

A group of students in a classroom are working on a project. In the foreground, a student in a green and white striped shirt is using blue-handled scissors to cut a piece of cardboard. Behind them, other students are also working with cardboard boxes and papers. The scene is brightly lit, suggesting a classroom or workshop environment.

ULTIMATE DESIGN CHALLENGE

Geometry Project | Grades 9-11 | 15-20 hours



BUCK INSTITUTE
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ULTIMATE DESIGN CHALLENGE: PROJECT OVERVIEW

WHAT MAKES THIS PROJECT GOLD-STANDARD PBL?

FINAL PRODUCT

Students choose a product with problematic packaging (from a sustainability perspective), and design a prototype that creatively solves the sustainability issues.

AREA OF STUDY

Mathematics

TIMEFRAME

15-20 hours

AGE GROUP

Grades 9-11

KEY STANDARDS ASSESSED

[M.PRACTICE.MP2 >>](#) Reason abstractly and quantitatively.

[M.PRACTICE.MP4 >>](#) Model with mathematics

[M.CONTENT.HSG.GMD.3 >>](#) Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems

[M.CONTENT.HSF.IFB.4 >>](#) Interpret functions that arise in applications in terms of the context

[M.CONTENT.HSG.MG.A.1 >>](#) Use geometric shapes to describe objects

[M.CONTENT.HSG.MG.A.3 >>](#) Apply geometric

RUBRICS

[Project Rubric >>](#)

[BIE Presentation Rubric >>](#)

PLANNING TOOLS AND TEMPLATES

[Project Design Companion >>](#)

[Student Planning Sheet >>](#)

DRIVING QUESTION

How can we redesign a product's packaging to make it more environmentally friendly?

PROJECT DESCRIPTION

WHY ULTIMATE DESIGN CHALLENGE?

Much American product packaging uses materials and processes that negatively impact the Earth. In their role as design engineers, students use the engineering design process and geometric modeling to redesign a product's packaging to render it more sustainable.

CHALLENGING PROBLEM OR QUESTION

The driving question for this project—"How can we redesign a product's packaging to make it more environmentally friendly?"—asks students to consider a challenging real-world problem that companies, activists, and governments are exploring, yet is also accessible to students.

PUBLIC PRODUCT

Students showcase prototypes of their design solutions to consumers in order to address their concerns.

KEY KNOWLEDGE, UNDERSTANDING, AND SUCCESS SKILLS

Central to this project are both the design process and [geometric modeling >>](#). As they design and model, students use geometric shapes and their measurements to describe objects, and they apply geometric thinking to solve design problems. In addition, students explore the arena of sustainable packaging design.

AUTHENTICITY

To tackle this project, students learn and use the mathematical process of geometric modeling, which mathematicians employ when working on applied math problems and issues. As students take on packaging design projects, they engage in the same design process that professionals employ—define the problem, ideate and determine a solution, create and refine a prototype, and present a solution.

SUSTAINED INQUIRY

While geometry has many real-world applications, it's still rare for high school students to have the opportunity to explore them in a sustained way. This project places [geometric modeling >>](#) at the center of the learning experience as students develop new geometry skills in their exploration of sustainable product packaging.

STUDENT VOICE AND CHOICE

Individual student interests and creativity drive this project. Students identify environmental packaging design challenges and determine which geometric models will help them devise sustainable solutions, choose the use of materials, and develop a unique prototype grounded in the research they have undertaken and the issues they have identified.

CRITIQUE & REVISION

There are three specific "moments" when critique and revision are essential: after the packaging is redesigned, after the design of the prototype, and after the final presentation of the packaging.

REFLECTION

Reflection is embedded in each stepping stone. It will be particularly essential after each critique on their designs and prototype, BEFORE they begin the revision and improvement process. Students reflect on the key content and skills, the fit between their product and their identified challenge, how geometry is being used as a tool to address the challenge, their contributions to the group, and their group's effectiveness as a team.

EXPLORING CRITICAL PACKAGING DESIGN ISSUES

EXPLORING PACKAGING ENGINEERS

A CASE STUDY: PROMOTING SUSTAINABLE PACKAGING

More than 3 billion pizza boxes are thrown away each year in the United States! The grease from those wonderfully cheesy pies makes them almost impossible to recycle. (Mixing food-contaminated cardboard into non-contaminated cardboard can ruin an entire load of recycled cardboard.) And a dinner of takeout pizza often creates additional non-recyclable waste, like paper plates and foil or plastic wrap for the leftover slices.

Watch [GreenBox's pitch on Shark Tank >>](#) to see one company's solution to this design challenge. How's that for geometry saving the planet?

WHO ARE PACKAGING ENGINEERS?

Packaging engineers are the people behind the packaging of items as diverse as frozen peas, anti-aging lotions, refrigerators, cough medicine, organic juices, and light bulbs. The packages they design ensure products arrive safely to the consumer, improve the utility or visual appeal of the item, or conserve resources to increase profits or decrease environmental impact. Packaging engineers have science, engineering, technology, and design backgrounds. They work in consulting firms, manufacturing plants, large corporations, and research and development companies. Their tasks include identifying a packaging design challenge (such as how to keep the fresh taste in frozen peas or how to prevent light bulbs from breaking during shipping), brainstorming and researching possible solutions to the challenges (by examining different materials or shapes for packaging), modeling and creating a prototype of the design, and testing and refining the prototype.

click to explore:

click to explore:

RESOURCE #1
Trash by the Numbers: Startling Statistics About U.S. Garbage
>>

RESOURCE #2
The Pizza Box Mystery
>>

RESOURCE #3
The Greatest Pizza Box Known to Man
>>

RESOURCE #1
Package Design Makes a Difference
>>

RESOURCE #2
Packaging Digest
>>

RESOURCE #3
DSN Hero: Packaging Design
>>

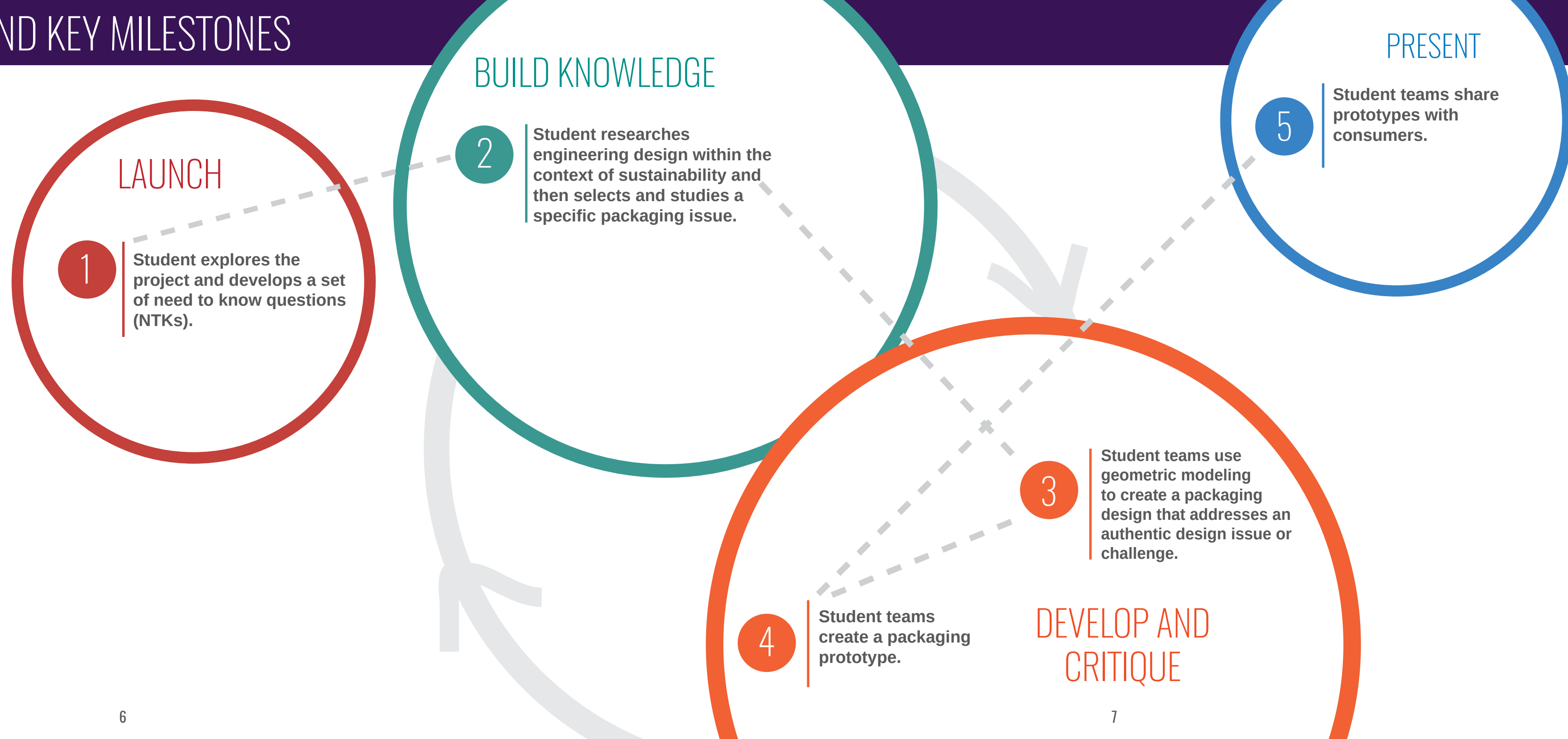
THE PROJECT PATH AND KEY MILESTONES

The Project Path illustrates the learning process in a project-based, competency-based setting.

Project Milestones help clarify the path from Launch to Present, as learners move through an iterative process of building new knowledge and skills, and applying their new knowledge and skills to develop, critique, and refine their products in collaboration with peers.

The Project Path and the Project Milestones provide a concrete but flexible structure for project design and implementation.

The Project Milestones are color coded in this Project Path and throughout the document.



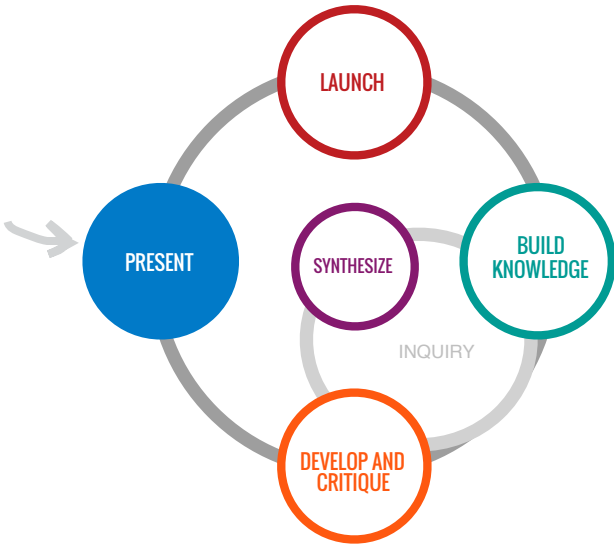
PROJECT MILESTONES AND STEPPING STONES

MILESTONE #1: Student explores the project and develops a set of need to know questions (NTKs).		MILESTONE #2: Student researches sustainable engineering design and selects a packaging design issue to investigate.		
ENTRY EVENT Student examines the environmental impact and recycling difficulties of the pizza box.	PREVIEW THE PROJECT Student is introduced to the expectations for the final product.	EXPLORE THE DRIVING QUESTION Student examines examples of innovative packaging and brainstorms possible design challenges.	GREENER PACKAGING DESIGN Student explores how and why packaging engineers are designing packaging to be more environmentally and ecologically friendly, driven by their NTKs.	CHOOSE A PACKAGE TO REDESIGN Student teams select a package to redesign and evaluate the package's strengths and weaknesses.
MILESTONE #2 (CONTINUED)		MILESTONE #3: Student teams use geometric modeling to create a packaging design to address a sustainability challenge.		
WHAT IS ENGINEERING DESIGN Student uses NTKs to drive research about the design process and learn what it takes to become a design engineer.	IDEATE AND EVALUATE Student teams use the ideation process to develop possible packaging solutions and evaluate their ideas to choose a solution to pursue.	MODEL THE DESIGN Student teams use geometric modeling to develop a viable design.	SOLICIT CONSTRUCTIVE CRITIQUE Student teams listen and respond to design engineers' or mathematicians' critiques of geometric models.	
MILESTONE #4: Student teams create a packaging prototype.		MILESTONE #5: Student teams share prototypes with consumers.		
DEVELOP A PROTOTYPE Student teams use their geometric models to develop prototypes.	IMPROVE THE PROTOTYPE Student teams revise, tinker with, and improve the prototype, using feedback.	PRACTICE AND PREPARE Student teams make final preparations for sharing their prototype.	PRESENT Student teams share their designs with consumers.	REFLECT Students and teacher reflect on their original NTKs and their current sense of understanding.



CUSTOMIZING THE PRODUCT OR PERFORMANCE

Begin with the end in mind! It's time to tee up a few significant decisions you'll need to make about the final project. As you make decisions, reflect on what you believe will work best with your students and your community, as well as time constraints, budgets, and your own skills and comfort level.



WHAT TO DO:



1. Review the three decision points below.
2. After weighing your options, make your decision and document them in your [Project Design Planning Companion >>](#).

DECISION POINTS:

	Low Complexity	Medium Complexity	High Complexity
What will the product and/or performance include?	Students include the prototype and detailed drawings that show the geometric modeling in their final product.	Students include the prototype, detailed drawings that show the geometric model, and an analysis that compares the new design to the original in their final product.	Students include the prototype, detailed drawings that show the geometric modeling, and a "pitch" to sell the customers on the new design in their final product.
Who will the audience be, and how will you ensure an audience?	Students bring their designs to the school community, which will bring a consumer perspective to the design solutions.	Students bring their designs to a local grocery store, department store, or mall, and survey customers regarding their improvements.	Students identify a company whose product packaging they will redesign and present their plans to the company.
How much decision-making power will students have regarding the topic, audience, and final product?	Students are given a set of products with packaging that needs to be rethought for sustainability.	Students choose the product for which to redesign the packaging for sustainability.	Students determine the packaging design challenge and the form and format of their presentation.



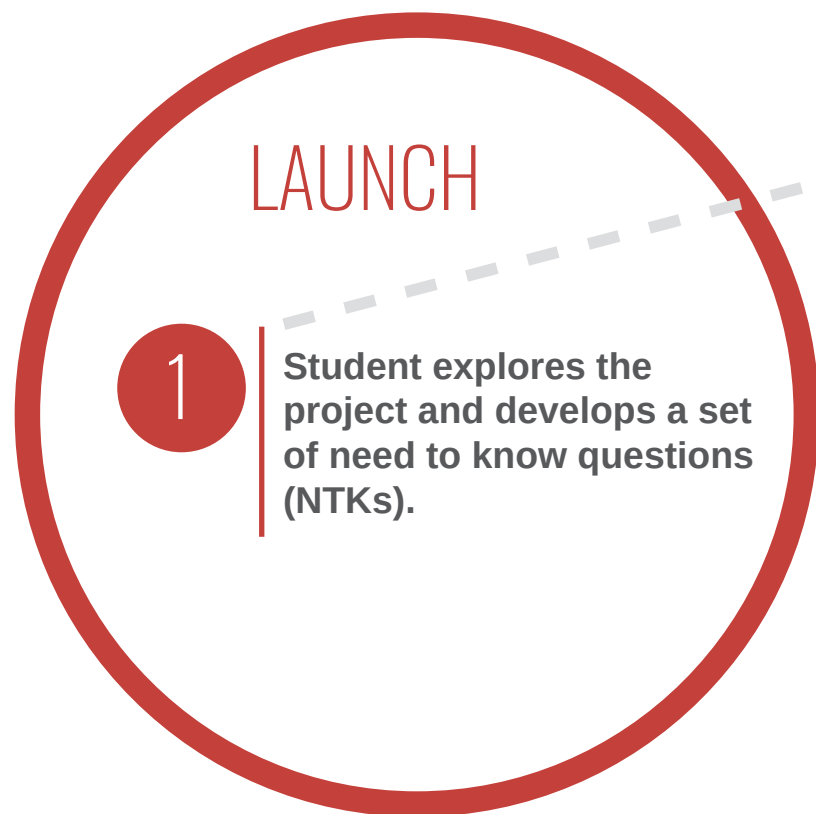
MILESTONE #1: LAUNCHING INQUIRY

Welcome to the Launching Inquiry milestone. This is the entryway into Ultimate Design Challenge. Students begin their exploration of the driving question, “How can we redesign a product’s packaging to make it more environmentally friendly?” by exploring how one company used geometric modeling to reinvent the pizza box to decrease its impact on the Earth’s resources.

As you plan the entry event, make sure there is time for students to develop their own questions about packaging. These may touch on the skills of design engineering, the work of geometric modeling, and the challenges of sustainable packaging, or they may venture into territory you have not anticipated.

The key is to honor all questions as students orient to the project.

Note: The recommended resources will be helpful as you design lessons for this milestone.



STEPPING STONES

ENTRY EVENT

Student examines the environmental impact of the ordinary pizza box and learns how Green Box has approached this problem by viewing their pitch on *Shark Tank*.

PREVIEW THE PRODUCT

Student is introduced to the expectations for the final product.

EXPLORE THE DRIVING QUESTION

Student explores the question: “How can we redesign a product’s packaging to make it more environmentally friendly?”

Student develops a list of need to know questions to guide their inquiry.



RECOMMENDED RESOURCES

TEXTS AND DATA

- [35 Recyclable and Eco-Friendly Packaging Designs for Inspiration >>](#)
- [Compact Cup Noodle Packaging >>](#)
- [Essentials of Sustainable Packaging Course >>](#)
- [The Pizza Box Mystery >>](#)
- [The Greatest Pizza Box Known to Man >>](#)

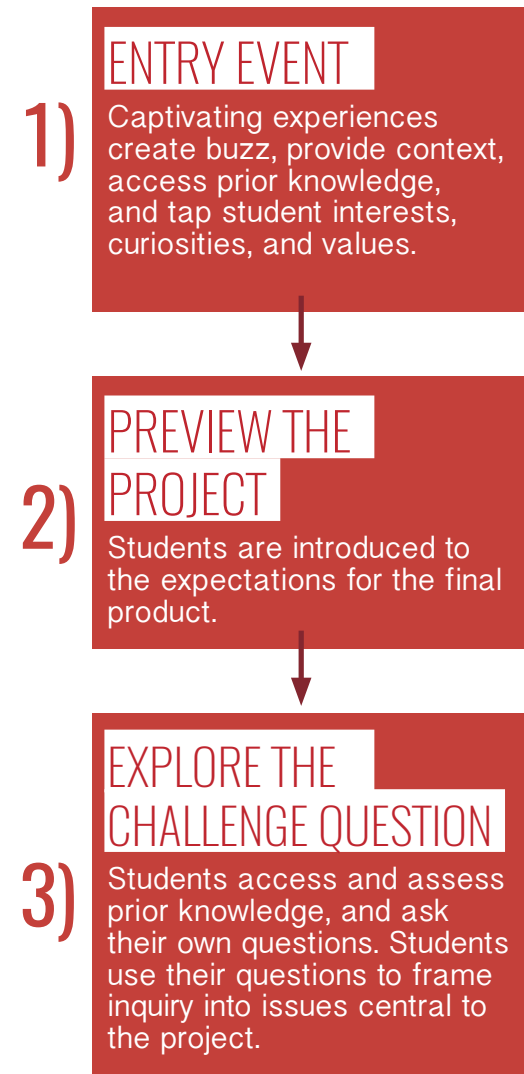
AUDIO AND VISUALS

- [GreenBox's pitch on Shark Tank >>](#)

TOOLS AND FORMS

- [Know/Want-to-Know Chart >>](#)
- [Inquiry Chart >>](#)
- [Student Planning Sheet >>](#)
- [Identify an Engineering Challenge >>](#)

Structure of a Launch...



As you design your launch, consider this three-part structure to help guide your efforts: Entry Event, Project Preview, and Driving Question Exploration. The launch may be only one lesson, but these three key segments each involve careful decision-making, planning, and materials development. Let's take a closer look.

DESIRED OUTCOMES



MATCH, LIT.

Students participate in an engaging shared experience that generates excitement about the Ultimate Design Challenge project.



PROJECT, LINKED.

The connection between the provocation or entry event and the final project is totally clear; basic project expectations are communicated upfront.



INQUIRY, LAUNCHED.

Opportunities to generate their own need to know questions pique learners' innate curiosity as they begin to connect with the driving question.

MIGHT LOOK LIKE...

- Students learn about the amount of trash generated by greasy cardboard pizza boxes. They then view Green Box's pitch to *Shark Tank* to learn how a company solved this design challenge.

- Students review the elements of the final project, the [Student Planning Sheet >>](#), and the [Rubric >>](#).

- Students examine examples of innovative, sustainable packaging. Working in pairs, they research design considerations for particularly problematic products (such as potato chip bags or water bottles). Then they work in small groups to brainstorm a list of their need to know questions for this project.

EXAMPLES OF INITIAL STUDENT NEED TO KNOWS

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K

The need to know process is essential to the project. It helps students activate their prior knowledge and identify their own questions for exploration. To support your planning, we've provided a list of example questions that students might ask about the design engineering process and final product.



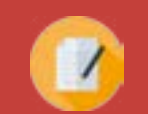
To support your planning, these questions are examples of what students may ask for this project.

QUESTIONS ABOUT THE DESIGN ENGINEERING PROCESS

- Can I redesign something to make it look more interesting?
- Does the challenge have to be related to sustainability?
- How am I supposed to come up with a new packaging idea?
- What if my idea doesn't work?

QUESTIONS ABOUT HOW MATH INFORMS THE FINAL PRODUCT

- How can I build a prototype of a bottle (or some other container)?
- Do designers really use geometry to solve design problems?
- What shapes will be needed to create my model and prototype, and how will I determine the dimensions so it works?



LESSON LAUNCH



THE ENTRY EVENT

More than 3 billion pizza boxes are thrown away each year in the United States! The grease from those wonderfully cheesy pies makes them almost impossible to recycle. (Mixing food-contaminated cardboard with non-contaminated cardboard can ruin an entire load of recycled cardboard.) And a dinner of takeout pizza often creates additional non-recyclable waste, like paper plates and foil or plastic wrap for the leftover slices.

Watch [GreenBox's pitch on Shark Tank >>](#) to see one company's solution to this design challenge. Respond in your journal to the following prompts:

- Why is GreenBox's design more sustainable than the traditional pizza box?
- Are there other environmental solutions to the greasy pizza box problem?
- What can you do to avoid contributing to the 3 billion pizza boxes thrown away each year?

How's that for geometry saving the planet?

INVESTIGATE



PREVIEW PROJECT EXPECTATIONS

Your project is to choose a product and solve the design challenge of making its packaging more sustainable. By applying the steps in the design process, you will identify, research, develop, and refine a packaging design solution to your chosen challenge. You will create a geometric model and a prototype for your design solution and present them to consumers for feedback. As you explore the expectations and the [Student Planning Sheet >>](#), complete a [Jot Thoughts >>](#) activity with a small group of your peers.



Be sure that students are able to identify the design challenge related to sustainability that GreenBox is addressing. They should see the box as more than just a gimmick.

Create a document that provides students with a clear picture of the project's expectations.

In reviewing the project, raise the fact that many sustainable redesigns for current packaging will be outside the scope of this project. For students to be able to apply geometric modeling to this task, they should focus on solutions related to "design optimization" rather than "source sustainability" or "design for recovery" solutions.

For more information, see [Essentials of Sustainable Packaging >>](#).

INVESTIGATE (CONT'D)



EXPLORE THE DRIVING QUESTION

It's not only pizza boxes. People interested in sustainable design are rethinking other common product packages, too. Cup of Noodles is designed with space for hot water, but this means that trucks delivering Cup of Noodles have to transport half-empty packages. Computers, already an environmental stressor, are packaged with Styrofoam and plastic bags to ensure safe delivery. What other design challenges are out there waiting to be solved?

INITIATE THE NEED TO KNOW PROCESS

Drawing from the discussions you've just had, let's organize our shared knowledge using this graphic organizer. What do you already know about package design engineering, the engineering design process, sustainability, and green design? What do we need to know or learn in order to be able to redesign a product's packaging to solve a sustainability challenge?



Choosing a few examples that highlight geometric solutions and "design optimization" from lists such as [35 Eco-Friendly Designs >>](#) to find engaging and focused ways to explore some other sustainable design solutions. For a Cup of Noodles redesign, go to [Green Product Award >>](#).

Give students an opportunity to view a product's packaging from the perspective of a sustainability design challenge by bringing in common products and asking students to list problems with the packaging. Be clear that at this point they are naming but not trying to solve the problems. Emphasize the challenges that are about the design (for instance, the shape, use, or size).

SYNTHESIZE AND REFLECT



CLOSING THE LAUNCH

Close your eyes and think of a recent purchase you made. How was it packaged? What shapes and materials were used? Why might the company have designed the packaging as it did? What part of the packaging did you recycle? What part of it could you reuse? What part is headed for a landfill—or worse? Were there other environmental impacts of this packaging? Now, think about how YOU can make it better. Open your eyes, turn to a partner, and share your vision.

MILESTONE #2: ENGINEERING DESIGN FOR SUSTAINABILITY

This milestone focuses on helping students strengthen their ability to synthesize research as they build their knowledge base about the issues of package sustainability and the profession of package design engineering. With this new perspective, they will be ready to revisit the project's requirements and use what they learned to drive their work.

Students develop a more nuanced understanding of packaging's impact on the environment and how some companies are addressing this issue. They apply their new understanding as they choose a package to redesign. They also learn about the role of engineers in this work and delve into the design cycle.

Note: The recommended resources will be helpful as you design lessons for this milestone.

BUILD KNOWLEDGE

2

Student researches engineering design within the context of sustainability and then selects and studies a specific packaging issue.



STEPPING STONES

GREENER PACKAGING DESIGN

Student explores how and why packaging engineers design packaging to be more environmentally and ecologically friendly, driven by their NTKs.

CHOOSE A PACKAGE TO REDESIGN

Student teams select a package to redesign and evaluate the package's strengths and weaknesses.

WHAT IS ENGINEERING DESIGN?

Student uses NTKs to drive research about the design process and learns what it takes to become a design engineer.

IDEATE AND EVALUATE

Student teams use the ideation process to develop possible packaging solutions and evaluate their ideas to choose a solution to pursue.



RECOMMENDED RESOURCES

TEXTS AND DATA

- [Good Product, Bad Packaging >>](#)
- [Reducing Packaging Waste >>](#)
- [Ways to Prevent Packaging Waste >>](#)
- [Packaging Digest >>](#)

AUDIO AND VISUALS

- [Seas of Plastic >>](#)
- [Paper Beats Plastic? How to Rethink Environmental Folklore >>](#)
- [Package Design Makes a Difference >>](#)
- [DSN Hero: Package Design >>](#)
- [What Is the Engineering Design Process? >>](#)

TOOLS AND FORMS

- [Engineering Design >>](#)
- [Explore the Engineering Process >>](#)
- [Identify an Engineering Challenge >>](#)

STEPPING STONES TO ENGINEERING DESIGN FOR SUSTAINABILITY



1. GREENER PACKAGING DESIGN

In this stepping stone, create a few lessons that help students [make meaning >>](#) of some of the recommended resources (listed on the previous page), which explore how and why packaging engineers are designing more sustainable packages. Try using the recommended activities, or find your own, but look for ways to help students keep track of their learning and share it in an efficient way.

If students are struggling, identify additional activities that will help them [determine key ideas >>](#). An [Iceberg Diagram >>](#) is one example, but there are other options.

ACTIVITY IDEAS

Develop a [grouping strategy >>](#) for students: Think about whether hetero- or homogeneous groups would be best for this project. Consider student choice vs. teacher choice, and consider random options vs. strategic options.

As you design lessons, look for ways to help students use their NTKs to mine information from the recommended texts, but also help them make connections to the core engineering content (we'll get to geometry content in the next milestone!).

Check out the recommended resources on the previous page!

	1. GREENER PACKAGING DESIGN	2. CHOOSE A PACKAGE TO REDESIGN
Standards	CCSS.ELA-LIT.RST.11-12.8 >> , CCSS.ELA-LIT.RST.11-12.9 >> , CCSS.ELA-LIT.SL.11-12.1.C >> , CCSS.ELA-LIT.SL.11-12.1.D >>	CCSS.ELA-LIT.SL.11-12.1.B >> , CCSS.ELA-LIT.SL.11-12.1.C >>
Students will be able to...	Explain how and why packaging engineers are designing packaging to be more environmentally and ecologically friendly.	Identify a packaging design challenge related to sustainability that meets the project's constraints and expectations.
Ideas for Activities	<ul style="list-style-type: none"> Drawing Conclusions Thinking Guide >> Jigsaw >> 	<ul style="list-style-type: none"> Identify an Engineering Challenge >> ABC Brainstorming >>
Reflection and Synthesis Prompts	<ul style="list-style-type: none"> What makes the "paper" or "plastic" question so complicated? How does the "reduce, reuse, recycle" campaign fit into the sustainable packaging movement?? 	<ul style="list-style-type: none"> How does your group's design challenge connect to issues of sustainability? Why did you choose this design challenge over others?
Formative Assessment Ideas	<ul style="list-style-type: none"> Have small groups of students generate a list of ways a common product's current packaging could be considered a sustainable alternative and ways it could be considered problematic. 	<ul style="list-style-type: none"> Give a 30-second elevator pitch about your design challenge. List three things about the packaging your group chose that could pose a threat to the environment and three things about the packaging that could be considered more environmentally friendly.
Suggestions for Feedback and Support	<ul style="list-style-type: none"> If students are struggling to identify key information, try asking them to use Iceberg Diagrams >>. 	<ul style="list-style-type: none"> If students are struggling, the Concept Map >> is a simple scaffolding activity for identifying key ideas.



2. CHOOSE A PACKAGE TO REDESIGN

In this stepping stone, create a lesson that facilitates pairs of students in [Identifying an Engineering Challenge >>](#) related to packaging sustainability. There are many activities that can help students generate ideas about possible packaging challenges. We've suggested two here to help students brainstorm ideas and choose a design challenge.

REFLECTION & SYNTHESIS:

For this stepping stone, the reflection and synthesis prompts help students consolidate their learning (by connecting their specific challenge to the larger issue of sustainability) and ask them to use metacognition to think about their decision-making process.

FORMATIVE ASSESSMENT IDEAS:

The suggested formative assessment activities will provide students with the opportunity to deepen their thinking about design constraints while also asking them to show that they understand the nature of their own design challenge.

STEPPING STONES TO ENGINEERING DESIGN FOR SUSTAINABILITY



3. WHAT IS ENGINEERING DESIGN?

In this stepping stone, you'll create a lesson that helps students [synthesize](#) >> information about the engineering design process and the roles and responsibilities of sustainability-oriented design engineers. As you plan the lesson, find ways for students to use their NTKs as the driver for this inquiry.

If students are struggling, identify additional activities that will help them build the necessary background knowledge about the design process and design engineering. The [Concept Collage](#) >> is one example, but there are [other options](#) >>.

LEARN FROM THE EXPERTS:
Invite a design engineer to speak to the class so students can learn firsthand about the profession and the engineering design process.

REFLECTION & SYNTHESIS:
Less is definitely more with [concept learning](#) >>. For example, students need to understand the design process and how they will use it to redesign a package. The reflection and synthesis questions should help students consolidate their new learning so it's available to them when they begin to develop their own packaging.

	3. WHAT IS ENGINEERING DESIGN?	4. IDEATE
Standards	CCSS.ELA-LITERACY.RST.11-12.9 >>	CCSS.ELA-LIT.RST.11-12.9 >>, CCSS.ELA-LIT.SL.11-12.1.A >>, HS-ETS1-1 >>
Students will be able to...	Describe the engineering design process and explain the work of a packaging design engineer.	Ideate and evaluate (with appropriate creativity) possible solutions to a product's problematic packaging.
Ideas for Activities	<ul style="list-style-type: none"> Frameworking >> Generative Summarizing >> 	<ul style="list-style-type: none"> Ideate >> Evaluate >>
Reflection and Synthesis Prompts	<ul style="list-style-type: none"> List three important tips you would share with someone embarking on designing sustainable packaging. What do you anticipate as potential challenges as you undertake the design process? 	<ul style="list-style-type: none"> What were some ideas that you dismissed, and what research convinced you to do so? All packaging has benefits and drawbacks. What are they for your design solution, and how did you decide the benefits outweighed the costs?
Formative Assessment Ideas	<ul style="list-style-type: none"> Scramble the steps of the engineering design process, and have students put them in order. 	<ul style="list-style-type: none"> Confer with groups to discuss how their identified design solutions meet the project's constraints and expectations.
Suggestions for Feedback and Support	<ul style="list-style-type: none"> If students are struggling to understand the engineering process or the role of a design engineer, the Concept Collage >> can help them visualize the main ideas. 	<ul style="list-style-type: none"> If students are struggling, the Question Formulation Technique >> is a helpful way to help students figure out what questions they have.



4. IDEATE

In this stepping stone, you'll be creating two lessons that support student pairs as they explore the problems inherent in a product's current packaging and examine the benefits and challenges of potential solutions. There are many activities that can help students undertake the second and third steps of the design process. The activities listed are two possibilities.

As you plan these lessons, think about how students can connect their brainstormed and culled ideas to their understanding of the complex issues of sustainability and packaging waste.

INTEGRATING RESEARCH
An important element of the design process is [researching](#) >> the identified challenge and exploring how others have tried to solve it. Decide how (or if) you will have students investigate the current state of the problem.

Don't forget about the recommended resources at the beginning of the milestone.

REFLECTION & SYNTHESIS:
The reflection and synthesis questions should help students name the reasons why they choose their design solution over other ideas.

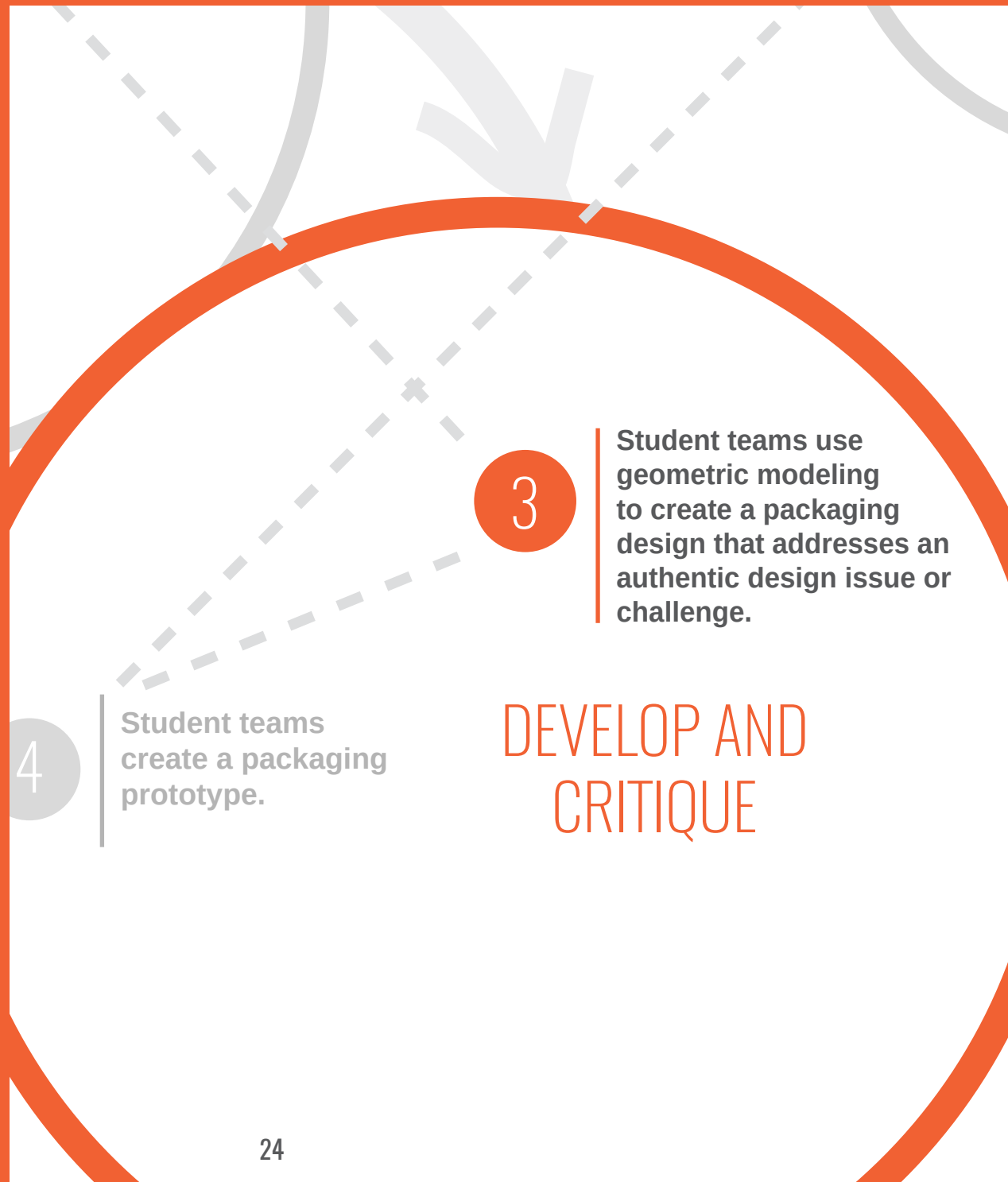
Their reasons should be related to sustainability and other potential design elements.

MILESTONE #3: GEOMETRIC MODELING OF PACKAGING DESIGN

This milestone focuses on helping students strengthen their capacity to use geometric shapes, measures, and properties to describe objects, and to apply geometric methods to solve design problems. Unlike typical geometric problems, those that involve mathematical modeling are messier, requiring students to identify essential data, recognize the traditional geometric shapes found within complex ones, and approximate or choose measurements to solve design problems.

Design lessons to help students develop geometric modeling skills that they can use to draw and diagram a sustainable package design model. Students then solicit constructive critique to advance their model.

Note: The recommended resources will be helpful as you design lessons for this milestone.



3

Student teams use geometric modeling to create a packaging design that addresses an authentic design issue or challenge.

DEVELOP AND CRITIQUE

4

Student teams create a packaging prototype.



STEPPING STONES

MODEL THE DESIGN

Student teams use geometric modeling to develop a viable design.

SOLICIT CONSTRUCTIVE CRITIQUE

Student teams listen and respond to design engineers' or mathematicians' critiques of their geometric models.



RECOMMENDED RESOURCES

TEXTS AND DATA

- [Hexagonal Pattern of Beehives >>](#)
- [How Thick Is a Soda Can \(Variation 1\) >>](#)
- [How Thick Is a Soda Can \(Variation 2\) >>](#)
- [Ice Cream Cone >>](#)
- [Interchangeable Wristwatch Band >>](#)
- [Yogurt Land Container >>](#)
- [Efficient Cutting >>](#)
- [Engineering Drawing and Sketching >>](#)
- [Methods of Development >>](#)

AUDIO AND VISUALS

- [Reading a Dieline >>](#)
- [Customizable Dieline Creator >>](#)
- [Meatballs >>](#)
- [World's Largest Hot Coffee >>](#)

TOOLS AND FORMS

- [Mathematical Modeling >>](#)
- [Math Process Log >>](#)
- [Improve the Design >>](#)

STEPPING STONES TO GEOMETRIC MODELING OF PACKAGING DESIGN



1. MODEL THE DESIGN

Think about how you can create several lessons that help students [model with geometry >>](#). It may be challenging for students to do this, even without the additional element of applying the modeling to a real-life design problem. As you plan lessons, think carefully about the geometry concepts with which students will need to be comfortable in order to successfully develop a packaging design. Mine the recommended resources (listed on the previous page) for ideas as you plan these lessons.

This stepping stone culminates with groups creating diagrams of their proposed packaging design.

MATH LEARNING ACTIVITIES TIPS

There are two layers of work occurring at this stage of the project: (1) students use their geometry skills and knowledge to make calculations and determine measurements, and (2) they use these calculations and measurements to solve a packaging problem. As you design lessons, think about how to have students succeed in both layers. This is an iterative process that needs several lessons to support it.

CONFERRING TIPS

Meet with students groups so they can explain the math behind their packaging designs and demonstrate how their designs are beginning to address the packaging issue they're tackling.

	1. MODEL THE DESIGN	2. SOLICIT CONSTRUCTIVE CRITIQUE
Standards	M.PRACTICE.MP2 >> , M.PRACTICE.MP4 >> , M.CONTENT.HSG.MG.A.1 >> , M.CONTENT.HSG.MG.A.3 >> , M.CONTENT.HSG.GMD.3 >> , M.CONTENT.HSF.IF.B.4 >> , HS-ETS1-2 >>	HS-ETS1-1 >> , HS-ETS1-2 >> , HS-ETS1-3 >>
Students will be able to...	Use geometric shapes, measures, and properties to describe objects and apply geometric methods to model their solution to the design challenge.	Interpret and respond to critiques of their geometric models.
Ideas for Activities	<ul style="list-style-type: none"> Math Process Log >> My Favorite No >> 	<ul style="list-style-type: none"> Gallery Walk >> Improve the Design >>
Reflection and Synthesis Prompts	<ul style="list-style-type: none"> What did the different geometric modeling problems have in common? How are these problems different than typical geometry problems? Explain the reasons behind the decisions your group made when developing your model. 	<ul style="list-style-type: none"> What are some common suggestions you received about your packaging? What element of your design (sustainability, usability, aesthetics, etc.) did people respond to most strongly, and why do you think they responded that way?
Formative Assessment Ideas	<ul style="list-style-type: none"> Confer with groups to discuss how their design solution models address their challenges. 	<ul style="list-style-type: none"> Have students create Thought Bubbles >> to document how they process feedback and plan design improvements.
Suggestions for Feedback and Support	<ul style="list-style-type: none"> If students are struggling to solve "ill-defined" geometric problems, Costa's Questioning >> is a way to help improve their ability to approach problem solving. 	<ul style="list-style-type: none"> For students in need of additional support to synthesize the feedback on their models, use an activity like the Drawing Conclusions Thinking Guide >> to help them assemble multiple perspectives into actionable ideas.



2. SOLICIT CONSTRUCTIVE CRITIQUE

In this stepping stone, you'll create a couple lessons that provide opportunities for groups to listen and respond to design engineers' or mathematicians' critiques of their geometric models. This feedback and related design improvement is the fifth step in the engineering process.

[Improve the Design >>](#) provides several suggestions for ways to support students in this work. A [Gallery Walk >>](#) is one way to have students, consumers, or experts see and respond to all the prototypes efficiently.

You can also use or adapt aspects of the [Conferencing Process >>](#) as a way to have peers and others provide feedback.

LEARN FROM THE EXPERTS

Including design experts, engineers, or applied mathematicians in the feedback loop can provide welcome authenticity and authority at this point. If this isn't possible, you'll need to find another way to ensure students recognize the importance of this fifth step in the design process.

FOCUS ON STUDENTS' NTKS

This is a good time to revisit students' NTKs and address any questions that are related to the modeling process.

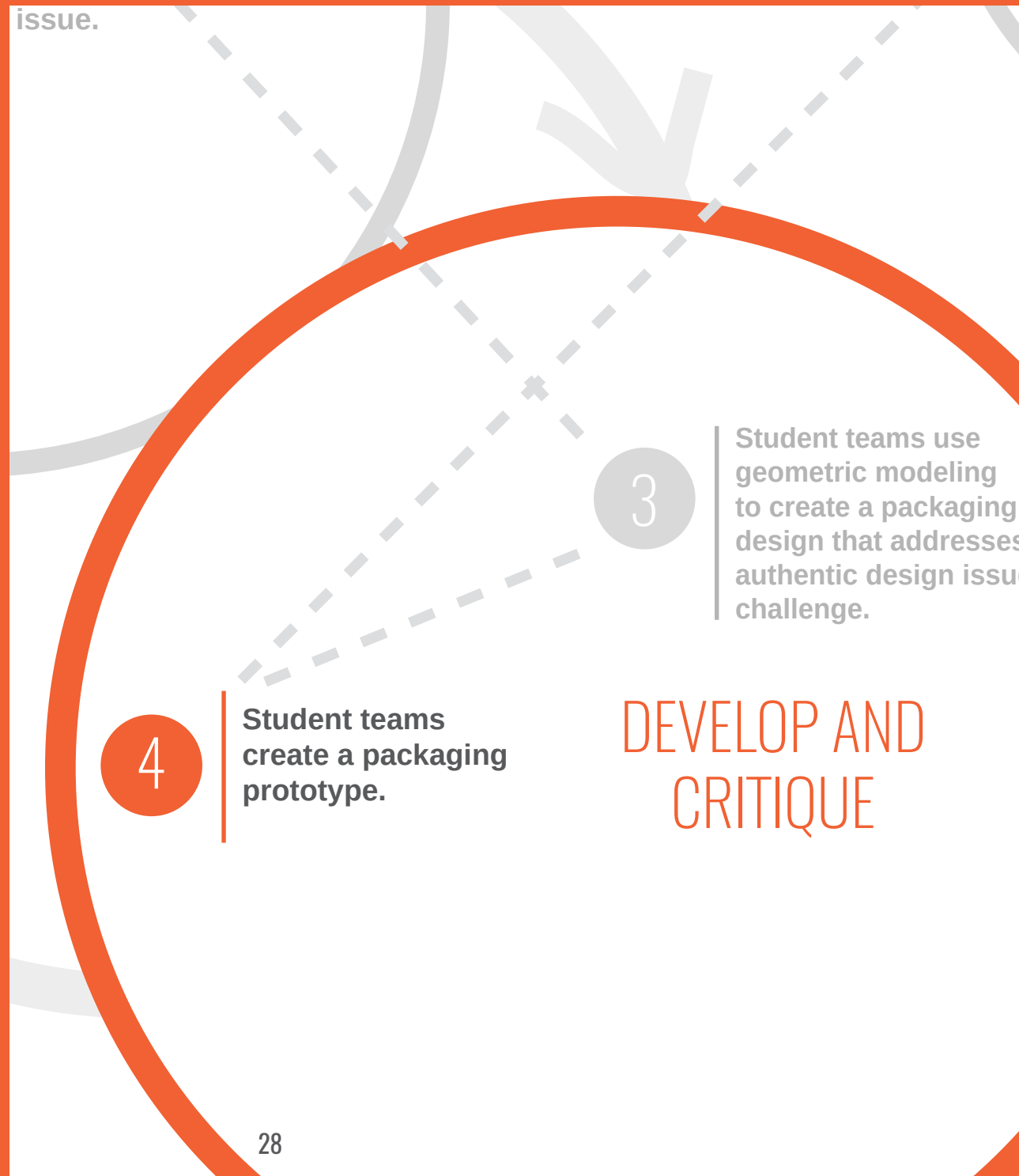
Don't forget to refer to the recommended resources at the beginning of the milestone.

MILESTONE #4: CREATE A PACKAGING PROTOTYPE

In this milestone, students turn their revised geometric drawings into a full-scale prototype. Prototype development is an important step in the engineering design process. It brings initial ideas to life three-dimensionally and allows students to pressure-test their designs with experts. This will provide them with essential data that will inform the final round of revisions.

Students use a range of materials to build prototypes of their design solution drawings. They will then gather feedback on their prototypes and go through another round of revisions. While this is a fluid process, think about developing critical checkpoints that help you keep the process tight, ensuring students move forward.

Note: Check out the recommended resources for prototyping suggestions.



STEPPING STONES

DEVELOP A PROTOTYPE

Student teams use their geometric models to develop prototypes.

IMPROVE THE PROTOTYPE

Student teams revise, tinker with, and improve the prototype, using feedback from a design expert.



RECOMMENDED RESOURCES

TEXTS AND DATA

- [How to Go From Idea to Prototype in One Day >>](#)
- [What Is a Makerspace? >>](#)
- [The Maker Map >>](#)

AUDIO AND VISUALS

- [Science, Engineering, and Design! Video 4: Prototyping >>](#)
- [How to Make a Cardboard Prototype >>](#)

TOOLS AND FORMS

- [Construct a Model or Prototype >>](#)
- [Math Process Logs >>](#)
- [Drawing Conclusions Thinking Guide >>](#)
- [Generative Summarizing >>](#)

STEPPING STONES TO CREATE A PACKAGING PROTOTYPE



1. DEVELOP A PROTOTYPE

In this stepping stone, create a set of lessons that help students structure their time so they can build prototype models guided by their geometric drawings.

As students assemble their prototypes from their drawings, it's likely that they'll need to recalculate measurements as they shift from two to three dimensions. There are several activities that can support discussions of this rethinking: try [My Favorite No >>](#) or [Problem-Solving Models >>](#). There are also suggested activities in the formative task [Construct a Model or Prototype >>](#).

PROTOTYPE CHALLENGES

Students will be able to assemble some designs with cardboard, but others—like the redesign of a bottle—will be challenging. How will you help your students address this? See if there is a makerspace or 3-D printer your class could use. If not, help students get creative with cardboard, paper mache, or clay.

Providing a range of materials will be key to making this stepping stone successful. Be sure to have items like cardboard, foam board, clay, cutting mats, X-ACTO® knives, hot-glue guns, duct tape, dowels, etc.

	1. DEVELOP A PROTOTYPE	2. IMPROVE THE PROTOTYPE
Standards	M.PRACTICE.MP2 >> , M.PRACTICE.MP4 >> , M.CONTENT.HSG.MG.A.1 >> , M.CONTENT.HSG.MG.A.3 >> , M.CONTENT.HSG.GMD.3 >> , M.CONTENT.HSF.IFB.4 >> , HS-ETS1-2 >>	M.PRACTICE.MP2 >> , M.PRACTICE.MP4 >> , M.CONTENT.HSG.MG.A.1 >> , M.CONTENT.HSG.MG.A.3 >> , HS-ETS1-2 >> , HS-ETS1-3 >>
Students will be able to...	Create prototypes based on geometric models.	Revise, tinker with, and improve the prototype, using feedback from a design expert.
Ideas for Activities	<ul style="list-style-type: none"> Construct a Model or Prototype >> Problem-Solving Models >> My Favorite No >> 	<ul style="list-style-type: none"> Drawing Conclusions Thinking Guide >> Problem Solving Via Imagery >>
Reflection and Synthesis Prompts	<ul style="list-style-type: none"> What problems did you need to solve as you created a three-dimensional prototype from your two-dimensional drawings? How would your experience building a prototype have been different if you hadn't first drawn and received feedback on a model? 	<ul style="list-style-type: none"> What feedback will you incorporate into your prototype before you are ready to present your final product, and how will it improve your design? How does the feedback you received on your prototype compare to the feedback you received on your drawings?
Formative Assessment Ideas	<ul style="list-style-type: none"> Prototype 	<ul style="list-style-type: none"> If a company asked if your product was ready for mass production, what would you tell them, and why?
Suggestions for Feedback and Support	<ul style="list-style-type: none"> The Math Process Log >> is a useful tool to help students review their thinking and identify areas of confusion. 	<ul style="list-style-type: none"> The use of Generative Summarizing >> can help students integrate the feedback on their prototypes into a few focused, actionable ideas.



2. IMPROVE THE PROTOTYPE

In this stepping stone, students receive concrete feedback on their designs from a packaging expert to help them improve their designs.

The feedback they receive is likely to require additional calculations and measurements. As you design lessons, make sure to help students understand the benefits of engaging in an iterative process, even when it can feel frustrating. This is an essential learning moment for students regarding perseverance.

While students are improving their prototypes, continue to conference with them.

NOTE ON TIME MANAGEMENT

This stage of the project is very fluid and can become challenging to manage. While fluidity is essential, students will likely need help remaining productive. Think about creating checkpoints that help you ensure that the project continues to move forward effectively.

REVISIT THE DRIVING QUESTION

This is a good time for students to return to the driving question to see how well they struck a balance between the competing issues of cost, sustainability, and aesthetics.

Don't forget to use the recommended resources as a support while you plan.

MILESTONE #5: SHARING THE PROTOTYPE

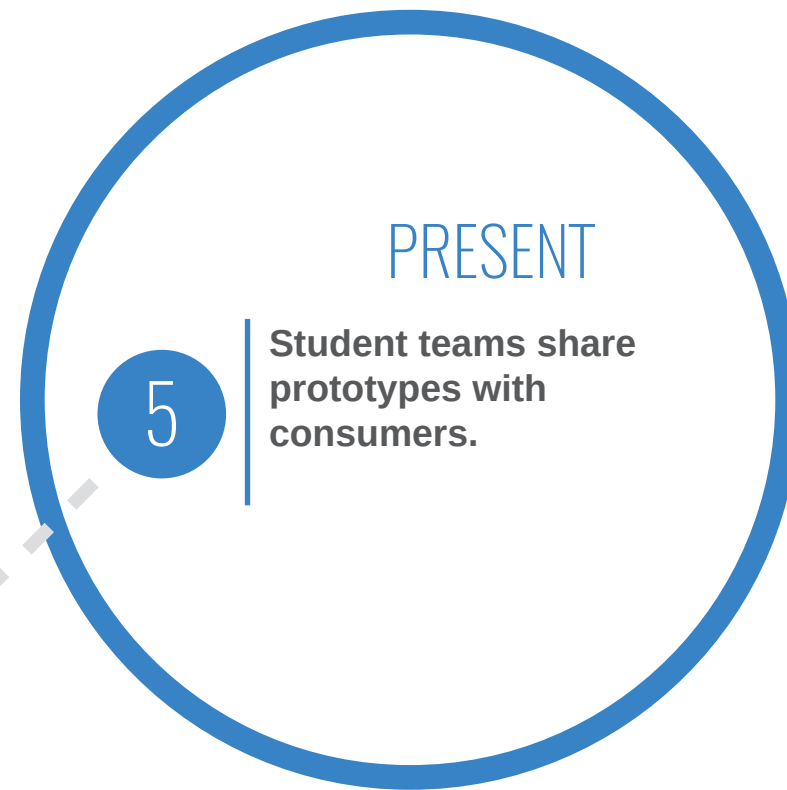
This milestone has three stepping stones: prepare, present, and reflect. All three are essential, as they provide students with both the authentic experience of bringing their work out into the world with elegance and grace, and reflecting on their learnings to inform future projects and classwork.

As you plan lessons to help students prepare, think about how you might support them in striving for a very high level of readiness. For the presentation, take the stance that anything that can go wrong will, and plan accordingly. For the reflection, try to create an open, thoughtful, and calm moment for students to look inward, backward, and forward.

Note: The recommended resources will be helpful as you design lessons for this milestone.

3

Student teams use geometric modeling to create a packaging design that addresses an authentic design issue or challenge.



STEPPING STONES

PRACTICE & PREPARE

Student teams make final preparations for sharing their prototype.

PRESENT

Student teams share their designs with consumers.

REFLECT

Students and teacher reflect on their original NTKs and their current sense of understanding.



RECOMMENDED RESOURCES

TEXTS AND DATA

- [7 Ways to Teach Public Speaking to Kids >>](#)
- [How to Do Engineering Projects >>](#)
- [Plan an Event >>](#)
- [Create & Implement an Action Plan >>](#)

AUDIO AND VISUALS

- [Intel International Science and Engineering Fair >>](#)

MULTIMEDIA

- [Public Speaking How-To >>](#)

TOOLS AND FORMS

- [Reflection on Engineering Design >>](#)
- [Reflect on Learning Process >>](#)
- [Debrief the Event >>](#)

STEPPING STONES TO SHARING THE PROTOTYPE



1. PREPARE

Preparations will vary depending on whether students will share their prototypes in school or in the community

Because teenagers and adults are consumers, the simplest sharing would be with members of the extended school community. They could share either at an event such as an engineering fair or by setting up tables during lunch or before school and asking students to take a look at a prototype or two and give feedback. They could also take the same approach in a mall or on a main street.

	1. Prepare	2. Present	3. Reflect	
Standards	HS-ETS1-2 >> , M.PRACTICE.MP4 >> , CCSS.ELA-LIT.SL.11-12.1.C >>	CCSS.ELA-LIT.SL.11-12.1.D >> , HS-ETS1-2 >> ; CCSS.ELA-LIT.SL.11-12.1.C >> , CCSS.ELA-LIT.SL.11-12.4 >>	N/A	Standards
Students will be able to...	Make final preparations for sharing their prototype with consumers.	Share with and explain their designs and prototypes with consumers.	Reflect on their original NTKs and their current sense of understanding.	Students will be able to...
Decision Points	<ul style="list-style-type: none"> Who is the audience of consumers? Will consumers be invited to the school or met in the community? What (if any) materials will students need to prepare to support their prototypes? 	<ul style="list-style-type: none"> How can the experience be structured so that consumers give legitimate feedback on the prototype designs? 	<ul style="list-style-type: none"> Reflection Engineering Design >> PMI >> 	Ideas for Reflection on Work Product and Process
Ideas for Activities	<ul style="list-style-type: none"> Use the rubric to self-assess, and ask peers to assess the prototype and presentations. Write a presentation script, and rehearse with a partner group. 	<ul style="list-style-type: none"> The event. 	<ul style="list-style-type: none"> What? So What? Now What? >> 	Reflection on Presentation
Logistics	<ul style="list-style-type: none"> Community event: Contact a mall or main street association to set up a few tables with the prototypes and additional materials. Organize transportation and setup/breakdown. 	<ul style="list-style-type: none"> Arrive with enough time to set up. Figure out how consumers will be invited to engage and how students will organize themselves so people don't have to listen to descriptions of all the prototypes in order to give substantive feedback. 	<ul style="list-style-type: none"> Reflect on Learning Process >> 	Ideas for Reflection on NTKs and Key Knowledge



2. PRESENT

When you plan an in-person event, it's important to anticipate and plan for all the logistical details and potential complications.

As you plan for the event, imagine all that can go wrong, and think of a way to address it: What if a student misses the bus? A chaperone doesn't show up? The consumers won't engage? The weather is prohibitive? Students aren't prepared or have too much anxiety? Students forget their prototype?

3. REFLECT

Use this time to help students reflect on their new understanding of geometric modeling, sustainable packaging design, the engineering process, and the presentation itself.

Each of the project's elements provided students with experiences that are messier than math problems typically experienced in school. Student reflection should include time to discuss how they used math and engineering to solve ill-defined problems with competing interests, as well time to celebrate their accomplishments and effort.

Keep referring to the recommended resources at the beginning of this milestone for additional planning support.

APPENDIX I: STANDARDS

BUILD KNOWLEDGE (MILESTONES 3-4)

Geometry

[M.PRACTICE.MP2 >>](#)

Reason abstractly and quantitatively.

[M.PRACTICE.MP4 >>](#)

Model with mathematics.

[M.CONTENT.HSG.MG.A.1 >>](#)

Use geometric shapes to describe objects.

[M.CONTENT.HSG.MG.A.3 >>](#)

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

[M.CONTENT.HSG.GMD.3 >>](#)

Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems

[M.CONTENT.HSF.IFB.4 >>](#)

Interpret functions that arise in applications in terms of the context

BUILD KNOWLEDGE (MILESTONES 2-4)

Research

[CCSS.ELA-LITERACY.RST.11-12.9 >>](#)

Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

[CCSS.ELA-LITERACY.SL.11-12.1.D >>](#)

Respond thoughtfully to diverse perspectives; synthesize comments, claims, and evidence made on all sides of an issue; resolve contradictions when possible; and determine what additional information or research is required to deepen the investigation or complete the task.

DEVELOP & CRITIQUE (MILESTONES 2-4)

Engineering Design/Prototype

[HS-ETS1-1 >>](#)

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

[HS-ETS1-2 >>](#)

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

[HS-ETS1-3 >>](#)

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

DEVELOP & CRITIQUE CONT'D (MILESTONES 2-4)

Collaborate & Discuss

[CCSS.ELA-LITERACY.SL.11-12.1 >>](#)

Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

[CCSS.ELA-LITERACY.SL.11-12.1.A >>](#)

Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas.

[CCSS.ELA-LITERACY.SL.11-12.1.B >>](#)

Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed.

[CCSS.ELA-LITERACY.SL.11-12.1.C >>](#)

Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.

PRESENT (MILESTONE 5)

[CCSS.ELA-LITERACY.SL.11-12.4 >>](#)

Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.

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acknowledgements

Helen Keller said it best, “Alone we can do so little; together we can do so much.”

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