as a responsible and contributing citizen and employee. 2. Apply appropriate academic and technical skills. 12. Work productively in teams while using cultural global competence. **NYCSDF Standards**	Lesson: What is 3D Printing • Describe what 3D printing is and how it is used in manufacturing. • Compare Additive and Subtractive Manufacturing.	Professional Notebook 3-2-1 summary Know/Need-to-Know	Video: What is 3D Printing Video: What is 3D Printing and How does it work? Article: What is 3D Printing Article: Additive and Video: Challenge Coin Production Process

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Unit Phase	Career Ready Practices and Digital Fluency Standards (CSDF)	Skills/Topics	Assessments	Resources and Texts
	7-8.DL.5 Transfer knowledge of technology in order to explore new technologies.			Sections from the MakerBot Guide ● 2.1 From Digital Model to Physical Print ● 2.2 How Does It Work? (part 1) ● 2.2 Beyond the Basics (part 2) ● 2.3 Components of a 3D Printer ● Parts of a 3D Printer
	Career Ready Practices 1. Act as a responsible and contributing citizen and employee. 4. Communicate clearly and effectively and with reason. 8. Utilize critical thinking to make sense of problems and persevere in solving them. 11. Use technology to enhance productivity. 12. Work productively in teams while using cultural global competence **NYCSDF Standards** 7-8.DL.5 Transfer knowledge of technology in order to explore new technologies.	3D Printing ● Use a 3D printer to print my coin Update Design Portfolio and Know/NTK Chart	Printed 3D Coin Design Portfolio Know/Need-to-Know Rapid Prototyping Project Rubric – 3D Modeling and Printing	MakerBot Guide

Unit Phase	Career Ready Practices and Digital Fluency Standards (CSDF)	Skills/Topics	Assessments	Resources and Texts
	7-8.CT.10 Document the iterative design process of developing a computational artifact that incorporates user feedback and preferences.			
Evaluate/ Improve 2 Days	**Career Ready Practices** 1. Act as a responsible and contributing citizen and employee. 6. Demonstrate creativity and innovation. 8. Utilize critical thinking to make sense of problems and persevere in solving them. 11. Use technology to enhance productivity. 12. Work productively in teams while using cultural global competence	Test and Improve Prototype • Improve our design	Improvement notes in the professional notebook Updated 3D Model Reprinted product (optional)	
	Career Ready Practices 1. Act as a responsible and contributing citizen and employee. 2. Apply appropriate academic and technical skills. 4. Communicate clearly and effectively and with reason 11. Use technology to enhance productivity. 12. Work productively in teams while using cultural global competence **NYCSDF Standards**	Lesson: Density, Volume and Mass, Oh My! • Choose a material for our final design. • Find the density of the materials. • Measure or calculate the volume of my coin. • Calculate the mass of my coin using the density formula	Professional Notebook Volume Calculations Mass Calculations Design Portfolio Know/Need-to-Know	Lesson PPT Slides Video: Finding the Volume of a Penny Using Water Displacement (3:06) Video: Finding the Volume of a Penny Using a Ruler (3:06) Phet Density Simulator (optional)

Unit Phase	Career Ready Practices and Digital Fluency Standards (CSDF)	Skills/Topics	Assessments	Resources and Texts
	7-8.CT.10 Document the iterative design process of developing a computational artifact that incorporates user feedback and preferences.	Update Design Portfolio and Know/NTK Chart		
Communicate **1 Day**	**Career Ready Practices** 1. Act as a responsible and contributing citizen and employee. 2. Apply appropriate academic and technical skills. 4. Communicate clearly and effectively and with reason 11. Use technology to enhance productivity. 12. Work productively in teams while using cultural global competence **NYCSDF Standards** 7-8.DL.2 Communicate and collaborate with others using a variety of digital tools to create and revise a collaborative product. 7-8.DL.4 Select and use digital tools to create, revise, and publish digital artifacts.	Create a Product Specification Sheet ● Write a spec sheet for my product	Product Specification Sheet Rapid Prototyping Project Rubric – Spec sheet	Article: Spec Sheet Guide
	Career Ready Practices 1. Act as a responsible and contributing citizen and employee. 2. Apply appropriate academic and technical skills.	Poster Presentation ● Create and present a poster presentation for my final design.	Rapid Prototyping Project Rubric Design Portfolio Know/Need-to-Know	Poster Presentation Guide

Unit Phase	Career Ready Practices and Digital Fluency Standards (CSDF)	Skills/Topics	Assessments	Resources and Texts
	4. Communicate clearly and effectively and with reason 11. Use technology to enhance productivity. 12. Work productively in teams while using cultural global competence **NYCSDF Standards** 7-8.DL.2 Communicate and collaborate with others using a variety of digital tools to create and revise a collaborative product. 7-8.DL.4 Select and use digital tools to create, revise, and publish digital artifacts. 7-8.CT.10 Document the iterative design process of developing a computational artifact that incorporates user feedback and preferences.	Final Update Design Portfolio and Know/NTK Chart	Professional Notebook	

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Rapid Prototyping: Ask Phase

Goal of Phase
This phase introduces the problem to students and gives them some background on design processes and how they are used in a manufacturing process.

Teacher Notes & Preparation
Key Concepts and Big Ideas ● The design process is a structured process for turning ideas into workable solutions. ● A design will need to determine material, shapes, dimensions, and other specifications so manufacturers can plan how best to produce the product to the designers' specifications. ● Prototyping our designs allows us to inspect them for imperfections and test them under the conditions they will be used. 3D printers help in this process by providing a cheap and relatively quick way to produce a first-draft prototype. **Preparation Notes** One of the requirements for this project is for students to tell their “design story” of their tokens using a design portfolio and eventually a design poster. Consider how and where you want students to keep their portfolios. If you want them to keep a virtual portfolio, you will need to determine the best software for this (Google Slides, Google Site, Padlet, Google Doc, Canva, etc). At the end of each phase of the process, direct students to update their portfolios with the most important information from that phase.

Key Questions	Key Vocabulary
What is the difference between creation and design? How does the design process help the manufacturing process? What decisions do we need to make about or design to help in the manufacturing process?	**Design Process** – a structured approach to solving problems. (in these projects the identified process is Ask, Imagine, Plan, Create, Evaluate & Improve, and Communicate) **Manufacturing Process** – the process of turning raw materials or parts into finished goods through the use of tools, human labor, machinery and chemical processing.

Map of Student Learning

Day	Learning Goals	Student Learning Tasks	Teacher Supports
1	Learning Targets: ● Launching the Project Career Ready Practices: 1, 12 Power Skills Needed: ● Collaboration ● Initiative ● Self-Management	**Project Launch** ● Show students the Video: What is 3D Printing and How Does it Work? ● Ask students to discuss in pairs or teams any Wows and Wonders from the video. ● Lead students in a whole class to share their Wows and Wonders. **Task Analysis & Team Contract** ● Divide students into their design teams of 2 – 4 students. Once in teams, have students complete the team contract. (For this project, it is recommended to have teams of two so each student has a chance to design something in the 3D Modeling software). The following authentic career roles are recommended for this project and have been added to the team contract. a. Project Manager—responsible for ensuring that each team member has tasks to do for the day and that they have the materials, equipment, and software needed to be successful. b. Project Engineer – responsible for maintaining good records of the design process and ensuring the team understands how to use the software and equipment as needed. c. c. Both people are responsible for producing an element of the overall design (for example, the Project Engineer designs the front of the coin/pendent/token, and the project manager does	As students read through the project scenario, rotate and help students pull out the most important information. As students work through the K/NTK chart, help them pull out information from the project scenario they need to solve the problem and put this in their Know column. Help students bring in prior knowledge they may have about 3D printing, 3D Modeling, Design or Manufacturing. Encourage students to be curious and ask questions as they fill out the NTK column. Students will revisit this chart several times throughout the project to track their learning and progress. It also helps to have a class Know/NTK chart on a wall or on a class Learning Management System (such as Google Classroom) that can be a class visual for their progress through the project. Use the NTK to see what questions students are asking and how future activities will help them to answer those questions.

Day	Learning Goals	Student Learning Tasks	Teacher Supports
		the pack). • Introduce the guiding question, "How can we translate artistic ideas into a manufactured product?" for this project and hand out the project scenario. • Have them individually read the scenario and highlight key facts they will need for this project. • Either give each student a copy of the Know/NTK chart or have them copy the chart into their design journals. Teams will complete the K-NTK charts as a team, but everyone should write their information individually on their chart. • Student teams first complete the Know column, "What do you know that will help you solve this problem?" First, start by sharing important facts from the project scenario, then add in their own personal background knowledge about the topic. • You may want to pause and have each student group share one thing on their KNOW column that gets collected on a class K-NTK Chart • Student teams then develop questions for their project, "What will you need to know to solve this problem?" • Ask students to go through their questions and pick out the top three questions that will need to be answered right away. • Have each group share one question. If their top question was answered, they share their 2nd most important questions, and so on. • After each group has shared one question, open it up for anyone to share questions relating to the project. • Ask students to write any questions they didn't consider on	

Day	Learning Goals	Student Learning Tasks	Teacher Supports
		their NTK chart. **Note on Rubrics:** A single-point rubric has been provided for this project. Some students like to see a rubric up front; for others, providing it just as they need it for revising work may be more helpful. The rubric is designed so you can isolate sections at a time as needed. Use your best judgment of your students on how you wish to use the project rubric.	
2 – 3	Learning Targets: ● Diagram the design process ● Explain what information is needed to start the design of their coin. ● Explain how the design process helps the later manufacturing process Career Ready Practices: 1, 2, 12 Power Skills Needed: ● Collaboration ● Professionalism ● Self-Management	Lead students through the **Lesson: Design and the Manufacturing Process**. This will help refresh students' memory of the design process and how they have used it. This lesson will also show students how a Challenge Coin company approaches their coin's design and help them determine what decisions they will need to make before designing. ● Lesson PPT Slides ● T-chart notetaking form ● Video: Challenge Coin Design Process ● History of Utica Video ● Design Inspiration Notes Optional: One direction this project can take is for students to design their product based on the history of Utica. To do this, ● Have students watch the video History of Utica Video and take note of important facts or features about Utica. ● Design teams then discuss what they learned from the videos and stories from their families. They can use the Design Inspiration Notes handout to record inspirations and possible design ideas.	This lesson is intended to refresh and deepen students' understanding of the design process. If students have already had a lot of experience with the design process, you may be able to shorten this lesson; however, the Video: Challenge Coin Design Process is still a good video to watch because it shows an example company that produces a similar product to what the students will design in this project.

Day	Learning Goals	Student Learning Tasks	Teacher Supports
4	Learning Targets: ● Write a problem statement for our coin, token, or pendant design. Career Ready Practices: 1, 2, 4, 6, 8, 12 Power Skills Needed: ● Collaboration ● Professionalism ● Problem-Solving ● Self-Management ● Initiative	**Team Meeting**: Students meet in their design team to determine: ● What event or hobby will they depict on their coin, token or pendant? ● What attributes do they want to include in their design? ● What colors do they want to include in their design? ● What rough dimensions do they want their design to be? ● Student teams write a problem statement for their proposed design and turn it into the teacher (aka CEO) for feedback and approval. **Design Portfolio Setup** ● Have students set up their design portfolio with a Title for their design, their team members' names and their problem statement. Should their problem statement change, they can always go back and edit it later. ● Students should also update their Know/NTK chart. ○ What questions have been answered? (check-off from the NTK column) ○ What new knowledge have you gained? (add to the KNOW column) ○ What new questions do you have? (add to the NTK column)	As students turn in their problem statements for your approval, provide feedback to help them consider all the different aspects of their design before going into the brainstorming phase of the process.

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Rapid Prototyping: Imagine Phase

Goal of Phase
Students will brainstorm ideas for the design of their coin, token, or pendant. At this stage, they are just focusing on how it will look, the colors they will use, and possibly its rough dimensions (length, width, and thickness). Students will determine which design is the best moving forward.

Teacher Notes & Preparation
Key Concepts and Big Ideas ● Brainstorming helps designers to create innovative solutions by exploring all possible ideas. ● We can use a decision matrix to choose the best idea given our initial criteria and constraints. **Preparation Notes** At the end of this phase, students will start learning how to use 3D modeling software. Make sure that your chosen software is loaded on the computers or that students can access it through your school's internet filters.

Key Questions	Key Vocabulary
What is the point of brainstorming? How does it help us to be creative? What is our best idea and why is it the best? How can I use 3D Modeling Software to	**Brainstorming** – group discussion to produce ideas or solve problems **Extrude** – the process of stretching a flat, 2D shape vertically to create a 3D object in a scene; modeling technique that allows for the creation of objects with depth and dimension **Fillet** – created between the adjacent lines and faces in 2D and 3D CAD models, curving the surfaces between two lines or planes **Revolve** – Creates a 3D solid or surface by sweeping an object around an axis **Spline** – a technique that uses curves, called splines, to define the shape of a 3D model

Map of Student Learning

Day	Learning Goals	Student Learning Tasks	Teacher Supports
Optional	Learning Targets: ● Explain what brainstorming is and how it helps in the design process. ● Practice brainstorming techniques and reflect on how they can help us with this project. Career Ready Practices: 1, 6, 8, 12 Power Skills Needed: ● Collaboration ● Professionalism ● Problem-solving ● Initiative ● Adaptability	If students need a refresher, lead them through the **Lesson: Brainstorming (Advanced).** It will strengthen their brainstorming muscles. ● PPT Slides ● Video: IDEO Brainstorming ● IDEOU Simple Rules of Brainstorming article ● Brainstorming Lesson Notes ● Video: How To Generate Ideas with the SCAMPER Technique ● Video: How To Generate Ideas with the SCAMPER Technique ● SCAMPER Handout ● Ready Set Design Group Activity ○ Paper Bag per group that contains samples of the following items ▪ 2 – 3 Fastener items such as paper clips, rubber bands, or paper clips. ▪ 2 – 3 Surface items such as aluminum foil, coffee filters, or tissue paper. ▪ 2 – 3 Structure items: popsicle sticks, toothpicks, or straws. ○ Colored pencils or markers for sketching	If students went through the 7th-grade Health Science Modules, they may have experienced a lesson on Brainstorming. This lesson will serve as a refresher on brainstorming and give them some experience with brainstorming before heading into their team brainstorming session. Other brainstorming resources: ● Critical Thinking Toolbox: How to Brainstorm ● IDEO's Rules for Brainstorming ● Video: A Better Way to Brainstorm: How to Get Students to Generate Original Ideas ● Video: Brainstorming Techniques: How to Innovate in Groups ● Video: Effective Brainstorming

		○ Banner paper, professional notebook, sticky notes or other writing paper for group brainstorming. ● Design Challenge Cards ● Video: 6-3-5 Brainwriting Method ● 635 Brainstorming Writing form	
5 – 6	Learning Targets: ● Individually develop an idea for our coin design. ● Brainstorm ideas for our final design with my team. Career Ready Practices: 1, 6, 8, 12 Power Skills Needed: ● Collaboration ● Professionalism ● Problem-solving ● Initiative ● Adaptability	**Individual Think Time**: Students research and develop at least one idea for their coin independently. This should be documented in their professional notebooks. Encourage the use of colored pencils or markers. **Collaborative Brainstorming**: In their design teams, students Choose a brainstorming technique: SCAMPER or 6-3-5 Brainstorming. If students use 6-3-5 brainstorming, they may want to combine with another group. Each group helps each other brainstorm ideas for their product. ● SCAMPER Handout ● 635 Brainstorming Writing form	This is a great lesson to integrate with art. The individual portion may start with researching ideas on the computer or gathering reference images, but encourage students to step away from the computer and plan an idea independently. When they are in teams, most of this should be done off the computers and it helps to have larger paper with colored pencils or markers on hand to indicate colors.
7	Learning Targets: ● Narrow my design ideas down to a design. Career Ready Practices: 1, 2, 4, 5, 8, 12	**Decision Matrix** ● If students need a refresher on how to use a decision matrix. Give each design team a blank decision matrix and one of the scenarios below (or one of your own). ○ Ways that we can improve the school lunch experience	If students went through the 7th Grade Agriscience Module, they may have already learned how to use a decision matrix. This is a good lesson to use if they did not experience that lesson.

	Power Skills Needed: ● Collaboration ● Professionalism ● Problem-solving ● Initiative	○ Best movie to see on a date ○ Locker organizer ○ Backpack/purse organizer ● As a class, brainstorm criteria to determine what we are looking for in a solution. ● As a class, brainstorm ideas to solve the problem and label the ideas. ● In their design teams, have students practice using the decision matrix. With the criteria and ideas from the whole class. ● Rotate and help teams as needed. ● Once students are clear on how to use the decision matrix, have students use another decision matrix to discuss their design ideas and determine their best idea for moving forward. ● Once a design team has determined their best solution, they submit it to their teacher for feedback and approval. **Design Portfolio** ● Students update their design portfolio with their top 3 brainstormed ideas, their decision matrix and a summary of their chosen design and how it fits their problem statement. ● This is also a good time to have students update their problem statement should they have added or taken away constraints or changed the direction of their project. ● Students should also update their Know/NTK chart.	Resources on Decision Matrices ● What is a Decision Matrix ● 7 Steps for Creating a Decision Matrix

		○ What questions have been answered? (check-off from the NTK column) ○ What new knowledge have you gained? (add to the KNOW column) ○ What new questions do you have? (add to the NTK column)	

Rapid Prototyping: Plan/Create Phase

Students will develop a 3D software model of their design or different elements of their designs. They will also learn about additive manufacturing methods and 3D print their prototype.

Teacher Notes & Preparation

Key Concepts and Big Ideas

- 3D modeling software translates our artistic ideas into a virtual model (or prototype).
- Additive manufacturing uses processes that add material to a product as part of the production process.
- Subtractive manufacturing uses processes that build a product through subtracting material.
- 3D printing is an additive manufacturing process.
- 3D Printing allows designers to get a prototype of their design quickly to assess and fix flaws before production.

Preparation Notes

As students transition from learning about 3D modeling, they will need to determine who will do what on the 3D software to model and eventually print their designs. If possible, help students break down who will do what so that each student has something to do with the 3D modeling software. For example, if they are doing a coin or pendant, one student can do the front design, while the other student will do the back design.

Students will also need access to 3D printers to print their coins. If you have not already done so, ensure your 3D printers are operational and what they will need to transition the *.stl file from the modeling software to the printer. Some printers require intermediary software to translate the *.stl files into code for the printer. This will also allow you to possibly print multiple projects on the same run.

Key Questions	Key Vocabulary
What is 3D printing and how is it used in manufacturing? How are virtual designs used to make complex objects? What things can be made using 3D printers How are additive and subtractive manufacturing complementary designs?	**3D Printing** – the action or process of making a physical object from a three-dimensional digital model, typically by laying down many thin layers of a material in succession. **Additive Manufacturing** – the process of creating an object by building it one layer at a time. **Subtractive Manufacturing** – the process of removing material to create parts. This involves material removal with turning, milling, drilling, grinding, cutting, and boring.

Map of Student Learning

Day	Learning Goals	Student Learning Tasks	Teacher Supports
8 – 10	Learning Targets: ● Perform basic functions on a 3D modeling Software. ● Use 3D modeling software to develop a virtual prototype of my object. Career Ready Practices: 1, 2, 6, 8, 11 Power Skills Needed: ● Perseverance ● Professionalism ● Self-Management	**3D Modeling Software Tutorials**: Based on the designs students have developed, you will need to give mini-workshops for them to develop their 3D Modeling skills on your chosen software. Tutorials may include: ● Creating a cylinder using sketch and extrude or sketch and revolve ● Creating solid shapes using sketch and extruding ● Inserting an image on the surface and using spline to sketch over the image ● Creating text on a surface ● Using the fillet feature to round edges **3D Modeling of Design** ● In their design teams, students determine who will do each component of their final design. For example, if students make a coin or pendant, they can each model a different side of the design.	Mini-workshops are a PBL teaching strategy where you provide small group lessons on targeted skills and knowledge. Students can sign up for a workshop based on their needs, or you can assign different students to attend a workshop. This allows for differentiated instruction based on the needs of the students and their design for the project. This section's goal is for students to acquire the skills they will need to develop a 3D model of their design in the next phase.

	• Adaptability	If students choose to do a trophy or more sculpted piece, one student can do the base (as long as it is more than a rectangular block), and another student can do the figure. Each team member can also create an element of the design that will be glued together to make the final piece. The goal is to give each student experience translating ideas to 3D modeling software. • Students work on their designs and use each other as needed to accomplish their tasks. • Once completed, they should check that the dimensions of their virtual prototype match their design. Manufacturing connection: The Extrude feature in most 3D modeling software can be both an additive and a subtractive process, depending on its use. When students “add extrude” they are engaging in an additive process. When they “cut extrude” they are engaging in a subtractive process. In the next phase, students will learn about 3D printing and additive manufacturing. In the next project, students will learn about CNC milling and subtractive manufacturing processes. This may be a good time to start making those connections as they are working on the 3D modeling software.	
11 – 12	Learning Targets: • I can describe the concept of 3D printing and how it is used in manufacturing. • I can compare Additive and Subtractive Manufacturing. Career Ready Practices:	Lead students through the **Lesson: What is 3D Printing?** – help students to know what they need to do as they prepare to design and print a product • Lesson PPT • Professional Notebook • Know/NTK documents created during the launch of the project • Sticky Notes • Video: What is 3D Printing (2.5 min) • Video What is 3D Printing and How does it work? (1.5min) • What is 3D Printing article	

	1, 2, 12 Power Skills Needed: ● Collaboration ● Professionalism	● Additive and Subtractive Manufacturing Article ● MakerBot Educator's Guide Selections ○ 2.1 From Digital Model to Physical Print ○ 2.2 How Does It Work? (part 1) ○ 2.2 Beyond the Basics (part 2) ○ 2.3 Components of a 3D Printer ○ Parts of a 3D Printer	
13	Learning Targets: ● Use a 3D printer to print my coin Career Ready Practices: 1, 4, 8, 11, 12 Power Skills Needed: ● Perseverance ● Collaboration ● Professionalism ● Problem-solving ● Adaptability	**3D Printing** ● Students follow the teacher's instructions to take their 3D models and import the files into the software for the 3D printer. ● While the printer is running, you may wish to engage students in small-scale engineering design challenges such as the ones below from TeachEngineering.org. These give students more experience with the design process and how engineers and designers think. ○ Design a Catapult ○ Build a Tower with an Egg on Top ○ Straw Bridges ○ Clay Boats ○ Design Your Own Snazzy Sneakers **Design Portfolio** ● Students update their design portfolio with pictures of their 3D-modeled parts ● Students summarize how their design changed as they worked to put it in the 3D modeling software. ● Students should also update their Know/NTK chart. ○ What questions have been answered? (check-off from the NTK column)	Review the MakerBot Educator's Guide for more detailed information on working the bot and for resources and activities to support students using the 3D printer. 3D Printing can take some time and students may have some downtime. This is a good time to do minor design challenges like the ones provided. This also helps to break up the monotony of a project.

		○ What new knowledge have you gained? (add to the KNOW column) ○ What new questions do you have? (add to the NTK column)	

UTICA CITY SCHOOL DISTRICT

Rapid Prototyping: Evaluate/Improve Phase

Goal of Phase
Students will visually analyze their 3D-printed products and determine what improvements they need to make to their designs. If you choose, students can update their 3D models and reprint their designs before the final presentations. Students will also need to determine the chosen material they would like to propose for their final design (note: This is just a proposal. They will not produce their final designs beyond using the 3D printer). Students will calculate or measure the total volume of their piece and calculate the weight of their final piece using the density of the material.

Teacher Notes & Preparation
Key Concepts and Big Ideas: ● 3D printing allows designers to see their design idea so they can test it before it moves into production. ● Density is the ratio of the mass of an object to its volume. We can use this to estimate the final weight of our manufactured product. **Preparation Notes**: In this phase, students will estimate the volume of their coin, token, pendant or trophy. If they have an irregular shape, one way to estimate the volume is to immerse the object in water and determine the volume difference of the water before and after. In engineering, not everything can be found with a neat mathematical equation, so engineers may use methods such as this to get a close approximation. For our purposes, that will be good enough. You may need to secure some graduated cylinders and water to do this. 3D printed materials are made from plastic and will most likely float, so consider how you might weigh it down or hold it submerged in the water while you take volume measurements. This will have a small effect on the volume calculation. The math students will need to perform to find the final mass of their design may include: ● Finding the volume of 3D objects (if dealing with non-complex shapes such as cylinders or boxes) ● Substituting knows into a simple formula (density = mass/volume) ● Using ratios for unit conversions ● Solving a one-step algebraic equation to find the mass of an object.

Key Questions	Key Vocabulary
How might we improve upon our designs? What material will we want our design made from?	**Physical Properties of Matter** – characteristics that can be observed or measured without changing the substance's chemical nature

How can we use density to determine the final mass of our design? How much will the final design weigh?	**Density** – degree of consistency measured by the quantity of mass per unit volume **Mass** – the property of a body that is a measure of its inertia and that is commonly taken as a measure of the amount of material it contains and causes it to have weight in a gravitational field. **Volume** – a measurement of the amount of space that a substance or object occupies or that is enclosed within a container.

Map of Student Learning

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14	Learning Targets: ● Improve our design Career Ready Practices: 1, 6, 8, 11, 12 Power Skills Needed: ● Perseverance ● Collaboration ● Professionalism ● Problem-solving ● Initiative ● Adaptability	**Test and Improve Prototype** ● 3D printing allows us to see if our designs created using 3D modeling software translate to the physical world. ● Students visually inspect their 3D printed designs and evaluate them based on their original criteria. They also need to consider other flaws that may not be captured in their original criteria, such as the text being too small, prints out blurry, or some details not emerging in the printing process. ● If time and materials allow, students update their 3D models and reprint their coins. If they are not able to do this, they will still need to explain the improvements they would make to the design before it moves into the production phase of the process.	
15 – 16	Learning Targets: ● Choose a material for our final design.	Lead students through the **Lesson: Density, Volume and Mass, Oh My!** – students will learn how to find the volume of complex shapes, research and look up the density of a chosen material, and finally calculate the mass of their final product using the density formula.	If the project is going too long, you can skip this lesson. When students do the Spec Sheet,

	• Find the density of the materials. • Measure or calculate the volume of my coin. • Calculate the mass of my coin using the density formula Career Ready Practices: 1, 2, 4, 11, 12 Power Skills Needed: • Perseverance • Collaboration • Professionalism • Problem-Solving • Communication	• Professional notebook • Video: Finding the Volume of a Penny Using Water Displacement (3:06) • Video: Finding the Volume of a Penny Using a Ruler (3:06) • Metric rulers (one per student) • 50 ml graduated cylinder – that will fit the width of a penny • Pennies (5 per student) • Water • Their printed coins • Phet Density Simulator (optional) **Team Meeting** • Based on the Lesson "Density, Volume, and Mass, Oh My!" Students meet in their design teams and choose the material for their products. • Students will estimate the mass of their coin using the displacement or density method. Most 3D printers use ABS plastic, and the density of solidified ABS plastic at room temperature and pressure is 1.05 g/cm3 on average. • Students find the density of the material and use it to calculate the mass of their final product. **Design Portfolio Update** • Students update their design portfolio with any changes they plan to make. • Students also include the specifications for their final design: important measurements, colors, the chosen material, and the final mass. • Students should also update their Know/NTK chart.	they can skip the final weight portion.

		○ What questions have been answered? (check-off from the NTK column) ○ What new knowledge have you gained? (add to the KNOW column) ○ What new questions do you have? (add to the NTK column)	

UTICA CITY SCHOOL DISTRICT

Building Better Health: Your Community, Your Plan: Communicate Phase

Goal of Phase
Students will finalize the project by creating a spec sheet for their product and preparing a poster presentation about their design process and their final product.

Teacher Notes & Preparation
Key Concepts and Big Ideas: ● Spec sheets give essential details on the manufacturing and shipping of your product. ● Poster presentations are a way to visually present your work on a larger canvas. **Preparation Notes**: Students will prepare a poster presentation for this product. This gives students experience with this type of presentation and helps reduce their reliance on Google Slides or PPTs as the only medium for presentations. Students can do this with physical posters and using PPT or Slides to create each poster section. Students can also use online media such as Canva to create a digital poster. If you have access to a poster printer, these can be printed out to size (or students can present from an overhead screen). You can also create a poster presentation using Google Slides. This link provides a template that students can use.

Key Questions	Key Vocabulary
What information will manufacturers need to know about my product to produce and safely ship it? How do I communicate my design process and final product?	**Spec Sheet** – a document that provides performance and technical details about a product

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Day	Learning Goals	Student Learning Tasks	Teacher Supports
17 – 18	Learning Targets: • Write a spec sheet for my product. Career Ready Practices: 1, 2, 4, 11, 12 Power Skills Needed: • Collaboration • Professionalism • Integrity • Communication	Students create a spec sheet with their product. Their spec sheet needs to include • Picture of their product (front and pack if applicable) • Rough Dimensions • Final material • Final mass (weight) • Packaging requirements • Brief summary of their design process • Any other essential design details Students can use this Product Specification Template or create their own. Lead students through the Product Specification Activity if they need more in-depth knowledge about product specifications sheets.	Creating the spec sheet will help students start thinking about their coin's packaging requirements. They will need this for the next project. For this project, rough LxWxH dimensions. Students may also begin to think about protection that needs to be included in the packaging to prevent product damage or to display the product better.
19 – 20	Learning Targets: • Create and present a poster presentation for my final design. Career Ready Practices: 1, 2, 4, 11, 12 Power Skills Needed: • Collaboration • Professionalism	**Poster Presentation** • Students will create a poster detailing their design process and the specifications for the final coin design. You will play the part of the CEO (or may decide to invite a community partner or another teacher or principal to play this role). • Give students the Poster Presentation Guide to help them create their poster. Students present their work.	This is another area that can be skipped if the project is long. You may choose to have students produce a poster after all three projects, and each student presents a poster to community partners on their favorite project in class.

	● Integrity
	● Communication
		Final Design Portfolio Update
		● Students update their design portfolio with their Spec Chart and picture or copy of their poster presentation
		● Students should also update their Know/NTK chart.
		  ○ What questions have been answered? (check-off from the NTK column)
		  ○ What new knowledge have you gained? (add to the KNOW column)
		Use the Project Rubric to provide feedback on each component of the project.	