Strand: 6.2.4

**Emphasis:** Energy flow/engineering

**Anticipated Time Required:**
- LE 1: 30 minutes
- LE 2: 35-60 minutes (depending on how long you give students to plan and conduct their investigations)
- LE 3: 30 minutes
- LE4: 45-60 minutes (or even more, depending on how long you give students to test and rebuild their prototypes)
- LE 5: 20-30 minutes to diagram and build final designs
  10-15 minutes to provide feedback on the design after it has been tested

**Dominant CCC:** Energy and matter

**Dominant SEP:** Planning and carrying out investigations, engaging in argument from evidence

**Management Strategies** to support equitable access to content:
- Explain-regroup-explain the explanation (students work with a group to construct an explanation; new groups are made, and students explain their explanations to their new group members)
- Group discussion with alternating leaders (students take turns leading their group in a discussion)
- Question stems for partner and small group discussions

**Shopping list:**
Buy/order enough materials for students to:
- Use samples to test structural features in LE 2; for this LE, have enough materials for each group of 3 students to have a sample or two of each material
- Build and test prototypes during LE 4; for this LE, each individual student will need several samples of each material (exact amounts depend on how much time students have to investigate; how many iterations will they have time to do?)
- Build a final design in LE 5; for this LE, each individual student will need samples of each material to build their final design

**Material ideas:**
- Aluminum foil
- Cotton (balls or batting)
- Plastic (ziploc bags, tupperware, plastic cups, etc.)
- Bubble wrap (which is really just air)
- Foam wrap (used for packing; can buy a large roll or order [https://www.amazon.com/UBOXES-Foam-Wrap-Thick-Perforated/dp/B005K0A9WY/ref=sr_1_1?ie=UTF8&qid=1499997457&s=office-products&sr=1-1&keywords=foam+wrap+roll](https://www.amazon.com/UBOXES-Foam-Wrap-Thick-Perforated/dp/B005K0A9WY/ref=sr_1_1?ie=UTF8&qid=1499997457&s=office-products&sr=1-1&keywords=foam+wrap+roll)
- Styrofoam (cups, rectangles from a craft store)
- Paper (newspaper could be used)
- Cardboard

For their prototype construction and final design, also have various types of tape and scissors available to students.
### 6.2.4 Heat Transfer and Engineering - Storyline Overview

**Anchor Phenomenon/Problem:** When the cafeteria serves ice cream sandwiches for lunch, you have to eat yours, even if you wanted to save it for later, because it will melt.

*Note: This problem should be adjusted to fit your school/class. Other ideas for framing the problem:*

- A student’s older sister is dropping off ice cream sandwiches for the student’s birthday, but will be dropping them off in the morning and the students can’t eat them until lunch
- Ice cream is going to be included in the sack lunches students will be taking on a field trip, but they can’t eat them until the lunch time
- The PTA is dropping off ice cream sandwiches in the morning for field day, but students can’t eat them until after the field day activities
- You and your friends like to walk to the park and play in the summer, and it would be nice to be able to bring ice cream and eat it after you are tired of playing

You could also have your students work on a problem that is a bit less first-world; these problems require empathy design, but since students are not trying to solve a peer’s problem, the interview pieces would need to be adjusted/deleted from the storyline. A few ideas of problems that require keeping something the same temperature:

- Ebola vaccines need to be kept cold. How could we package them in a way that they would stay cold without refrigeration? Is there a way to package the vaccines so they could be dropped into an area where there is an ebola outbreak and they could land without breaking and stay cold?
- Babies need to stay warm. In some places, mothers may have to walk for a day or more to get their sick or premature baby to a clinic, and during this time, the baby could get too cold and die. Design a baby carrier that a mother could use to transport her baby on foot without the baby losing heat. Search “design that matters” or go to embraceinnovations.com for additional ideas and information.

Allowing for student choice here is also an option. Students could engage in the same activities and graded according to the same rubric while working on a design challenge of their choice (ice cream sandwich saver, vaccine packaging, baby warmer, etc.).

**Target question:** How can we keep the ice cream from melting until you want to eat it?

**Student Performance Expectation:**

**6.2.4** Design an object, tool or process that minimizes or maximizes heat energy transfer. Identify criteria and constraints, develop a prototype for iterative testing and analyze data from testing, and propose modifications for optimizing the design solution. Emphasize demonstrating how the structure of differing materials allows them to function as either conductors or insulators.

**6.2.4 evidence statement:** [https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/MS-PS3-3%20Evidence%20Statements%20June%202015%20asterisks.pdf](https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/MS-PS3-3%20Evidence%20Statements%20June%202015%20asterisks.pdf)

Note: if empathy in design is new to you, this document is a good introduction: [https://dschool-old.stanford.edu/sandbox/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf?sessionID=573efa71aea50503341224491c862e32f5edc0a9](https://dschool-old.stanford.edu/sandbox/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf?sessionID=573efa71aea50503341224491c862e32f5edc0a9)
<table>
<thead>
<tr>
<th>CCC/SEP</th>
<th>What are students doing? (This should match your SEP!)</th>
<th>What specific Disciplinary Core Idea understandings should students get from this experience?</th>
<th>New questions students have to propel us to the next science experience</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: The ice cream sandwich problem</td>
<td>Gather: Students are introduced to the problem; record own concerns; interview client to determine criteria and constraints</td>
<td>Students should understand problem and criteria and constraints of possible design solutions</td>
<td>Which of the available materials are conductors/insulators? What other properties of the materials need to be considered as I design my product?</td>
<td>Formative: Initial student designs, including structure-function relationships; Student discussions</td>
</tr>
<tr>
<td>CCC: Stability and change, structure and function, cause and effect</td>
<td>Reason: Students brainstorm designs; identify structure and function relationships</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEP: Defining problems, obtaining information</td>
<td>Communicate: Students meet with client and describe possible designs; record features that the client likes/does not like</td>
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<td></td>
</tr>
<tr>
<td>2: Investigating materials for ice cream savers</td>
<td>Gather: Students investigate different materials to learn about their ability to conduct or insulate thermal energy, as well as other structures that may serve a function in their solution design</td>
<td>Some materials more efficiently minimize transfer of thermal energy; increasing amount/thickness of materials can affect their ability to minimize energy transfer</td>
<td>How can these materials be used effectively in the product design to meet the needs of the client?</td>
<td>Formative: Student ability to plan an investigation, record data and analyze it; Arguments about which materials could be useful in the solution,</td>
</tr>
<tr>
<td>Step</td>
<td>Activity</td>
<td>Reason</td>
<td>Developing prototype for iterative testing; address criteria and constraints</td>
<td>What changes need to be made to meet the needs of the client?</td>
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</tr>
<tr>
<td>3: Design a prototype</td>
<td>Communicate: Students construct a short argument regarding which structural features/properties would provide a function in their solution</td>
<td><strong>Reason I:</strong> Students create detailed diagram of prototype, which includes materials and descriptions of how the prototype solves the problem and addresses constraints</td>
<td>Communicate: Students present diagram to their group (client is not in the group) to get feedback and discuss ways to revise and improve the design</td>
<td>What changes need to be made to meet the needs of the client?</td>
</tr>
<tr>
<td>4: Build a prototype</td>
<td>Communicate: Students present prototype to client</td>
<td><strong>Reason II:</strong> Students use feedback from their group to make a new iteration of the prototype design</td>
<td>Gather: Students record feedback from client to use in future iteration</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Reason:</strong> Students use data from client and materials investigation, feedback from group to design, test, modify and build a prototype</td>
<td>What changes need to be made to meet the needs of the client and keep the ice cream insulated?</td>
<td></td>
</tr>
<tr>
<td>5: Final ice cream saver iteration</td>
<td>Gather/reason: Students use feedback from client to build and test final design</td>
<td>Communicate: Students present final design to client; and the design is tested using ice cream sandwiches</td>
<td>Students create final design blueprint with explanation and complete an evaluation for their engineer</td>
<td>How well did the final design work? What changes could be made for the next generation of this product?</td>
</tr>
</tbody>
</table>
6.2.3 Learning Episode 1

Student Science Performance

| Topic: Heat Transfer/engineering design | Title: The ice cream sandwich problem (intro) |

Overarching Performance Expectations (Standard):
6.2.4 Design an object, tool or process that minimizes or maximizes heat energy transfer. Identify criteria and constraints, develop a prototype for iterative testing and analyze data from testing, and propose modifications for optimizing the design solution. Emphasize demonstrating how the structure of differing materials allows them to function as either conductors or insulators.

Lesson Performance Expectations:
Students will define a problem and determining the criteria and constraints they will have while designing a solution to the problem.

CCC: Structure and function
SEP: Defining problems, constructing solutions, communicating information

Students Will. . . To Construct Meaning

**Engage with a Problem:** When the cafeteria serves ice cream sandwiches at lunch, you have to eat it at lunch, even if you wanted to save it for later, because it will melt.

**Gather:** Sometimes the cafeteria serves ice cream sandwiches, but you may not want to eat yours right away. Since the ice cream will melt, you either have to eat it or throw it away. You are going to design a system to keep the ice cream from melting until you want to eat it. In your lab book, record problems associated with having an ice cream sandwich between lunch and the end of school (besides the ice cream melting). These should be problems that you would face.

Your partner will be your engineer. As the client, you will be telling your engineer the problems that you wrote in your lab book. When it is your turn to be the engineer, listen to your client and record what he tells you. Also ask questions if you are not sure what your client means. You will have 60 seconds to tell your engineer the problems you listed, and then you will switch roles.

Teacher Will. . . To Support Students

Present the problem to your class; consider bringing in an ice cream sandwich or two (and maybe seeing what happens as they melt). This may be especially helpful if you have students from other countries who may not know what an ice cream sandwich is.

Allow them 1-2 minutes to record the problems in their lab books (or provide guiding questions to help students think of specific problems; examples are included in the student handout). If needed, provide examples of problems that may arise, such as:

- you like to play on the monkey bars at recess, and don’t want to be holding an ice cream sandwich in your hand
- your desk is a mess and you don’t have room to store an ice cream sandwich in it

Emphasize that everyone is going to have different problems because everyone has different needs. Also reiterate that students are not designing a system that they want; they are thinking ahead to problems that they would have if given an ice cream sandwich that they weren’t going to eat until later.

Determine how you want to group students. The simplest way to do this is to pair the students and have them design systems for each other. You could also do this in groups, with a small group of students designing a solution for another group or individual. This allows students to work together on their
Reason: In your lab book, brainstorm as many designs as you can; but come up with at least four. For each design, make a quick sketch (no little details here!). The goal here is to make several different designs.

Look over your design ideas, and find at least two features where the structure is related to the function. Make a note of how these structures are related to their functions.

Management Strategy: Students are going to be meeting with their partners several times during this unit, so setting up norms for discussions is important. For this discussion, you may want to model the discussion and/or provide sentence stems as a guide, but let students know that their discussions might look a little different, depending on their concerns:

- “I would have a problem storing the ice cream in my desk because ______.”
- “At recess, I like to ______.”
- “My main concern with keeping ice cream with me at recess (or during class) is ______.”

Before students meet with their partners, tell them how long they have to discuss; setting a timer allows students to monitor their discussions. Students should know that the first time they hear the timer they switch roles, and the second time they hear the timer they return to their seats. This same process can be used each time they meet together, and the consistency helps the transition from the discussion back to their seats very smooth.

Allow a specific amount of time to do this (somewhere in the neighborhood of five-seven minutes); emphasize to students that they should come up with as many ideas as they can. If needed, give them an example of an outlandish idea so they know that at this point, they shouldn’t discount any idea (for example, maybe a student sketches a hot air balloon that carries the sandwich up in the atmosphere where it is cold). As students work on their designs, circulate through the room. Quietly remind students who are spending a lot of time perfecting one sketch that the goal is to come up with many different ideas, and that they will have time to add in details later.

Throughout this unit, students will need to consider the relationship between structure and function, and having them identify a few structural features on their own designs may be a good introduction. You may need to provide examples to help students identify these relationships. For example, a student designed a
Communicate: Present your design ideas to your client. Quickly show them the designs and explain anything they have questions about. When it is your turn to be the client, tell your engineer the features that you like and the features that you don’t like, and why. As the engineer, make note of the things your client does and does not like.

Now that you have talked with your client, you should have a better idea of design features that he may or may not like. In your lab book, make two lists. One list of features you really want to have in the solution you design, and one list of features that you definitely do not want to have. You should write at least two features in each list. Next to each feature, record why you think that feature would or would not work for your client.

Ice cream sandwich container that can be worn as a belt. One function of the belt is to wrap around your waist, and the structural feature that allows this is flexibility. Another structural features that would allow the belt to function might include the length and width, as well as the thickness.

Instruct students on what they will be discussing when they meet with their partner; again, allow a specific amount of time and use a timer so students can switch roles and return to their seats on their own. If needed, provide sentence stems and/or model what the discussion should look and sound like.

- “I like _____ because _______."
- “I don’t think _____ would work for me because _______."
- “_______ would be o.k. if you changed it so that ______.”

Before students meet with their partners, encourage them to make notes of what their client tells them about their designs. They will be able to use their notes as they continue to design and build the device.

Management Strategy: As students discuss their designs, circulate through the class with a clipboard and make note of student communication skills that you want to highlight to the class. If there are students who would be embarrassed to be recognized this way in front of the class, you can quietly tell the student and/or tell the class what you observed without naming the student.

- “I loved the way Hazel made eye contact with her client.”
- “I noticed that Micah made a lot of notes on his sketches. It showed he was really listening to what his client did and didn’t like.”
- “Mike asked his engineer a question about one of the designs. That is a great way to make sure you understand each other.”

Allow a few minutes for students to make specific notes on features that would work (or not) for their clients. At some point, students will need to be familiar with the words “iterate” and “iteration.” You can begin using them now, by telling students that
they will be able to use these notes on future iterations of their design.

If needed, facilitate a class discussion about the importance of listening to your client. In the real world of engineering, you might have a great idea, but if other people don’t find it useful, no one is going to pay you for it. You have to be able to listen to what other people need and design solutions that will work for them.

### Assessment of Student Learning

*Partner discussions should be used to assess students’ communication skills; notes that students make about their initial design ideas should reflect how well they listened to their client.*

Example of student recording of features to include or not include; note that this engineer not only listened to his client’s feedback, but took into consideration other things he knew about his client:

<table>
<thead>
<tr>
<th>Features I should have in the design:</th>
<th>Features I should not have in the design:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Something pink -- because my client kept talking about how much he loves pink, and he wears a pink shirt all the time</td>
<td>Buttons or zippers -- because he told me once in fourth grade that he hated the sound of zippers and one of my designs had buttons and he said he didn’t like them</td>
</tr>
<tr>
<td>Can be worn on wrist -- because my client liked that feature in my design ideas, plus he already wears lots of bracelets so this would fit in with his style</td>
<td>Hat -- because one of my ideas was to make an ice cream holder on a hat and he said it would be embarrassing to wear</td>
</tr>
</tbody>
</table>
The Ice Cream Sandwich Problem

If you were given an ice cream sandwich at lunch but didn’t want to eat it until after school, what are some problems that you might run into (besides the ice cream melting)? Think about what you do at recesses and in the classroom between lunch and the end of school. What are some things that would make keeping an ice cream sandwich difficult or inconvenient?

<table>
<thead>
<tr>
<th>What do you usually do at recess?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describe anything about this activity that might make keeping an ice cream sandwich with you difficult:</td>
</tr>
<tr>
<td>Describe your desk:</td>
</tr>
<tr>
<td>Is there anything about your desk that would make storing an ice cream sandwich in it difficult? What?</td>
</tr>
<tr>
<td>Describe your backpack:</td>
</tr>
<tr>
<td>Is there anything about your backpack that would make storing an ice cream sandwich difficult? What?</td>
</tr>
<tr>
<td>What else could make keeping an ice cream sandwich with you difficult or inconvenient?</td>
</tr>
</tbody>
</table>
Possible Design Solutions

Sketch as many designs as you can. Don’t worry if an idea is “good enough” or not. If you have a crazy idea, sketch it out anyway! Don’t add details to your sketches; you’ll have time to fill in the details later. For now, the goal is to come up with as many ideas as possible.
Features to include (and not)

After presenting your ideas to your client, record at least two features that you think you must include in the design and at least two features that you really shouldn’t include. Also make a note of why you should (or shouldn’t) include each feature. Remember that you are thinking about your client’s needs, not your own! You will be using these notes in later iterations of your design.

An example of each has been done for you.

<table>
<thead>
<tr>
<th>Features I want to include:</th>
<th>Features I do not want to include:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can be worn on wrist -- because my client liked that feature in my design ideas, plus he already wears lots of bracelets and things so this would fit in with his style.</td>
<td>Zippers -- because he told me once in fourth grade that he hated the sound of zippers, and one of my designs had a zipper and he thought it might be hard to use</td>
</tr>
</tbody>
</table>
### 6.2.3 Learning Episode 2

<table>
<thead>
<tr>
<th>Topic: Heat Transfer/engineering design</th>
<th>Title: Investigating materials for ice cream savers</th>
</tr>
</thead>
</table>

**Overarching Performance Expectations (Standard) from State Standards or NGSS:**

**6.2.4** Design an object, tool or process that minimizes or maximizes heat energy transfer. Identify criteria and constraints, develop a prototype for iterative testing and analyze data from testing, and propose modifications for optimizing the design solution. Emphasize demonstrating how the structure of differing materials allows them to function as either conductors or insulators.

**Lesson Performance Expectations:**

Students plan and carry out an investigation to understand the structure of various materials, and then relate those structural features to the function they could possibly perform in the solution students are designing.

- **CCC:** Structure and function
- **SEP:** Planning and carrying out investigations; analyzing and interpreting data; engaging in argument from evidence

<table>
<thead>
<tr>
<th>Students Will. . . To Construct Meaning</th>
<th>Teacher Will. . . To Support Students</th>
</tr>
</thead>
</table>

**Engage with a Problem:** When the cafeteria serves ice cream sandwiches at lunch, you have to eat it at lunch, even if you wanted to save it for later, because it will melt.

**Gather:** You will be investigating different materials that will be available to use when you create your ice cream sandwich saver. Some properties of the materials that you may want to investigate:
- Ability to conduct heat
- Ability to insulate heat
- Flexibility
- Strength
- Texture
- Density
- What else?

With your group, determine how you will test the materials and how you will record your data. You may also want to investigate if changing the amount of a material affects its properties (for example, if you have a thicker layer of material, is the

**Teacher Will. . . To Support Students**

Provide students with a list of materials that will be available for them to use when they build their ice cream sandwich savers (the list could be written on the board or printed and distributed to the students). Examples of materials could include:
- Aluminum foil
- Cotton (balls or batting)
- Plastic (ziploc bags, tupperware containers, etc.)
- Air (in the form of bubble wrap)
- Foam wrap (used for packing; can buy a large roll at Home Depot or similar store)
- Styrofoam (cups)
- Paper (newspaper works well)
- Cardboard

Also provide students with other materials that will be available to them for the investigation:
- Thermometers
- Ice
- Rulers

Make sure that you choose materials that you can supply enough of for students to investigate (much of what they use during the investigation may be damaged/ruined), build and test prototypes and then build and test their final system. To limit waste, have all materials portioned out for the investigation; if students need additional materials they can ask for them (as opposed to putting everything out and allowing students to take as much as they want in the beginning; they tend to take more than they use and then throw the extra away). When purchasing supplies, note that...
Flexibility, strength and ability to conduct heat the same?).

| some materials will be more popular than others. For example, the foil is a conductor and will result in melted ice cream, so (hopefully) not many students will use it. The bubble wrap is a good insulator and flexible, so more students might incorporate it into their designs. Before students begin, you may want to help them set up data tables and/or allow students to share ideas for investigating the different properties with the class. You can also provide a form to help guide their investigation (example is included with the lesson materials; students can fill in the first two columns during the investigation; if using something like this, instruct students to ignore the third column for now). Encourage students to get help from other groups if their group gets stuck (with the expectation that they are still working with their own group, but just asking another group for advice/guidance). You may want to explicitly tell students to investigate how the amount of material may affect its properties. Depending on the class, you may also want to alert them to the fact that as the ice melts, it might get things wet. The ability of some materials to insulate is changed when wet, and students may not realize this. You could point out to the whole class that some properties might change if the material is wet (like the cardboard might not be as strong if wet) so that they can plan their investigation in a way that things stay dry or record properties of wet vs. dry materials. You could also just let them start finding this out on their own, and use questions with specific groups during the investigation to help them come to this understanding. As students investigate, circulate through the class and use questions to help them clarify their ideas and/or extend their investigations. Provide students with a graphic organizer or help them set up their notebooks to record this information (or use the third column in the example included with the lesson materials). Encourage students to look at the data they recorded during the investigation and also review the notes they made on their designs (including their list of must have features) to identify materials that may function well as part of their design. If needed, do one example together as a class to help students get started (the styrofoam is a good insulator so it might keep the ice cream cold; the cardboard is strong so it could keep the ice cream sandwich from getting smashed in a messy backpack). Put students in groups of four; you may want to group them with students they did not do the investigation with so they can hear what other students learned during the investigation. Assign each group a leader (use height, age, birthday, where they are sitting, etc. to assign the leader) and review norms for the discussion:  
- The group leader will call on a student to share  
- The student will share ONE material and the properties you think would make it useful |
**Reason:** Which of the materials may be useful in your ice cream sandwich saver design? In your notebook, list the materials you tested and identify the properties/structures that each material has that might make it function well in your design.

**Communicate:** Share your ideas with your group. The group leader will conduct the discussion. When it is your turn, clearly tell your group one of the materials that you think might be useful and why. If another student in your group says something that you missed, you can add it to your own notes.

- If you have questions about what the student said, raise your hand and the group leader will call on you to ask your question; the student can answer it
- Once all the questions are answered, the group leader will call on someone else to share
- Everyone has to share once before the group leader will call on anyone a second time

**Management Strategy:** Modeling what the discussion should look and sound like can help all students understand the expectations for the discussion. Setting a time limit and displaying a timer can help students monitor their discussion; you could even assign each group a timekeeper to make sure that no materials are discussed for longer than one minute to ensure that everyone has time to share at least one material.

*As students discuss their ideas, circulate through the class with a clipboard and make note of misconceptions that may need to be addressed.*

Conclude with a short whole group discussion to address misconceptions and/or allow students to share their ideas with the class.

**Assessment of Student Learning**

The investigations students carry out and the data generated should be used to assess their ability to plan and conduct an investigation, as well as their ability to use the data generated. Their descriptions of how they would use (or not use) each material can be used to assess their understanding of how the properties/structure of each material is related to its possible function in the ice cream saver design. Small group discussion should be used to assess students’ communication abilities.
Example of student assessment of the materials they investigate; the information in the third column shows how well students are able to relate the properties/structure of a material to its possible function in their ice cream saver design:

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties/structure</th>
<th>Which of these properties/structures would function well in an ice cream saver design? Why? How might it function in the ice cream saver design?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>White, soft, squishy and stretchy, absorbs the water as the ice melts, good insulator when there is a lot but not if there is only a little, not strong</td>
<td>It could be used to keep the ice cream from melting because it could insulate the ice cream from the hot air, but only if there was a thick layer of it. My client didn’t like the bulky design I made so I don’t know if cotton would be a good choice for my design.</td>
</tr>
<tr>
<td>Aluminum foil</td>
<td>Shiny, flexible, can hold its shape a little, conductor, one piece isn’t strong and you can tear it, but if it is thick it is stronger and you can’t tear it</td>
<td>This might make the ice cream melt because it is a conductor, but my client likes shiny things, so I think I could use it in the design, just not in the part that should keep the ice cream cold. Maybe it could be for decoration.</td>
</tr>
<tr>
<td>Ziploc bag</td>
<td>Clear, flexible, kind of strong but easy to cut with scissors, waterproof, not a good insulator</td>
<td>This wouldn’t keep the ice cream from melting because it isn’t a good conductor, but it is waterproof, so it might be good to have around the ice cream so that if it does melt, it doesn’t get all over everything and make a mess. Maybe there could be another layer of something else around the ziploc.</td>
</tr>
</tbody>
</table>
## Materials Investigation

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties/structures</th>
<th>Which of these properties/structures would make it functional in an ice cream sandwich saver design? Why? How might it function in the ice cream saver design?</th>
</tr>
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<tbody>
<tr>
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6.2.3 Learning Episode 3

### Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Heat Transfer/engineering design</th>
<th>Title: Design a prototype</th>
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#### Overarching Performance Expectations (Standard):

**6.2.4** Design an object, tool or process that minimizes or maximizes heat energy transfer. Identify criteria and constraints, develop a prototype for iterative testing and analyze data from testing, and propose modifications for optimizing the design solution. Emphasize demonstrating how the structure of differing materials allows them to function as either conductors or insulators.

#### Lesson Performance Expectations:

Students will use information obtained from different sources to develop a solution to the melting ice cream problem; their solution should include structural features that will enable the solution to function.

- **CCC:** Structure and function
- **SEP:** Obtaining information, designing solutions

#### Students Will . . . To Construct Meaning

*Engage with a Problem: When the cafeteria serves ice cream sandwiches at lunch, you have to eat it at lunch, even if you wanted to save it for later, because it will melt.*

- **Reason I:** You are going to begin the iterative process.

You will start by using the information you’ve collected from your client and from the investigation to design a prototype. For this iteration, you will be creating a diagram of a prototype. As you design the prototype, think about the needs of your client, the features that he did/didn’t like, and the structures of the materials that you investigated last time. Your diagram should include details such as:
  - What materials will be used for different parts
  - Different views (top down, inside, cross-section, or other views that will help people understand the design)
  - Descriptions/annotations
  - Measurements

#### Teacher Will . . . To Support Students

*Note: As students build their prototypes and final designs, you may want to limit how much of a material they are allowed to use. If this is the case, tell them these restrictions before they begin designing their prototypes so they can account for material availability. This can help you plan for how much to buy and can also allow you to discuss the limitations that real engineers face. Not only must they design around the needs/restrictions of their clients, they have limited money/resources, time, and can also be limited by policy/laws.*

Introduce or review the concept of iteration. Students should understand that they will design and test a solution, then use the information they learned to redesign and test it again (and again, and again…).

Before students begin their prototype diagrams, allow a minute or two for them to review their notes from previous lessons. Instruct them to look over their “must have” features list from the first lesson, and the notes they made after investigating materials.

Display the detail list so they can refer to it as they design, and encourage students to refer to their notes as they work. You may also want to provide a list of materials that will be available, and instruct students to identify which material will be used for each part of the design. Also, if you haven’t given them the
Communicate: You will be sharing your design sketch with a focus group, which will not include your client. The purpose of meeting with the focus group is to get feedback on how to improve your design. Your group will follow this procedure:

- Everyone passes his design sketch to the person on his left.
- You have two minutes to look over the design. What looks like it will work? What do you have questions about? What looks like it won’t work? Jot down your thoughts in your lab book.
- When you hear the timer, pass the design you just examined to the person on your left. Repeat this process until everyone has looked at all of the designs.

Once everyone has seen the designs, the group will discuss each design. The goal is to provide constructive feedback that can be used for the next iteration of the design. You will follow this procedure:

- The oldest person in the group will put his design in the middle of the table.
- You have two minutes for everyone to share their thoughts about the design and allow the designer to make notes and ask questions.
- When you hear the timer, the next oldest person will put his design in the middle of the table and you will repeat the process until everyone has had a chance to get feedback.

Reason II: After everyone has finished and returned to their seats, you will use the feedback you got to make your next iteration. As you make your new dimensions of the ice cream sandwiches, make sure you do that before they begin designing. Allow 5-10 minutes for them to create their diagrams; if some students finish early, review their diagrams and point out details that they should add. (Did they identify the materials? Can they write a note about why a particular material is going to be used for a specific part? Could they add a top down view or cross-section?)

Assign students groups and review the procedure (if needed, you can model what the group should be doing). Remind students to write down their ideas because they will be sharing them with the designer later; if needed, provide sentence stems:

- “I like _____ because _____."
- “When you build this, how will you _____?”
- “You might want to use a different material here, because _____.”
- “If you changed _____, it might be better because _____."

Help students set up a graphic organizer to record their ideas, or distribute organizers. As students work, circulate through the room and prompt students who are stuck. Note: some students will have a hard time recording all of their ideas if they use complete sentences; you may want to tell students that they don’t need to write complete sentences here and then provide the sentence stems for them to use during the discussion portion of the focus group.

Outline the procedure for the students and if needed, model what the group discussion should look/sound like. If needed, review norms for the discussion. Encourage students to make notes as they get feedback; you can instruct them to make notes directly on their design or in their lab books.

If using age (or height, birthday, etc.) for the order, allow students a minute to talk with their groups to determine the order students will go; ask groups to give a signal when they know their order; start the timer when all groups are ready to go.

As students discuss, circulate and remind students to take notes on the feedback they get.

Allow students about five minutes to make their new sketches. If there is time, facilitate a short class discussion to allow a few students to share something...
design, you will need to consider:
- Your client’s needs
- How the structure of the materials you will use will help them perform the function you need
- The feedback from your focus group
- Don’t forget that it needs to keep the ice cream from melting!

they changed in their design and why they changed it.

### Assessment of Student Learning

*This learning episode allows for a lot of peer- and self-assessment. Prototype design and focus group discussions should be used to assess how well students are able to integrate several pieces of engineering design: a solution to a problem, the needs of the people who will be using the product, the properties of the materials available, etc. Focus group discussions and prototype revisions can be used to assess ability of students to accept and use new information as it becomes available.*

E. Harward
Focus Group

You will have two minutes to look over each design. As you examine each design, think about the feedback you could give the designer to help him/her improve the design. This should take the whole two minutes, so if you think you are done and there’s still time on the timer, look for other feedback you could provide!

<table>
<thead>
<tr>
<th>Designer’s name:</th>
<th>Which parts do you think will work well?</th>
<th>What questions do you have about the design?</th>
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<tbody>
<tr>
<td></td>
<td>Which parts do you think won’t work well?</td>
<td>Other ideas about this design:</td>
</tr>
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</table>

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<tbody>
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<td>Which parts do you think won’t work well?</td>
<td>Other ideas about this design:</td>
</tr>
</tbody>
</table>
When it is your turn to provide feedback to another student in your focus group, please be specific! You should explain why something will work or not and ask questions to help the designer revise and improve his/her design.

- “I like _____ because _____.”
- “When you build this, how will you _____?”
- “You might want to use a different material for _____, because _____.”
- “If you changed _____, it might be better because _____.”
### Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Heat Transfer/engineering design</th>
<th>Title: Build a prototype</th>
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### Overarching Performance Expectations (Standard) from State Standards or NGSS:

**6.2.4** Design an object, tool or process that minimizes or maximizes heat energy transfer. Identify criteria and constraints, develop a prototype for iterative testing and analyze data from testing, and propose modifications for optimizing the design solution. Emphasize demonstrating how the structure of differing materials allows them to function as either conductors or insulators.

### Lesson Performance Expectations:

Students will design a solution to minimize heat transfer (to keep ice cream from melting); they will consider how the structure of their design solution will allow it to function well, and will test and modify their design.

**CCC:** Energy and matter; structure and function  
**SEP:** Designing solutions

### Students Will . . . To Construct Meaning

*Engage with a Problem:* When the cafeteria serves ice cream sandwiches at lunch, you have to eat it at lunch, even if you wanted to save it for later, because it will melt.

*Reason:* Use the design you made last time to build a prototype. Follow your teacher’s instructions for obtaining materials and clean up.

As you build your prototype, you should also be testing it. How is the size? Will it keep the ice cream cold? Is it durable enough? Think about what your client will be doing. Does he like to jump rope during recess? Will he be holding the device or will it be sitting on the ground? Does the device get wet and soggy? You can use ice and a heat lamp to see how well your device will insulate the ice cream sandwich.

### Teacher Will . . . To Support Students

*Note:* Depending on time, the prototype can be tested and rebuilt several times. The lesson below assumes minimal time for the iterative process, and allows for students to build one prototype out of actual materials before building their final product. If more time is available, you can start by having students build their first prototype out of newspaper. This prototype can be used to test size and shape of the design, as well as construction methods. Once students have built and gotten feedback on their paper prototype, they can then move on to building a prototype out of materials, which will allow them to test the ability of the device to actually keep the ice cream frozen.

Clearly explain the procedure students should follow for obtaining materials, guidelines for working (where should they be in the room, who can they be working with, etc.), time limits (you may want to give them a set amount of time and display a timer so they can self monitor), and clean up. You may want to tell the students how much time they have to work (at least 20 minutes; some students may need much longer, depending on how much testing they do as they build their prototype) and how much time they have to clean up (5 minutes), and then set a timer. The first time the timer goes off students know that they need to stop working and clean up; they should be cleaned up and back in their seats before the timer goes off again.

E. Harward
Communicate: Present the prototype to your client. When you do this, allow him to hold the prototype and interact with it before you dive into any explanation. As your client examines the prototype, watch to see how he interacts with it. Is it easy for him to figure out how to use it? If your client has questions, you can answer them. After he has had a chance to interact with the prototype, show him any features that he may have used wrong or missed. Watch to see how he interacts with these features after you have shown them to him. Once your client has had a chance to interact with the prototype, explain how the structure of the design will function to keep the ice cream from melting.

Some ideas for managing how many materials students take:

- Students must make a list of what they need and how much they need; before obtaining anything, they must show you their sketch and list of needed materials; they can then measure and collect their own materials (this is a good system to use if you did not give students limitations on amount of materials they would be allowed to use; setting the expectation that they carefully measure materials before taking them is important; make sure rulers are available)
- Materials are portioned out and students can pick up a set number of any item (for example, the bubble wrap is cut into squares and students are allowed to take up to two of the squares)
- Materials have a “cost” and students have a budget; they must “pay” for anything they take and when they are out of money, they can’t get any more materials (this system takes a bit of work to set up; providing each student with a budget sheet that has the cost of each material and space for them to keep track of what they’ve used and how much money they have left is helpful for them to monitor themselves)

Also, tape, glue, scissors, etc. should be made available for students to use as they construct their prototypes. Ice should be available as a stand-in for ice cream, and if available, shop lamps can be used to help test the insulating properties of the device.

Model what this should look like. Students may be eager to show off their prototypes, which usually looks like them holding the device and explaining it. Demonstrate to students that they should hand the device to their client, and watch to see how the client uses the device. To model this, you could hand a student a device that he may not know how to use (like an abacus, some type of fancy kitchen tool, etc.) and watch to see what he does with it. Use a think aloud to help students see what you are watching for and making mental notes of as the student interacts with the device. They should understand that you are trying to see how user-friendly the device is, and what E. Harward
Gather: Ask for feedback and listen to what your client says. What does he like? What doesn’t he like? If you are not sure why the client likes or doesn’t like a feature, ask him why, so you can avoid similar problems in future iterations. Make notes of your client’s feedback and experience to use for the final revision of the product.

Once students understand how to present their prototypes, give them a time limit (approximately 2-3 minutes) and allow them to meet with their partner. Again, you may want to use a timer, and tell students that when they hear the timer go off the first time they should switch roles; when they hear the timer go off the second time, they should return to their seats.

As students work, circulate through the class and listen to their discussions. If needed, remind individual students to let their clients interact with the prototype before showing them all the features.

If needed, allow students additional time to finish making notes. You may want to reiterate that keeping track of what changes have been made, and why these changes were necessary is an important part of the design process, because these notes can be useful in future designs.

Collect the prototypes for students to use for the next iteration; you may want to store them in a box, bag, or on a counter if you have space.

Facilitate a short class discussion to let students share examples of the relationship between the structure and function of the solution they (or their partner) engineered. Emphasize the concept of insulators; students should understand that using insulating materials will help minimize heat energy transfer into the ice cream, so it will stay cold longer. If time permits, you could also allow them to discuss features that they are thinking about changing on the final iteration and why these changes are needed.

Assessment of Student Learning
This learning episode allows for a lot of peer- and self-assessment. Formative assessments of student understanding and progress should be made through examining their designs/notes and listening to/observing their discussions and interactions with their partners.
6.2.3 Learning Episode 5

<table>
<thead>
<tr>
<th>Topic: Heat Transfer/engineering design</th>
<th>Title: Final ice cream saver design</th>
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**Overarching Performance Expectations (Standard) from State Standards or NGSS:**

6.2.4 Design an object, tool or process that minimizes or maximizes heat energy transfer. Identify criteria and constraints, develop a prototype for iterative testing and analyze data from testing, and propose modifications for optimizing the design solution. Emphasize demonstrating how the structure of differing materials allows them to function as either conductors or insulators.

**Lesson Performance Expectations:**

Build a solution to minimize heat energy transfer; use information from previous tests to modify and improve the design; explain how the structure of the materials allow the design to insulate the ice cream.

- **CCC:** Energy and matter; structure and function
- **SEP:** Design solutions; communicating and evaluating information

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<tr>
<th>Students Will. . . To Construct Meaning</th>
<th>Teacher Will. . . To Support Students</th>
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**Engage with a Problem:** When the cafeteria serves ice cream sandwiches at lunch, you have to eat it at lunch, even if you wanted to save it for later, because it will melt.

**Gather/reason:** Find your prototype and the design notes you made last time. Look over your prototype and notes to determine what changes need to be made, why they need to be made, and how you will make them.

Create a diagram of the final iteration of your design. Include labels, materials, different views, explanations, or anything else that would help someone understand the design. Your final iteration also needs to include an explanation of why it will keep the ice cream from melting. You can use evidence from the materials investigation, the testing of the prototype, and what you know about heat energy and heat transfer. Your final design diagram will be turned in.

Collect the materials you need to build your final product. Follow your teacher’s instructions regarding collecting materials, work time expectations, and clean up.

**Final design test:** Present the final design to your

**Have students look at their prototypes and find their notes; allow them a few minutes to review the changes they would like to make before creating a final diagram.**

Before starting the diagrams, you might want to review things that students found helpful when they looked at each other’s sketches in their focus groups. Allow students to share things they found helpful (cross sections, zoom-in boxes, written descriptions, etc.) and encourage students to incorporate these features in their final diagrams.

Students should create their final diagrams on a separate sheet of paper that can be handed to their client and then turned in. You may want to provide a checklist for their final design diagram (an example is included in the lesson materials).

**Again outline the procedure for collecting materials and work/behavior expectations during work time. Provide a time limit and display a timer so that students can self-monitor; allow time for clean up.**

Plan the logistics for students to get their device and...
client. Again, allow your client to interact with the
design first and then answer questions. Make sure
your client knows how to use the device properly;
how can you do this without just telling them what to
do?

Everyone will be given an ice cream sandwich after
lunch; use the device your engineer built for you. At
the end of the day, we will eat our ice cream
sandwiches.

Before eating your sandwich, meet with your partner.
Examine both ice cream sandwiches together so you
can see how well the device you designed worked.

Give your client the final design diagram you made
earlier. He will be turning it in with his evaluation of
the product.

| Communicate: Carefully review the grading rubric
  and provide a score for each category. You also need
to provide at least one piece of positive feedback and
one piece of constructive feedback for your engineer.
Your engineer will NOT see the scores on the rubric,
but will see the written feedback you provide.  |
| --- |
| **Positive:**  
  - “When you _____, it showed you were
    listening because _____.”  
  - “I know you understood what I was saying
    because _____.”  
  - “When you _____, it helped me understand
    your idea about _____.”  
  - “The _____ on your design would be useful
    to me because _____.”  |
| pick up their ice cream sandwiches. If devices were
designed with recess in mind, it is important that
students are able to test their devices during recess!

Model for students what they should do when they
examine their ice cream sandwiches. They should
examine them to see how melted they got, if they got
smashed or broken, etc. Allowing them to do this with
their partners lets them see how well the device they
designed worked. You can instruct students to give
their final design sketch to their client as it is, or
allow them to make notes of what revisions they
would make, now that they know how well their
device actually worked.

At this point, ice cream should be eaten (or cleaned
up), devices can be saved or thrown away, students
should have the diagram of the device that was
designed for them and be in their own seats. It is best
if they are not next to their engineer, so they can be
more honest in their assessment of the product.

Go through the rubric with the class to make sure they
actually read the requirements before assigning a
score. Have the students complete the rubric first,
even though it is on the bottom of the page.
Completing the rubric first can remind students of the
expectations and help them provide more effective
written feedback. Display the sentence stems on the
board and reiterate the expectation that students
provide at least one positive and one constructive
piece of feedback for their engineer. Also remind
them that their engineers won’t see the number
grades, but will see the written feedback.

When they are done, they should staple the diagram
to the rubric (stapling the diagram on the top might
make it easier for some students if they did not give
their engineer high marks) and turn it in. This way,
you have the feedback on a design stapled to the
design itself, making assessment more manageable.

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Constructive:
- “I didn’t feel like you were listening because _____.”
- “The product you designed wouldn’t work for me because _____.”
- “I needed something that _____, but the product you designed for me _____.”

You can use both the design and written feedback when grading the project (easier than trying to grade the devices themselves, which may or may not be broken, sticky messes by the time the kids are done). You can also use the previous designs and notes students made throughout the unit to assess their ability to incorporate new information/evidence and revise their designs.

After reviewing the design and student feedback, simply tear off the rubric portion of the paper. When you return the design diagram to the person who made it, the written feedback from his client will be stapled to it.

**Assessment of Student Learning**

*Student’s final diagrams and their client’s comments/feedback should be used to assess:*
- **Their communication skills throughout the design process**
- **Their understanding of heat transfer**
- **Their ability to use evidence (from the investigation and their client/focus group) to design a solution**
- **Their ability to revise ideas/designs to create a better product**
Final Design Diagram

Your final design diagram should include:

- Sketch of the design
- Materials
- Useful view(s) (top down, side, inside, cross-section, zoom-ins, etc.; can have more than one view)
- Explanation of why this design will keep the ice cream from melting (What structures function to keep the ice cream from melting? How are they able to do this?)
- Additional features that make it useful to your client
Your engineer’s name: ________________________________

Written feedback for your engineer (continue on the back top of this paper if you need more space):
________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

------------------------------------------------------------------------------------------------------------------------------------------------

Your name _______________________________________________________________________

Grading Rubric

Your engineer will NOT see the scores in the table below, but will be given the written feedback you provide above. Make sure your written feedback is constructive! If there is something your engineer could have done better, please tell him/her! Also let him/her know what s/he did well. Be specific and explain your position.

<table>
<thead>
<tr>
<th>Category</th>
<th>Score</th>
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<tbody>
<tr>
<td><strong>Communication</strong></td>
<td></td>
</tr>
<tr>
<td>4: My engineer did everything for a 3. PLUS s/he checked in with me more than was required</td>
<td></td>
</tr>
<tr>
<td>3: My engineer listened to me when I was talking and asked questions to learn more about what I needed</td>
<td></td>
</tr>
<tr>
<td>2: My engineer usually listened to me but sometimes interrupted or seemed like s/he wasn't listening</td>
<td></td>
</tr>
<tr>
<td>1: My engineer chatted with friends while I was talking or gave other indications that s/he wasn't really listening</td>
<td></td>
</tr>
<tr>
<td><strong>Design Process</strong></td>
<td></td>
</tr>
<tr>
<td>4: My engineer did everything for a 3. PLUS, it was obvious that s/he tested the prototype before building the final design because it worked well</td>
<td></td>
</tr>
<tr>
<td>3: Throughout the process, my engineer came up with at least three different ideas that allowed me to explain what type of features I would or would not like; the final design incorporated the feedback I gave to the engineer, even if it didn't end up working very well</td>
<td></td>
</tr>
<tr>
<td>2: My engineer came up with at least two different ideas that allowed me to explain what type of features I would or would not like and made revisions according to the feedback I provided</td>
<td></td>
</tr>
<tr>
<td>1: My engineer only presented me with one idea for a design and didn't make adjustments according to the feedback I provided</td>
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<tr>
<td><strong>Product</strong></td>
<td></td>
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<tr>
<td>4: The product worked well and met the requirements I gave the engineer, plus it had stylistic features that I like; it is clear that my engineer went out of his/her way to make something that would meet all of my needs</td>
<td></td>
</tr>
<tr>
<td>3: The product met the requirements I gave my engineer and worked fairly well; the ice cream didn't completely melt</td>
<td></td>
</tr>
<tr>
<td>2: The product met most of the requirements I gave my engineer and worked better than nothing</td>
<td></td>
</tr>
<tr>
<td>1: The product didn't meet the requirements I gave my engineer and didn't work very well</td>
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</tr>
</tbody>
</table>

E. Harward