Innovation Curriculum

Classroom Lesson 3

Plan & Build

Lesson Overview

Students will continue the GSA Innovation Process by completing the following steps: 1) make a plan to develop and test their chosen solutions; 2) build prototypes or models of their solutions

The New York Academy of Sciences

United Technologies

Lesson 3: Plan & Build

Lesson Overview: Students will continue the GSA Innovation Process by completing the following steps.

1. Make a plan to develop and test their chosen solutions
2. Build prototypes or models of their solutions

Time Frame: 1–2 weeks

- Part 1: Plan - 45–120 min (in class)
- Part 2: Build - 45–120 min (in class), 1–2 weeks (outside class)

Core Concepts

- A hypothesis is a preliminary, testable explanation for a phenomenon or for how something will work, based on minimal evidence
- Designing and testing a solution requires forming a hypothesis about how it will work
- Before building a solution, it is important to determine what kind of prototype or model best suits the design and can be tested

Lesson Objectives

Students will be able to:

- Form hypotheses about how their proposed solutions will work
- Devise an appropriate plan for developing prototype solutions
- Determine appropriate methods for testing and evaluating their hypotheses using their prototyped solutions

Lesson Inquiry Question: What is required to form and test a hypothesis?

Materials Needed

- Journals (optional)
- Sketch paper and pens or pencils for each team
- Copies of any resources below that you wish to share with students
- Templates for Deliverable 3—see Appendix C
- Supplies for building models/prototypes (will vary, but may include paper, pens, cardboard, string, tape, wireframe or storyboard app, etc). Students will create supply lists during Part 1 that instructors can use to prepare for Part 2.

Journal Opportunity (optional)

Students who are keeping science journals may want to use them before and after each step (planning and building) to set personal learning goals for each step and evaluate how well those goals were met.

NGSS Alignment

Lesson 3 provides opportunities for students to engage in the following Science & Engineering Practices (SEPs).

- ***Practice 1*** – Asking Questions & Defining Problems
- ***Practice 2*** – Developing & Using Models
- ***Practice 3*** – Planning & Carrying Out an Investigation
- ***Practice 5*** – Using Mathematical & Computational Thinking (*depending on design/ prototype*)
- ***Practice 6*** – Constructing Explanations & Designing Solutions

This lesson is directly aligned with the following Performance Expectations.

- ***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.

Educators may align the lesson to additional Performance Expectations and/or Disciplinary Core Ideas (DCIs) through challenge selection and/or the provision of specific related research resources.

Part 1: Plan

Estimated Time
45–120 minutes (in class; 1–2 class periods)

Preparation: Share with students that during the first part of this lesson each team will make a plan to build and test the solution they chose in Lesson 2. They will form a hypothesis about how their solution will work, decide on an appropriate format or model for building the solution, and determine how best to test and evaluate the solution. Before beginning, it may be helpful to introduce or review the Terms and Concepts at the end of this lesson.

Procedure
1. Explain to students that the first step in planning is to form a hypothesis, an informed explanation about how they think their solution will perform. One way to write a hypothesis is as an if/then statement: "If I do *x*, then *y* will happen." Hypotheses should be testable. In other words, if an experiment is conducted, students must be able to identify the kinds of results that would support the experimental hypothesis and the kinds of results that would disprove the hypothesis (or support a null hypothesis). Students will use the models or prototypes they build in Part 2 of this lesson to test their hypotheses.

> *Example:* Consider the traditional engineering challenge of designing a contraption that will allow a raw egg to be dropped from a second-story window and land without cracking. An example hypothesis could state: “The use of a parachute will cause enough drag to slow an egg’s falling speed sufficiently to prevent breakage when dropped from a second-story window.”
>
> For a particular experiment, a more detailed or specific experimental hypothesis should be generated, such as, “The use of a 1 meter by 1 meter tissue paper parachute will prevent an egg from breaking when dropped from a height of 4 meters,” or “The use of a 1 meter by 1 meter tissue paper parachute will work better at protecting an egg from breakage than a 1 meter by 1 meter plastic bag parachute when dropping an egg from a height of 4 meters.” Students should also consider what the null hypothesis would be. For example, “The use of a 1 meter by 1 meter tissue paper parachute will NOT protect an egg from breaking when dropped from a height of 4 meters.”

Teams should record their hypothesis (or hypotheses) in the “Hypothesis” section of Deliverable 3.

2. Invite students to think about how they will test their hypotheses, and how they will model or prototype their solutions to conduct their tests. Will they gather feedback from potential users of their solution, or conduct scientific experiments, or both? Will they use a

representation of their solution, such as a mock-up or sketch, or build a real working prototype? Encourage students to think about how they can best test their hypothesis, rather than how they can build a mock-up of their design solution. In other words, their prototype may not need to look like the final solution at all in order to test a particular variable. As students consider the variable, or variables, that they would like to test, they should also consider and identify dependent and independent variables, as well as a control.

> *Example*: The egg-drop hypothesis above might be tested using scientific experiments that consider the independent variables of parachute materials and/or parachute area to see if the dependent variables of egg drop speed or egg breakage are affected. If several independent variables are considered, there may be several experimental hypotheses (and several tests) that can help students determine whether they can support the general hypothesis they have proposed. A control, such as an egg without a parachute, should also be tested.
>
> On the other hand, if students are certain that a particular type of parachute will work, but are concerned that people who regularly drop eggs from second-story windows may have difficulty using the new technology, they may want to gather feedback from potential users or even conduct experimental tests of actual users dropping the eggs using the parachutes. A control may be an informed experimenter (presumably someone who knows how to correctly use the parachute).

There are many options for creating models or prototypes to meet the rigors of testing. Different solutions and hypotheses may require different types of prototypes/models. Share this list of possible models. Be sure students are familiar with each model and invite them to add their own ideas to the list.

- Diagrams
- Flow charts
- Sketches
- Wireframes (see linked resource in Build, Step 1, below)
- Storyboards (see linked resource in Build, Step 1, below)
- User experience maps (see linked resource in Build, Step 1, below)
- Working prototypes

Ask each team to meet to discuss and decide what model or prototype they will build. Share the following resources to help teams with this decision.

- Determine What to Prototype: IDEO's Design Kit shares four steps to help students decide how to prototype their ideas
- Identify a Variable: The Bootcamp Bootleg from Stanford University's Institute of

Design explains the *why* and *how* in "Identify a Variable" (card 37; page 40). You may have already downloaded this resource for Lesson 2.

Once students have settled on a model or prototype, ask them to reconsider their hypotheses. Will they need to express one or more experimental hypothesis to address the actual tests they will perform with their model or prototype?

Feedback Opportunity: Before moving on to the next step, meet with each team to be sure they have decided on an appropriate, useful way to build or represent their solution. As needed, use questions such as the following to prompt students to reconsider their plans.

- What is the hypothesis you wish to test?
- How will you test this hypothesis? If there are multiple independent variables, how will you test each one?
- What will be your dependent variable(s)? What variable(s) will you control?
- What will be your experimental hypothesis and null hypothesis?
- What results do you expect if your hypothesis is supported? What results do you expect if your hypothesis is disproven?
- Are there other questions you hope to answer with your test(s)?
- How will you use the prototype you plan to build to answer your question(s)?
- Would another type of model or prototype be easier to build, or provide more or better answers? Will you need more than one model or prototype to test various aspects of your solution?

3. Guide students to finalize their plans for testing and evaluating their solutions. If they plan to conduct scientific experiments, remind them to identify the variable(s) they will test, their experimental and null hypotheses for each test, and the method(s) they will use to test each one. If they plan to conduct user testing, suggest that they consider how they will identify and connect with users in their target audience. Remind students that the purpose of their tests is to help determine whether their hypotheses are supported and to answer other questions they may have about their solutions. Ask students to consider whether the testing methods they are planning will satisfy those objectives.

Students should complete the "Research Plan" section of Deliverable 3 with an outline of the methods they will use to test or investigate the viability of their solution.

4. Ask students to create a list of supplies they will need or would like to create their prototype or model. Before moving on to Part 2, review the lists and consult with students about alternatives if their ideal supplies are not available. It may be helpful to provide students with a list of standard supplies you can provide and indicate that additional items may be available upon request and dependent upon availability, cost, etc. If appropriate and practical, students may be invited to provide additional supplies.

Deliverable 3

Using the Deliverable 3 template (Appendix C), have students outline the following in one page or less.

- **Hypothesis:** State the hypothesis (or hypotheses) you plan to test.
- **Research Plan:** Outline the methods you will use to test your hypothesis or investigate the viability of your solution.

Part 2: Build

Estimated Time
45–120 minutes (in class; 1–2 class periods or more)
1–2 weeks (outside class)

Preparation: Tell students that it is now time to begin building their models or prototypes according to the plans they made in Part 1. Point out that it's not necessary or expected that students will get everything right on the first try. Prototyping is an iterative process in which you modify your design as you go, based on what you learn. During the course of the next lesson, teams will test their solutions and then have an opportunity to iterate and revise their designs. For an overview of the process, share the following resource.

- Rapid Prototyping: IDEO's Design Kit outlines the process of rapid prototyping a design solution

For information and guidance about how to build a prototype to test, share and review the following resource with students.

- Prototype to Test: The Bootcamp Bootleg from Stanford University's Institute of Design offers information and tips on prototyping to test (card 34; page 37)

Procedure
1. Once teams have gathered materials and assigned tasks to each member, they can begin building.

Teams that would like to develop a website or app can use the following web-based tool to develop wireframes, mockups, diagrams, and other kinds of prototypes. Invite students to use the app as applicable. This tool provides several layers of prototyping, so encourage students to use only the functionality they need and not get bogged down in details that are irrelevant to their prototype or testing.

- Moqups: A web-based tool for collaborative wireframing and prototyping

Teams planning to create storyboards or user experience maps may find the following resources helpful.

- Storyboard: IDEO's Design Kit explains how to create and use a storyboard in four steps
- User Experience Map: This guide from IDEO provides instructions and examples for making a User Experience Map

2. Allow teams sufficient opportunities to meet and work together until their models or prototypes are ready to be tested. Offer a minimum of one to two class periods so that you can provide input and feedback if necessary. Additional class periods and time outside of class may benefit students, but do not offer *too* much time. A prototype does not need to be perfect, and too much time may allow students to get bogged down in details that are unnecessary at this stage.

3. Encourage groups to photograph and/or video record the building process and the final prototype or model to be used in their final presentations.

Feedback Opportunity: Check in with each team at least once during the building process to assist with any challenges or obstacles they are facing. Check in again when each team has finished building to ensure that their model is ready for testing. As necessary, complete the following steps with students.

- Review their research plan
- Ask students to explain how they will use their model in executing their research plan
- Guide students to make any necessary adjustments or revisions to better prepare the model for testing

Terms and Concepts

- ***hypothesis*: a suggested answer or explanation to a scientific question, or a solution to a scientific or engineering challenge. A hypothesis must be testable, meaning that it can be supported or disproven based on observable evidence (i.e., that which may be gathered through use of the five senses and any tools that enhance the senses, such as microscopes or electronic sensors).
    - ***experimental hypothesis*** **or** ***alternative hypothesis*:** a prediction of what the results of a particular test will be *if the hypothesis is supported*. Typically, an experimental hypothesis suggests that there *is* a relationship between two variables: an independent variable that the experimenter is manipulating and a dependent variable that the experimenter is observing. For the egg drop example, one experimental hypothesis could be, "Fewer eggs will break when using a 3-meter square tissue paper parachute when the eggs are dropped from a height of 4 meters."
    - ***null hypothesis*:** a prediction of what the results will be *if the hypothesis is disproven*. Generally, a null hypothesis suggests that there is *not* a relationship between two variables—that changing or manipulating one variable will not affect the other.
- ***prototype*:** a preliminary model that may be tested and updated. Prototypes may be functional or illustrative.
- ***variable*:** a feature, factor, or quantity that may change in an experiment.
    - ***independent variable*:** a variable that the experimenter changes in an experiment. Ideally, an experiment should have only one independent variable, so that the results may be attributed to it. In the egg drop example, an experimenter might change the material used to make a parachute or the size or shape of the parachute to see whether it affects the outcome of the experiment.
    - ***dependent variable*:** a factor that may or may not change due to a change in an independent variable. These are the variables about which the experimenter is making observations, measuring, and collecting data. There may be one or more dependent variable. In the case of the egg drop, this may be as simple as a broken or unbroken shell, or the experimenter may develop a range of egg shell observations (e.g., small crack, several cracks, completely smashed).
    - ***controlled variable*:** a factor that is purposefully kept the same throughout an experiment so that it cannot inadvertently affect the dependent variable(s). In the egg drop example, if the experimenter wanted to test

different parachute materials to see which one best protects a dropped egg, the size and shape of the parachute are variables that should be controlled. The height of the drop, the landing surface, and other factors that may affect if and how an egg breaks should also be controlled.

- ***wireframe*:** a visual guide or schematic that gives a skeletal view of a website or app. A wireframe can be useful when designing a website to consider how various elements might be arranged to facilitate use.

Additional Resources

Plan

Students may find the following resources helpful when formulating hypotheses about their solutions.

- http://www.sciencebuddies.org/science-fair-projects/project_hypothesis.shtml
- http://www.wikihow.com/Write-a-Hypothesis

Build

These resources offer more information and ideas about prototyping, and might be especially useful to students planning to build a functional prototype.

- http://ideasuploaded.com/2011/05/31/how-to-make-an-invention-prototype-cheaply/
- https://www.entrepreneur.com/article/80678
- https://www.fastcompany.com/3045934/passion-to-profit/how-to-go-from-idea-to-prototype-in-one-day

The Scientific Method

This resource explains six steps of the scientific method—from asking and researching an initial question to presenting the results of testing and analysis—with links to additional information about each step.

- http://www.sciencebuddies.org/science-fair-projects/project_scientific_method.shtml

Lesson 3 Hyperlink Index

Determine What to Prototype: IDEO's Design Kit shares four steps to help students decide how to prototype their ideas. http://www.designkit.org/methods/34

Bootcamp Bootleg: Resource cards created by the dSchool at Stanford University's Institute of Design. https://dschool.stanford.edu/resources/the-bootcamp-bootleg

- *Identify a Variable:* card 37; page 40
- *Prototype to Test:* card 34; page 37

Rapid Prototyping: IDEO's Design Kit outlines the process of rapid prototyping a design solution. http://www.designkit.org/methods/26

Moqups: A web-based tool for collaborative wireframing and prototyping. https://moqups.com/

Storyboard: IDEO's Design Kit explains how to create and use a storyboard in four steps. http://www.designkit.org/methods/35

User Experience Map: This guide from IDEO provides instructions and examples for making a User Experience Map. https://d3gxp3iknbs7bs.cloudfront.net/attachments/5c28e26a-ba7f-44f4-859b-e82658264287.pdf