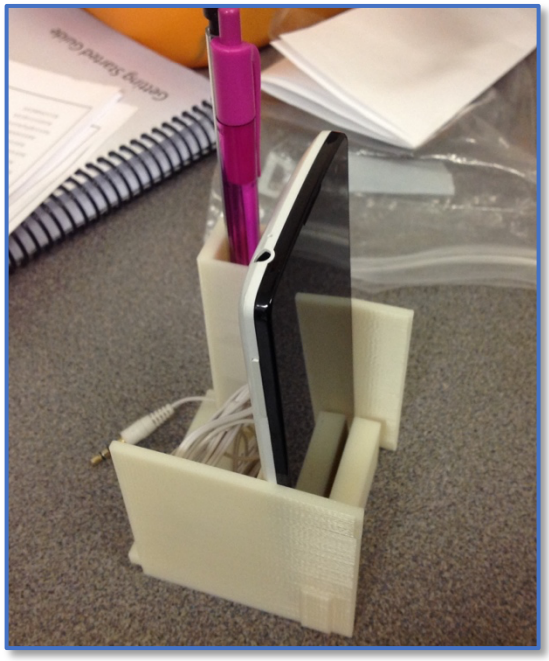
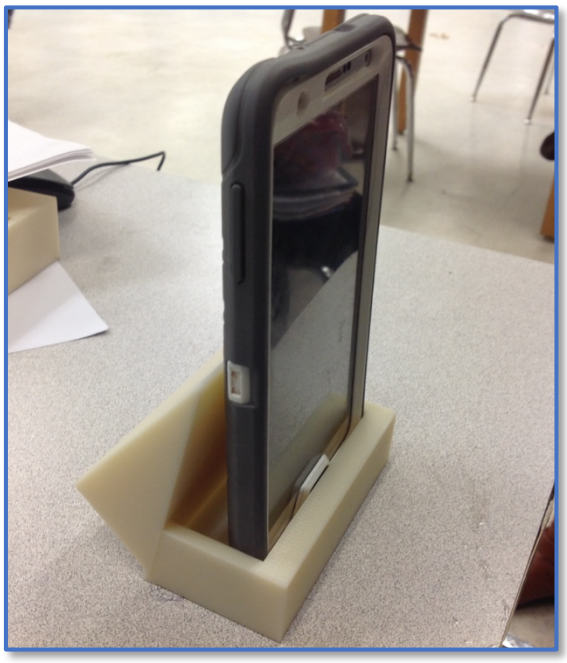
STEM INNOVATION & DESIGN

Cellphone Holder Design Challenge





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Georgia Tech Center for Education Integrating Science, Mathematics, and Computing

Cellphone Holder Design Challenge

Unit Introduction

This Cellphone Holder Design Challenge serves to introduce students to the steps of the engineering design process and to instill in them the importance of communication, documentation, and precise measurement in the creation of new products. The challenge also sets the tone for entrepreneurial thinking—i.e. that products are designed for clients.

During this challenge, students work with a partner and each designs a desktop holder for their partner's cell phone per their partner's requirements. Students must document the problem and the requirements and design a solution that meets their partner's approval. They render their design using 3-D modeling software and test the dimensions. Final solutions are 3D printed for additional testing and presentations.

Grade Level: 7th-9th

Time Required: 2-3 weeks. Plus after school time for 3D printing of designed items.

Standards and Learning Goals

<table>
<tr><td colspan="2">Physical Science Standard
MS-PS1-4: Matter and Its Interactions
https://www.nextgenscience.org/topic-arrangement/msstructure-and-properties-matter</td></tr>
<tr><td colspan="2">Performance Expectation
MS-PS1-3: Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.</td></tr>
<tr><td>Dimension</td><td>Classroom Connection</td></tr>
<tr><td>Science and Engineering Practice
Developing and Using Models</td><td>Students use CAD modeling software and 3D printing technology to develop, revise, and test models of their designs.</td></tr>
<tr><td>Disciplinary Core Idea
MS-PS1-4: Structure and Properties of Matter. The changes in state that occur with variations in temperature or pressure can be described and predicted using these models of matter.</td><td>Students observe the changes in state that occur during the 3D printing process.</td></tr>
<tr><td>Crosscutting Concept
MS-PS1-3: Structure and Function. Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped or used.</td><td>Students consider the relationship between structure and function as they prototype and test cellphone holder designs. Specifically, students evaluate whether the shape and dimensions of their cell phone holder designs along with the properties of the 3D printed material will enable full functionality of the cell phone when placed in the holder.</td></tr>
</table>

Engineering Standard MS-ETS1: Engineering Design https://www.nextgenscience.org/dci-arrangement/ms-ets1-engineering-design	
Performance Expectations MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	
Dimension	**Classroom Connection**
Science and Engineering Practice Asking Questions and Defining Problems	Students gather information from the Challenge Request for Proposals (RFP) and client meetings conducted with a classmate to identify multiple criteria and constraints that guide their cellphone holder designs.
Disciplinary Core Ideas Defining and Delimiting Engineering Problems. MS-ETS1-1: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. Developing Possible Solutions MS-ETS1-4: A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. MS-ETS1-2, MS-ETS1-3: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of the problem. MS-ETS1-4: Models of all kinds are important for testing solutions.	Students consider criteria and constraints presented in the Challenge RFP and conduct client meetings during which they discuss personal preferences for cellphone holder designs. Students record their statement of the problem in their Engineering Design Process (EDP) notebooks. Students develop at least three ideas for potential cellphone holder designs. Students sketch each design concept in the EDP notebook, along with descriptions of the design's basic functions. After evaluating possible solutions using an evaluation matrix, students use 3D modeling software to create prototype drawings that they refine based on testing (confirming measurements) and user feedback before ultimately 3D printing the design. Once printed, students once again test their prototypes to determine whether they meet client specifications and the criteria and constraints described in the Challenge RFP.
Crosscutting Concept MS-ETS1-1: Influence of Science, Engineering, and Technology on Society and the Natural World. The uses of technologies and limitations on their use are driven by	Students work directly with 3D modeling software and 3D printing technology to address the individual needs and desires of their client to create an innovative cellphone holder design. In doing so,

individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.	students gain real world experience using 3D modeling and printing technology to design a working prototype of a new cellphone holder.

Engineering Skill Learning Goals

- Students create sketches, drawings, and builds to understand the connection between visual representations and actual design artifacts.
- Students sketch, dimension, visualize, render and verify with advanced manufacturing tools and software to fabricate artifacts.
- Students conduct research and document design requirements to develop a design specification.
- Students iteratively document, communicate and evaluate design concepts to identify feasible solutions for a design problem.
- Students design and implement tests to determine how well design artifacts meet the design requirements.
- Students present all documentation, data, and design artifacts to illustrate understanding of the engineering design process.
- Students present relevant documentation, data, and design artifacts to pitch their design solutions to different audiences.

Activity #1: Challenge Planning

Students explore the challenge including the importance of engineers and documentation. They begin to learn how to use the Engineering Design Notebook and are introduced to the Cellphone Holder Design Challenge.

Time Required: 40-50 minutes

Preparation needed for the Activity:

- Laptops
- Engineering Design Process Poster (If not posted already in classroom)
- Engineering Design Process Student Handouts
- Engineering Mindset Video
- Request for Proposal (RFP) (1 per student)

Part 1 - Mindset of an Engineer: 10-15 min

The mindset of an engineer needs to be unconstrained and innovative. The Apollo 13 video clip demonstrates this mindset. Watch the *Engineering Mindset* video and ask students:

- What did you notice about the engineers in the video?
  - (They did not hesitate and no one said 'we can't do this')
- What was the one item that was requested as they presented their solution?
  - (A procedure to make the filter)

Part 2 - Importance of the Engineering Design Process and Engineering Design Notebook: 15-20 min

As engineers design and develop concepts, they use the Engineering Design Process. Guide the students through the parts of the Engineering Design Process, using the EDP Poster in your classroom (students should keep a copy of this in their notebooks). Emphasize that the **process** is not necessarily linear--that engineers might go through many rounds of ideating, evaluating, prototyping and testing before they decide on the best solution.

- **Identify the Problem**
  - *Identify and explain the problem you are trying to solve. This step should not include any information about a solution for the problem.*
- **Understand**
  - *In the Understand section, you should identify each requirement that the solution must meet. Requirements can be features that the solution must have, such as wheels, a handle, or an amount of profit, but also can be factors that restrict the solution as well, such as weight, price or who the user will be. These are also called Constraints.*

- **Ideate**
  - *The Ideate section is where you come up with possible ideas for solutions to the problem. This section should include a good description of your ideas, and possibly sketches of them.*
- **Evaluate**
  - *When you Evaluate, you compare each solution idea against your list of requirements to help you judge which ideas best meet the solution requirements. This will help you decide which ideas you should prototype and test.*
- **Prototype and Test**
  - *During this stage, you build a model, or prototype, of your solution so you can test it. You need to determine how you will test each of the requirements. The tests should have defined procedures so that every test that you perform will be consistent and will yield accurate results.*
- **Communicate Your Solution**
  - *During this stage you communicate to your audience (via Concept Review and Pitching) the results of your tests and your decision about which idea was best.*

When engineers work on a project, they need to keep an organized record of their ideas and procedure. Discuss with students how having a procedure document was helpful in the Apollo 13 video. Introduce students to the idea of the **Engineering Design Notebook.** This is the document that they will use to organize and record their ideas, process and testing results. It will support the Engineering Design Process (EDP) and students will be able to track their work and avoid repetitive decisions.

Part 3: Presenting the Challenge: 10-20 min

- Share the Request for Proposals (RFP) for the Cellphone Holder Design Challenge with the students
  - *An RFP is a document that companies produce and distribute that provides basic information about what the company needs, and some of the requirements for the product, so that interested people and companies will know how to submit their proposals.*
- Read the RFP aloud with the students and discuss the different requirements that are outlined in the document.

For this challenge, there are three basic types of requirements--

- Those specified in the RFP. In this case, they are primarily materials constraints, indicated by specific size restrictions.
- Those that students will generate, based on measurements of their partner's cell phone.
- Those that have to do with client preference--does the client want somewhere to hold their earbuds? What do they want it to look like? At what angle do they want it held? Etc.

Activity #2: Pitch vs. Design Concept Review (50-70 minutes)

Students will explore presentation formats for different audiences. In this section students will learn how to understand the audience that their presentations are directed to reach, and the differences in the data they should include in their presentation depending upon the audience. They will then compare and contrast two types of engineering presentations, a pitch and a concept review, and discuss how the audience influences the type of presentation made.

Time Required: 50-70 minutes

Preparation needed for the Activity:

- Shark Tank Video
- Shark Tank worksheet

Part 1 - Understanding your Audience: 15-20 min

Understanding your audience is a critical part of any presentation. Your audience helps determine the important items that should be included in the presentation. Let's look at a presentation and discuss the audience and whether this was a correct presentation for the audience.

- Play video: Shark Tank Drive Suit
- Students will fill out the Shark Tank Worksheet
- Use the following questions for discussion prompts:
  - *Was this an effective presentation for the audience?*
  - *Was this a pitch or a design concept review?*

Part 2 - Components of a Pitch: 5-10 min

Discuss with students the components of a **pitch:**

- Who is your audience? Potential investors or partners?
- What is the product or service you offer?
- What purpose/problem does it serve?
- What are the costs associated with the product?
- What is the potential for profit?
- What are the current sales and production capacity?

Part 3 - Components of a Concept Review: 5-10 min

Discuss with students the components of a **concept review/design review**:

- Who is your audience? Engineers, design consultants, market analysts
- What is the product or service you offer?
- What purpose/problem does it serve?
- How does it work?
- Technical details--how is it made?

- Possible options to improve
- A concept review probably doesn't include: current sales, cost analysis, production, profit projections

Here is a graphic organizer that you may choose to share with the students that shows how the pitch and concept review are similar and their differences.

Part 4 - Closing: 15-20 min

Re-watch the Shark Tank video have the students note the parts of the presentation based on what they learned about pitches and concept reviews.

- Suggestion for a Ticket Out The Door activity--have students list the components included in the video and their assessment about which type of presentation they watched.

Activity #3: Identify and Understand

Students begin using the engineering design process. Student pairs meet as client and designer to determine the requirements and dimensions for the product. They complete the Identify and Understand worksheets for their Engineering Design Notebook.

Time Required: 45-60 minutes

Preparation needed for Activity:

- Engineering Design Process graphic/poster displayed in room
- Identify and Understand worksheets
- Ruler or calipers for measuring cell phone dimensions

Part 1 - Meeting with your Client: 10-20 min

- Remind the students of the challenge and have them meet with their partner (client).
- Student pairs should have a short discussion about personal preferences for their design.
- Students should write down the preferences of their client, in the form of requirements.

Part 2 – Students begin to document their process in their Engineering Design Notebooks: 30-45 min

Step 1 – Identify the Problem: Students read, understand, and clearly restate the problem they are working on.

- Students should begin with the **Identify the Problem** worksheet. There are two important components to include in this section--the problem students are attempting to solve, and the customer or client.
    - Possible narrative to students:

        - *Part of engineering design is properly understanding the problem and the customer or client. It is a common mistake to make something that no one actually wants. To avoid that, it is important to research the problem and the customer. The problem and the intended client should both be described clearly on the 'Identify the Problem' worksheet.*
    - Students should Identify the customer and the problem on their worksheet
        - *In your own words, type of clear statement of the problem. It should include a specific client (in this case, a student's name) and a specific need that doesn't imply a certain solution. (For example, John needs a way to keep his phone upright on his desk to read texts as they arrive.)*
    - Students should Identify what products already exist. Possible narrative to students:
        - *It is always important to research what has already been done. You don't want to re-invent the wheel, nor do you want to repeat someone else's mistake.*
    - Provide students with time to go online and get some ideas about cellphone holders.

Step 2: Defining Design Requirements

- Students should access their **Understand** worksheet.
- The requirements list is a list of characteristics that the design must have, as well as a list of the constraints that are placed on the design.
- Students should refer to information from their client meeting to fill out the requirements about client preference.
- They should use a ruler, calipers or other measuring device to determine the dimensions of their client's cell phone.
- All requirements should identify the source of the requirement. In this case, it is from the client interview, the RFP, or a test result. Possible narrative:
    - *On this page of your engineering design notebook you will create a documented list of all of the requirements that your solution should meet, based on the needs of the client. You should document each design requirement with an appropriate source that indicates where that requirement came from. This will provide a dated list as you add requirements later in the process.*
    - *What are the requirements that must be met by your solution?*
    - *What are the desires of your client/customer?*
    - *What are the technical requirements (e.g. <u>dimensions</u> that must be considered)?*
- Later in the design process, students will test their prototypes against all listed requirements.

Note: The reason for dating each entry is that the list can be updated if needed.

Activity #4: Ideation--Generating and Evaluating Ideas

Students develop ideas and evaluate them against requirements. Students will use the engineering design notebook to record their solution ideas and descriptions. They will evaluate each design based on the determined requirements from their client and select one solution as the design to begin development.

Time Required: 70-90 minutes

Preparation needed for Activity:

- Engineering Design Notebook worksheets—Ideate and Evaluation Matrix
- Paper

Part 1 - Generating Ideas: Ideation 25-30 min

Continue to guide students through the Engineering Design Process.

Ideate: -- To create several ideas that could be designed, based on the problem statement and requirements. Similar to brainstorming. All ideas are welcome.

- Instruct students to individually sketch out (informally, but understandably) at least three different design concepts for the cell phone holder on their Ideate worksheet. At this point precise measurements are not taken or required. Each design idea is supported just with a rough sketch and a description of the design and its basic functions.
- Students should type a short description of what is novel about that idea and why they think it might work.
- Each concept can be given a descriptive name.

Part 2--Evaluating Ideas: 30-50 min

Evaluate- -Determining how well each concept design meets the requirements and then, based on that information, deciding which concept you will proceed with to the next step.

- **Pose question:** How do we evaluate our design concepts? Possible narrative:
  - *In the design process, we're now at the '**Evaluate**' stage. This means we need to pick the most promising concepts and then create a detailed drawing and prototype of that concept.*
  - *To do this, we'll use the **evaluation matrix** worksheet.*
- Students should list the names of their different design concepts across the top of the matrix—one per column.
- They then transfer all of their **Requirements** to the rows of the matrix.
- The form is designed to help the students think about which design concepts they want to go forward with, but it will not itself give a definitive answer. At this point, the information that students enter is predictive, based on their beliefs about how the different designs will perform with respect to the different requirements.

- In each matrix box, students should indicate whether they think that the design concept in that column will satisfy the requirement on the row. They can do by coloring the box either red and green, or writing Y/N, or Unlikely/Likely. The red/green colors make patterns easier to see.
- Once they have finished evaluating all the concepts, they are ready to make a decision on the prototype they feel is most promising to recommend when they meet with the client again.
- **Choose promising concepts**
  - The student should be prepared to show the client the other possible ideas if he or she doesn't like the first idea.
  - In the next section they will work on detailed designs and prototypes.

Part 3 - Closing: 10 min

Provide time (in class or for homework) and guidelines for students to prepare for their client meetings.

- *You will need the sketch of the promising solution to show the design that you have decided best meets the requirements provided. You will only present one design to your client based on your evaluation of the concepts.*

Activity #5 -- Review and 3D Modeling

Students review their design and begin to model their solution. Students will meet with their client to share the current progress of the designed solution. They will record the discussion in their engineering design notebook. Before prototyping, students will refresh or familiarize themselves with 3D Modeling software in preparation for building the solution.

Time Require: 50-75 minutes

Preparation needed for the Activity:

- Engineering Design Process worksheets
- Measurement device (calipers)
- 3D Modeling software

Part 1 - Client Review Meeting: 20-25 min

Have the students meet and share their chosen design with their client. They should discuss the design and any changes to the proposed design. Based on those discussions, students will either move on to the prototyping step or will iterate on their designs and return to the understanding step.

The Client Design Review Meeting:

- Students should pull together all of the materials they need to effectively share their chosen design with their client. Each student should take about 5 minutes to share with their partner, and then about 2 minutes to discuss any concerns and address any requirement changes. This is the final part of the evaluate step and leads to the prototyping step if both partners are in agreement.
- If any changes are needed, students must iterate on their design. As they do this, they should return to the **Understand** worksheet and update it with the new requirements.
    - *You will now meet with you client to share your proposed solution. During the meeting you will share all the information about the solution and have a discussion to determine if this solution is acceptable to the client.*
    - *If the client has ideas that require you to make changes, they should be captured to be added to the Understand worksheet as new requirements.*
    - **Iteration:** Making changes and going through the process again.
        - *During your client design review meeting, if a requirement is added or a change is needed for you to progress through the design process, you must **iterate** on your design(s). In the design process when you iterate you must return to the **Understanding** step and update your **Requirements**. Then **Ideate** again (if necessary) and re-**Evaluate** considering the updates.*

Part 2 - Preparing for 3D Modeling: 10-20 min

Students will use calipers to confirm measurements for their client's cell phone holder.

Introduce students to 3D modeling and the modeling software that they will be using:

- *3D modeling is a method to create a digital file of a product that you plan to manufacture. For this class we will use [specific modeling software] to build the model and create a file that can be processed by the 3D printer.*
- *Before you can create the 3D model you must have all the needed measurements to match your model's dimensions. Using a set of calipers, confirm the measurements that you made before for your client's phone holder. You should maintain a 5mm thickness on all parts and all dimensions should be in mm.*

Part 3 - Drawing with 3D Modeling Software--Introduction: 20-30 min

- Instruct students to set up a new 3D Modeling file with their units set to mm
- If they have not used the software before, they should view tutorials that show them how to construct the basic shapes they will need for their model.
- The tutorials are designed to show students how to construct and combine basic shapes. They may use other shaped objects that are not shown in the videos.
- Students should explore the use of the software. They will design their cell phone holder in the next section.

Activity #6: Prototype and Test

Part 1: Building and Virtual Testing your Prototype

Students complete the modeling and testing of their solution using the EDP. They will meet with their client for feedback as they develop a prototype of the solution. They will verify all aspects of the design with the client prior to finalizing the design and producing it on the 3D printer.

Time Required: 150-300 minutes

Preparation needed for Activity:

- 3D modeling software
- Printer
- EDP Test Procedures worksheet

Part 1 - Creating your Prototype: 25-45 min

- **Pose Question**: What does it mean to prototype? Possible narrative:
  - *A prototype is a version of a final product that can be used for testing. Designers only make a few prototypes at a time. They use them to help them make decisions about changes they need to make.*
  - *Prototypes include detailed drawings, models, mock-ups, 3D prints, and other physical artifacts. The key is that a prototype is testable—you might not be able to test every requirement with a given prototype, but it keeps you from investing too much time in a solution that isn't going to work.*
  - *Your 3D model will serve as your first prototype for the next client design meeting before it is printed on the 3D printer.*

Continue to monitor students as they design their model:

- As students work, they should reflect on their process and, if needed, update their requirements based on issues that arise. They should then return to the **Understanding** worksheet to add the new requirements before proceeding.
- When they have completed their 3D Model of the design solution students should give their prototype a name and save the file. This is their first prototype.

Part 2 - Defining Test Procedures: 15-20 min

- **Pose question:** *How can you test whether a prototype meets all the requirements?*
  - Each requirement needs to have an associated test. However, note that a single test might provide results for multiple requirements. For example, if there are multiple requirements about client preference, these can all be addressed at one client meeting
  - The test for whether requirements related to client preference are met can consist of a meeting with the client where they review whether the prototype satisfies the preferences.

- Dimensional requirements should be tested through measurements.
- Students should write the procedure for each test on their **Test Procedures** worksheet, indicating which requirements the test satisfies. They can add multiple steps, as needed. This should be a step-by-step guide to how the test is to be performed.

Part 3 - Testing the Prototype: 30-45 min

The 3D drawing that students have created is their prototype. They will test it through measurement and through a client meeting.

- **Dimensional tests**
  - Students should verify all dimensions before showing the prototype to the client. They should enter the data in the EDPL as a test trial.
- **Client Update Meeting test**
  - Students should meet with their client and share the current prototype or model.
  - If the client has suggestions or changes, these should be noted in the text box associated with that test on the Test Procedures worksheet. In that case students should indicate that the prototype did not pass the client test. They should then return to the 3D design software, make the modification, create a second prototype, and repeat the test.

Part 4 - Final Approval: 20-30 min

- Once the design is complete and the client has approved, the students will present the design and verification of measurements to the teacher prior to printing.
- After approving the design, set up the file for printing.
- Teachers should strive to have as many models as possible on a 3D printer plate. It will take some time to print all the student's models.

Activity #7: Final Test and Concept Review Presentations

Students present their process and the designed solution. Students will prepare for their presentations, meet with their clients and test their models before presenting their designs to the class.

Time Required: 90-120 minutes

Preparation needed for the Activity:

- Presentation Rubric Sheet
- 3D printed models

Part 1 - Preparing for a Presentation: 40-50 min

While the students are waiting for the models to print, they should prepare for their concept review presentation.

Remind students to look back at what was discussed previously about the main pieces of a concept review:

- What is the product or service that you offer?
- What purpose/problem does it serve?
- How does it work?
- Possible options to improve.
- Doesn't (generally) include: current sales, cost analysis, production or profit projections

Share the rubric that will be used to assess their presentation and model. For the most part, this part of the activity can be done without the final models completed. Students should be able to share this information and also clearly explain all of the functions included in their design.

Part 2 - Testing of Final 3-D Printed Holders: 10-15 min

- The 3D printed phone holder is also a prototype. This object should be tested against the requirements.
- They should run their tests again on this prototype to verify that the final 3D printed object still meets all the requirements. This includes meeting with their client for a final design review and verification.
- If time permit, students with models that don't pass all their tests could iterate on the design and create another model.

Part 3 - Concept Design Review Presentations: 40-50 min

- Students can present their designs to the class individually, but it will also work if the client pairs present together. In that case each student presents their solution but the client can open with the requirements that were set for the design.

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