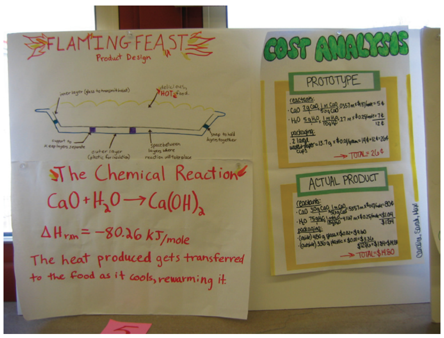
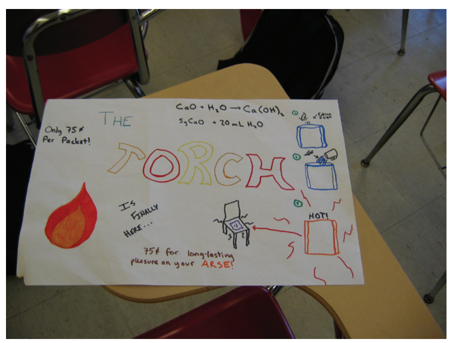
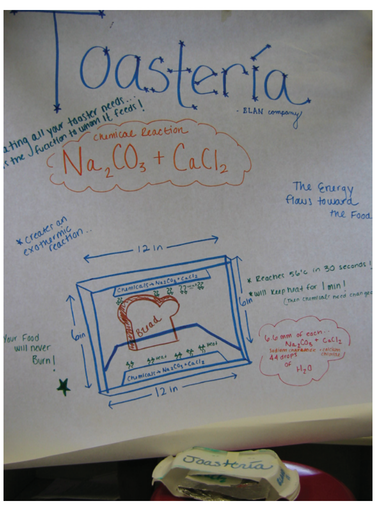
Teacher's Guide

Designing A Heating / Cooling System







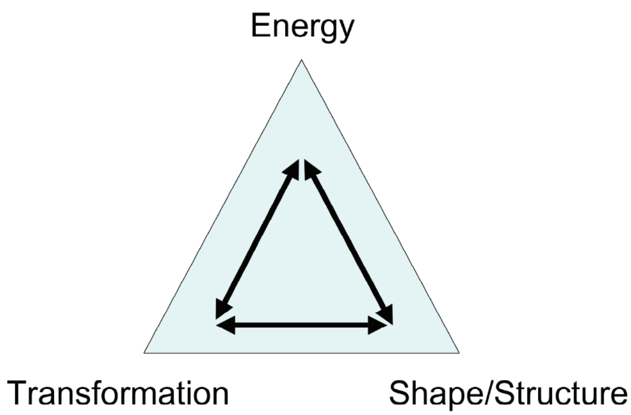
Development Team

Dr. Xornam Apedoe Dr. Michelle Ellefson Birdy Reynolds Dr. Christian Schunn

University of Pittsburgh
Learning Research and Development Center

Introduction

During this unit, high school students experience a design-based learning approach to consider energy changes in chemical transformations. The core concepts of shape/ structure, transformation, and energy/motion will form the conceptual basis for this design-based learning unit. The unit will enable students to make connections between and amongst these core concepts while they design a H/C system.



Special thanks to teacher collaborators who piloted the unit in 2006

Liz Cavanio - Langley High School

Sally Martin - Allderdice High School

Tracy Mueller - Penn Hills High School

Maria Orton - Oliver High School

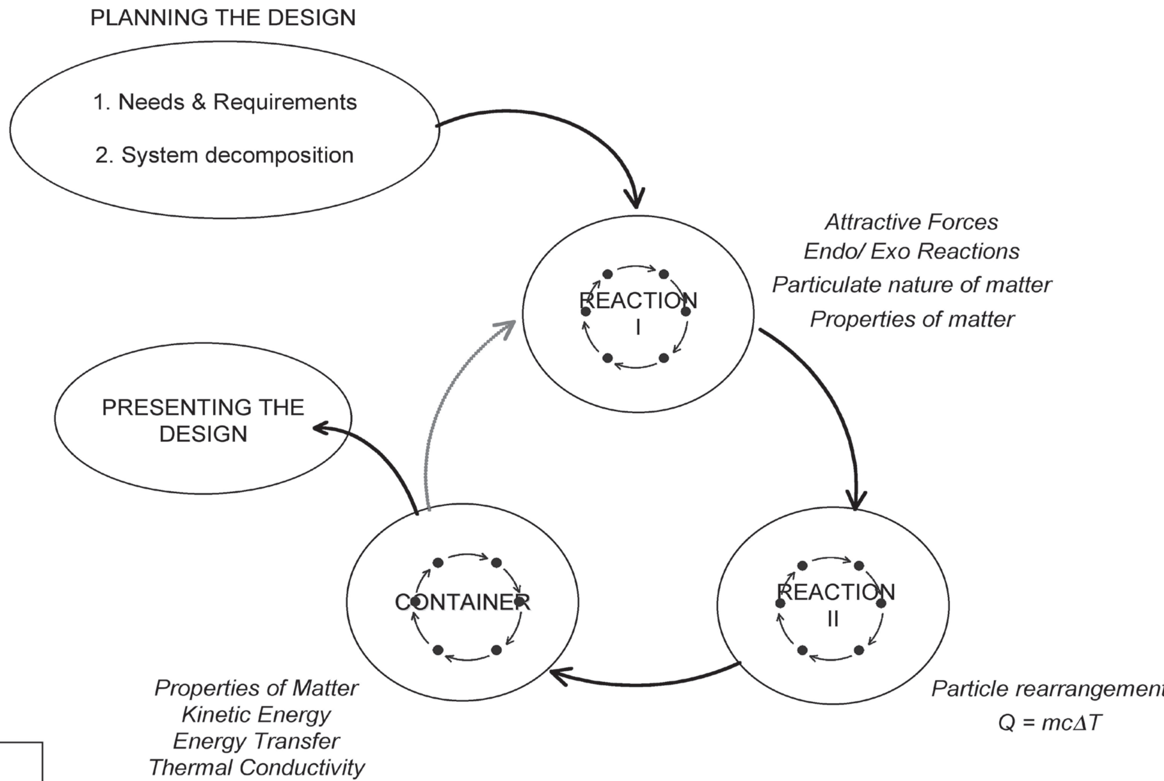
Jim Schultz - Penn Hills High School

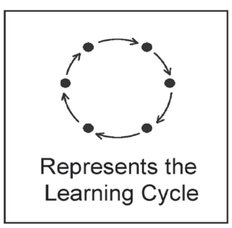
Udai Singh - Langley High School

Steve Wertheim - Langley High School

We hope that you and your students will have an enjoyable design and discovery experience over the next few weeks.

Heating/Cooling Immersion Unit Storyline





The model above is a graphic representation of the topics covered in the *Designing A Heating/Cooling System* immersion unit for high school chemistry. This immersion unit uses a design-based learning approach. In design-based science units, students make decisions about how they want to design and develop a specific kind of prototype. Creating and improving a design allows students to engage deeply in various experiences and improve their science learning. In this unit, students will create a prototype of a heating or cooling system that relies on chemical energy.

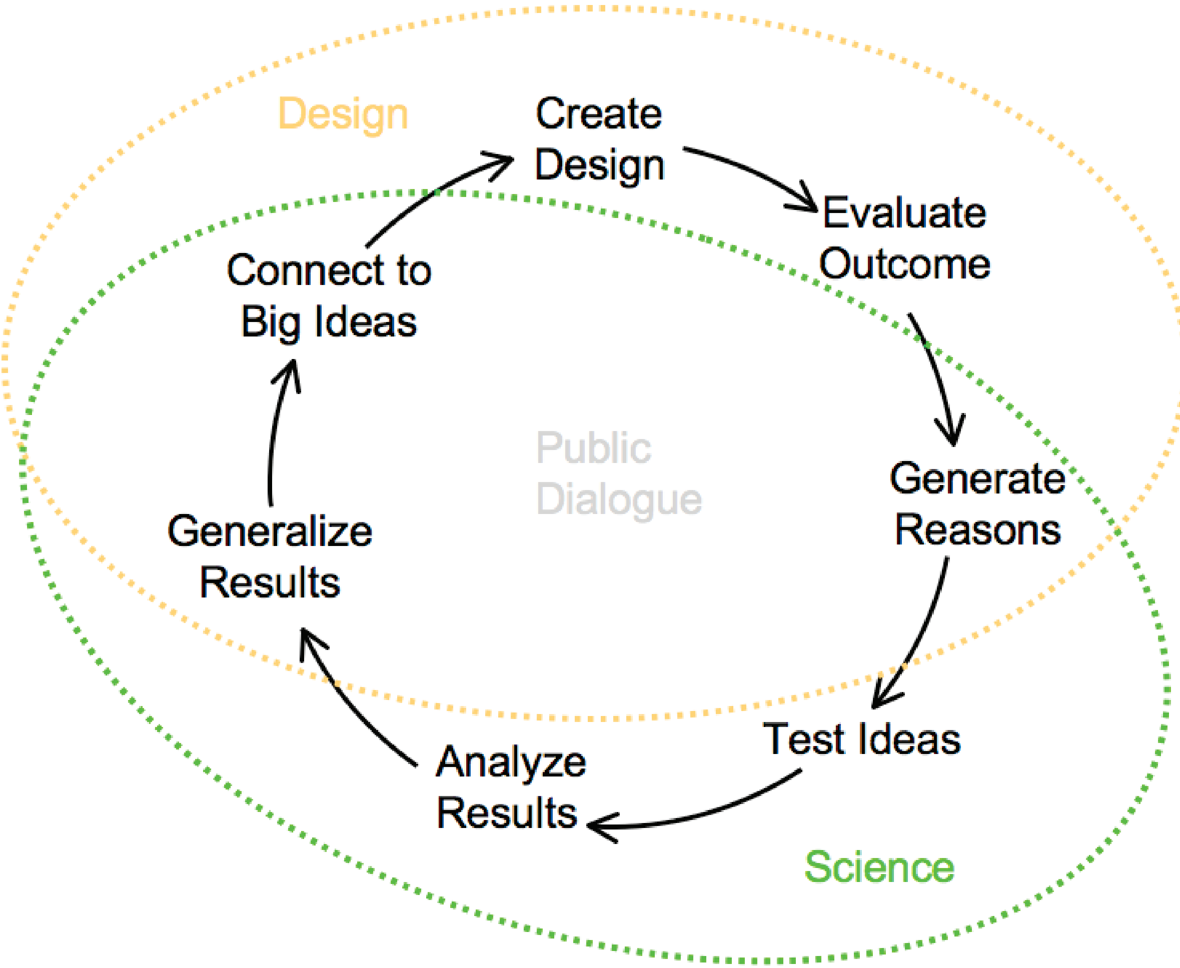
The H/C system is decomposed into two major subsystems: Reaction and Container. The students will make various modifications to their design as they cycle through each subsystem.

Once students determine what the needs and requirements are for their design, they will proceed through the Reaction I, Reaction II and finally the Container Subsystem. Students will conclude the unit presenting their design in a *Gallery Walk* and a mock patent application.

Heating / Cooling Big Idea(s)

- Energy released or absorbed during transformations is dependent upon the shape and structure of the particles involved in the transformation.
- Energy released or absorbed during transformations is dependent upon the mass and temperature of the system.
- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions.

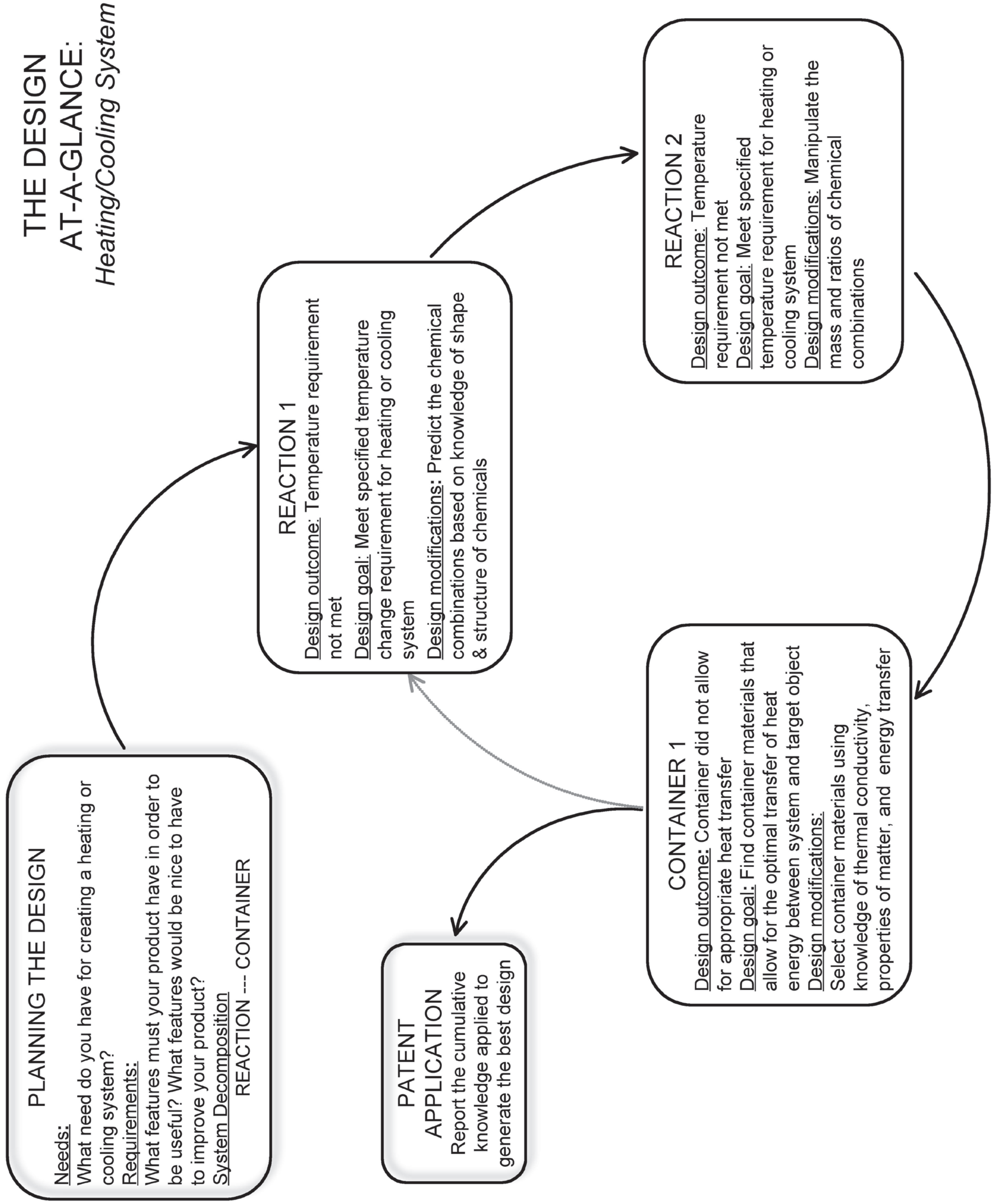
Learning Cycle



The model above is a graphic representation of the Learning Cycle, which shows the connections between design and science. As students pass through each subsystem they will cycle through this learning cycle. Each cycle begins at the Create Design node and proceeds clockwise through the cycle, leaving the subsystem when they Connect to Big Ideas. As shown in the diagram, science and design activities overlap in the *Public Dialogue* space. This *Public Dialogue* space becomes the part of the learning cycle where students will gain the most insight into how scientific ideas can be used to improve their design.

Students begin the Learning Cycle in the Design space at the *Create Design* node. Here, students will develop a design idea and try it out. Students must then make observations of how their design worked in the *Evaluate Outcome* node. Reasons for the outcomes they observe will be discussed as a class during *Generate Reasons.* Here, students will answer questions such as: Was my design successful? If so, what factors were important for its success? If no, what factors influenced its failed performance? Students will then propose ways to systematically test some of their generated reasons, and conduct these tests during *Test Ideas.* From here, students will analyze the results from their experiments in *Analyze Results*. They will discuss the results as a class during *Generalize Results* to uncover a pattern, theory, or trend. Finally, students will arrive at *Connect to Big Idea* where they will link their design to the key science concept(s) that can be used to improve its performance.

THE DESIGN AT-A-GLANCE:
Heating/Cooling System



Standards Alignment

The following standards are addressed within this unit.

National Science Education Standards

Content Standard B (9-12): Physical Science

Chemical Reactions

- B.CR.2: Chemical reactions may release or consume energy. Conservations of Energy and the Increase in Disorder.
- B.CEID.4: Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. For example, the transfer of energy from hotter to cooler objects.

Pennsylvania Science Standards
Academic Standards for Science and Technology

3.2: Inquiry and Design

- 10D/12D: Identify and apply technological design process to solve problems
- 3.2.10.D1: Examine the problem; rank all necessary information, and all questions that must be answered
- 3.2.10.D2: Propose and analyze a solution
- 3.2.10.D3: Implement the solution
- 3.2.10.D4: Evaluate the solution, test, redesign, and improve as necessary
- 3.2.10.D5: Communicate the process and evaluate and present the impact of the solution

3.4: Physical Science Chemistry and Physics

- 10B/12B: Analyze energy sources and transfers of heat
- 3.4.10.B3: Evaluate energy changes in chemical reactions
- 3.4.12.B4: Apply appropriate thermodynamic concepts (e.g., , conservation, entropy) to solve problems relating to energy and heat
- 3.4.12.B1: Determine the heat involved in illustrative chemical reactions
- 3.4.10.B4: Use knowledge of conservation of energy and momentum to explain common phenomena (e.g., , refrigeration system, rocket propulsion)

Teacher Guide Features

Lesson Plans

Within this Teacher's Guide are details outlining procedures and ideas important for facilitating each lesson. Included in each lesson plan are two major sections. The first section, ***Overview***, highlights the following information: *Lesson Goal(s), Student Activities, Materials, Key Concepts, Key Questions,* and the *Big Idea* for the subsystem. The second section, ***Implementing This Lesson***, provides text to support: *Thinking Ahead, Introducing the Task, Supporting Student Engagement, Asking Assessing/Advancing Questions, Facilitating Discussion, Looking Ahead,* and *Extending the Task.*

Overview

A graphic representation of the *Learning Cycle* is presented, with your current location in Learning Cycle highlighted.

Lesson Time: Indicates the number of days (class periods) it is expected that the lesson will take to complete.

Lesson Goal(s): Highlights the most important ideas, skills, etc., that students should take away from the lesson.

Student Activities: This is a brief description of the tasks that students will engage in during the lesson.

Material: A list of any documents or supplies needed to enact the lesson.

Key Concept(s): These are the ideas that are important for students to understand by the end of the lesson. These key concepts are ideas that build up to understanding of the *Big Idea* for the particular subsystem.

Key Question(s): Includes questions that may be useful for assessing or advancing student knowledge as you facilitate the lesson. The key questions can be used for whole-class discussions or they can be used in conversations with teams and/or individual students.

Big Idea: A statement of the core scientific idea that students should understand once they have completed the activities in the particular subsystem. Each lesson builds up students' understanding of this *Big Idea* through the exploration of key concepts.

Implementing This Lesson

One feature of a design-based learning immersion unit that makes it different from more traditional methods of teaching is the role of the teacher. Instead of being the authority on the content or endless fount of knowledge, the teacher must act as a facilitator of student learning. He or she becomes a senior collaborator with the students. The overall goal for this section of the lesson plan is to help you to begin to think thru some of the issues that you may encounter as you facilitate the lesson in your classroom. Throughout this section, questions are posed, so that you may better prepare to facilitate the lesson.

The *Implementing This Lesson* section begins with a brief description of the tasks that students will engage in during the lesson. Included in this description may be a brief rationale for the days activities, as well as notes related to issues that may be important for you to remember as you facilitate the lesson.

Thinking Ahead: This section is geared towards helping you begin to consider what ideas, knowledge, or misconceptions your students may bring to the task at hand.

Introducing the Task(s): This section is geared towards helping you begin to consider how to set up the task for students so that they are required to actively engage with the task.

Supporting Student Engagement: This section describes how students will engage in the task (individually? In teams?), as well as suggests strategies for promoting the active engagement of all students in the task.

Asking Assessing/Advancing Questions: Effective questioning in the classroom can help maximize student learning. Each lesson includes some suggestions for assessing and advancing questions that can be posed to students. *Assessing questions* are geared toward the initial evaluation of student learning. These questions can be used to help you understand where students understanding is currently, so that you may begin to think about ways to move them further. *Advancing questions* should be used to move student thinking forward. Previous research has shown that these advancing type questions result in greater learning gains than assessing questions alone.

Facilitating Discussion: This section highlights issues, concepts, and ideas that are important bring to the fore during the class discussion. In addition, some strategies for facilitating the discussion so that the science learning goals for the lesson are met, are presented. *Note: this section does not appear in every lesson.*

Looking Ahead: This section provides suggestions of ways that you can build on the ideas and knowledge generated in the current lesson in future lessons.

Extending the Task(s): This section provides suggestions of ways that the task can be extended to cover more advanced chemistry concepts. *Note: this section does not appear in every lesson.*

Lesson Time Line: Planning the Design

Lesson	Learning Cycle	Goals	Key Concepts	Student Activities
1	Create Design	• Students develop an awareness that design can be used to solve everyday problems	• Needs/ Problem Identification • Functional Decomposition • Iterative Design • Sketches and representations	• Read "Sweeping Up the Market" • Team Discussion: Complete "Sweeping Up the Market" Questions • Class Discussion: Identify key components of design
2	Create Design	• Teams brainstorm their need for a H/C system • Teams determine the type of H/C system they want to create to meet their need • Teams create a sketch of their ideal system design	• Needs are problems that require a technological solution	• Read "Planning Your Design" • Brainstorm Needs • Create a H/C system sketch
3	Create Design	• Students determine the similarities and differences between various H/C systems	• Needs refer to problems that require a technological solution • Energy levels in the surrounding environment can be increased or decreased • Temperature is a reflection of the amount of energy in a system	• Team Discussion: Uses & Needs of H/C systems • Class Discussion: Uses & Needs of H/C systems • Read "Now That You've Thought About It..."
4	Create Design	• Students will learn about systems and how they work • Students will define the essential parts as subsystems • Students will define the function of each subsystem • Students will be able to distinguish between 'must-have' and nice-to-have' requirements	• Systems can be decomposed into their essential parts called subsystems • Each subsystem has one function • Some requirements are necessary and others are not necessary	• Define subsystems and functions • Read "Now That You've Thought About It..." • Determine requirements
5	Create Design	• Students receive and provide appropriate and constructive critiques about their design ideas • Students should synthesize needs, subsystems, functions, and requirements in their design	• Scientists and engineers share their ideas to get feedback • Needs, subsystems, functions, and requirements are the foundation for good designs • Planning is a critical component for good designs	• Plan presentation • Present design ideas • Homework: Reflection I

Lesson Time Line: Reaction Subsystem (I)

Big Idea:

Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation.

Lesson	Learning Cycle	Goals	Key Concepts	Student Activities
1	Create Design	• Students categorize chemicals by their properties	• Matter is made up of particles that have mass and occupy space • Particles have a unique composition • The composition of particles determines their physical and chemical properties	• Read "Creating Your Design" • Chemical categorization activity (teams) • Class Discussion: Lab safety
2	Create Design	• Students will recognize that chemicals are a source of energy	• Particles interact with each other; this interaction may result in an increase or decrease in temperature	• Conduct chemical trials
3	Evaluate Outcomes	• Students will articulate the outcomes from their trials in terms of their temperature requirement • Students connect their outcome to possible chemical ideas that may affect it	• Exothermic reactions are measured by an increase in the temperature of the system • Endothermic reactions are measured by a decrease in the temperature of the system	• Conduct chemical grouping trials • Class Discussion: Evaluate outcomes • Homework: "Individual Think Time"
4	Generate Reasons	• Students will link chemical ideas to reasons for their outcome • Students will brainstorm ways to test their reasons for their outcome	• The composition of particles determines how they interact with each other.	• Team Discussion: Review "Individual Think Time" Homework • Class Think Time: Generate reasons • Class Discussion: Plan how to test ideas • Read "Now That You've Thought About It ... "
5	Test Ideas	• Students will test how their ideas might be responsible for the outcomes they observed	• Interactions between particles may result in transformations • Interactions are the attraction between particles • Transformations involve changes in attractions between particles	• CSI I: Considering Shape & Structure

Lesson	Learning Cycle	Goals	Key Concepts	Student Activities
6	Analyze Results	• Students will plot their data and interpret their results using graphical formats	• Generally, as the size of the cation / anion increases the final temperature of the reaction involving the rearrangement of these ions will be lower • Higher energy levels are related to the size of the cation / anion	• Analyze results • Prepare for presentations
7	Generalize Results	• Students will draw conclusions about the data	• Interactions are the attraction between particles • Transformations involve changes in attractions between particles • Higher energy levels are related to the size of the cation / anion • The size of the cation / anion is directly related to the distance to the nucleus and the attraction of the valence electrons of one nucleus to another nucleus	• Teams will Present CSI data • Students draw conclusions about the data
8	Connect to Big Ideas	• Students will see how the results of their CSIs relate to the big idea that energy released/absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation • Students will begin to think about how they can use the big idea to improve their design	• Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation	• Read Now That You've Thought About It ... • Class Discussion: Atomic/ Ionic Radius; Attractive Forces; Particle Arrangement • Make predictions based on the generalized results • Read Now That You've Thought About It ... • Class Discussion: Principles of Delta- H • Homework: Reflection II

Lesson Time Line: Reaction Subsystem (II)

Big Idea:

Energy released / absorbed during transformations is dependent on the mass and temperature change in the system.

Lesson	Learning Cycle	Goals	Key Concepts	Student Activities
1	Create Design	• Based on their findings from Reaction I, students will select and test new reactions for their design	• Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation.	• Conduct trials to select a reaction for Reaction II Subsystem
2	Create Design Evaluate Outcome	• Students will articulate the outcome of their trials in terms of their requirement • Students will connect their outcome with possible chemical ideas that may have affected it	• Mass affects the amount of energy in the system	• Finish conducting trials and calculate average outcomes • Evaluate Outcomes • Homework: "Individual Think Time"
3	Generate Reasons	• Students will generate ideas for reasons for their observed temperature changes • Students will brainstorm ways to test their reasons for the outcomes	• An increase in mass results in more particle interactions, and consequently increases the energy of the system	• Team Discussion: Review Individual Think Time • Class Think Time: Generate Reasons • Class Discussion: Determine how to test ideas
4	Test Ideas	• Students will test how their ideas might be responsible for the outcomes they observed	• An increase in mass results in more particle interactions, and consequently increases the energy of the system	• Complete CSI II: "Considering Mass & Volume"
5	Analyze Results	• Students will plot their data and interpret their results using graphical formats • Students will evaluate whether their data support the idea they tested	• The mass of a reactant affects the change of temperature of the system • All reactions have a specific maximum amount of energy	• Analyze results • Prepare for presentations
6	Generalize Results	• Students will draw conclusions about the data	• Increases / decreases in mass are not directly proportional to increases / decreases in temperature • Changes in temperature are directly proportional to changes in energy	• Team presentations • Class Think Time: Generalize Results

Lesson	Learning Cycle	Goals	Key Concepts	Student Activities
7	Connect to Big Ideas	• Connect students general ideas to scientific ideas about energy	• Energy released / absorbed during transformations is dependent on the mass and temperature change in the system	• Read "Now That You've Thought About It ..." • Class Discussion: Temperature and energy changes in the system • Complete Energy Problems • Homework: Reflection III
8	Create Design	• Based on their findings from Reaction I and II, students will select and test new reactions for their final design	• Review all previous key concepts from Reaction I and Reaction II	• Test and select reaction for final design

Lesson Time Line: Container

Big Idea:

Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions.

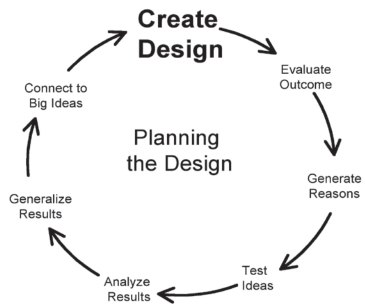
Lesson	Learning Cycle	Goals	Key Concepts	Student Activities
1	Create Design	• Students will organize the container materials by their properties	• The container is made up of particles that have unique composition which determines how they interact with the environment	• Categorize container materials • Class discussion: Container groupings
2	Create Design	• Students will create designs that will allow energy to transfer between target object and environment	• Conduction is the mechanisms by which energy is transferred when two objects are in contact • Energy transfers from particles with more kinetic energy to particles with less kinetic energy through collisions	• Conduct trials of container groupings
3	Evaluate Outcome	• Students will articulate the outcome of their trials in terms of their requirement • Students will connect their outcome with possible chemical ideas that may affect it	• Conduction is the mechanisms by which energy is transferred when two objects are in contact • Energy transfers from particles with more kinetic energy to particles with less kinetic energy through collisions	• Evaluate Outcomes • Class Discussion: Evaluate Outcomes • Homework: "Individual Think Time"
4	Generate Reasons	• Students generate ideas for reasons for their observed temperature changes • Students will brainstorm ways to test their reasons for the outcomes	• Thermal conductivity is the transfer of kinetic energy through conduction • Thermal conductivity is a unique property of matter	• Team Discussion: Review Individual Think Time • Class Think Time: Generate Reasons • Class discussion: Determine how to test ideas
5	Test Ideas	• Students will test how their ideas might be responsible for the outcomes they observed	• Thermal conductivity is the transfer of kinetic energy through conduction • Thermal conductivity is a unique property of matter	• CSI: Conductivity & Insulation
6	Analyze Results	• Students will plot their data and interpret their results using graphical formats • Students will evaluate whether their data support the idea they tested	• Thermal conductivity is a unique property of matter	• Analyze results • Prepare for presentations

Lesson	Learning Cycle	Goals	Key Concepts	Student Activities
7	Generalize Results	• Students will draw conclusions about the data	• The atomic mass and structure of a substance affect its ability to transfer energy between adjoining atoms • Substances that transfer heat energy quickly are called conductors • Substances that transfer heat energy slowly are called insulators	• Team Presentations • Class Think Time: Generalize Result
8	Connect to Big Ideas	• Connect students generalized ideas to scientific ideas about energy transfer	• Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions	• Read "Now That You've Thought About It ..." • Complete Energy Flow Practice Problems • Class Discussion: Wrap Up

Lesson Time Line: Presenting the Design

Lesson	Learning Cycle	Goals	Key Concepts	Student Activities
1	Create Design	• Students will draw sketches of their system and construct a design (model)	• Review all previous key concepts	• Draw system sketches • Construct model of design using basic materials to represent container materials
2	N/A	• Students should incorporate the key concepts and big ideas learned throughout this unit to complete their patent application	• N/A	• Patent Application
2	N/A	• Students should incorporate the key concepts and big ideas learned throughout this unit to prepare their posters, and during their Gallery Walk presentations	• N/A	• Gallery Walk

Planning the Design. Lesson 1: Introduction



Overview
Lesson Time: 1 day

Lesson Goal(s)

- Students develop an awareness that design can be used to solve everyday problems

Student Activities

- Read *Sweeping Up the Market* [5 min.]
- Team Discussion: Complete *Sweeping Up the Market* Questions [10 min.]
- Class Discussion: Identify key components of design [15 min.]

Materials

- *Sweeping Up the Market (p. 6-8)*
- *Learning Cycle* (p. 9)

Key Concept(s)

- Needs/ Problem Identification
- Functional Decomposition
- Iterative Design
- Sketches and representations

Implementing This Lesson

This is the first lesson in the unit and it will serve as the introduction to the context that students will be working in over the next several weeks. In this lesson, it is important for students to begin thinking about the ideas associated with engineering design – particularly the notions of Needs; Functional Decomposition; Iterative Design; and Sketches. During the class discussion you can also talk with students about how engineering design is a process that happens in the real world, and that everyday products can be redesigned and improved to meet a need.

Today students will read the *Sweeping Up the Market* article and within their teams engage in a discussion about the ideas presented in the article Using the article as a framework, students will have a class discussion about the Learning Cycle.

The important terms and concepts in this lesson are:

Needs refer to problems that require a solution.

Alternative Designs are used to think about different ways to solve a problem.

Functional Decomposition is the process of breaking down a design into its components and functions. This process helps clarify the goals for the design.

Iterative Design is important for optimizing and improving a design.

Sketches are important to engineering design because they provide a concrete representation of a design idea that can be easily modified and critiqued.

Thinking Ahead

In what ways does the task build on students' previous knowledge?

This task builds on students prior knowledge and conceptions about how products are designed. Students have the opportunity to discuss their preconceptions about engineering design is and how products are created. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

Do not present students with the terms listed in the Key Concepts ahead of time. Rather, encourage students to identify what they consider to be important factors for the successful design of the Dyson Vacuum. Once students have discussed and brainstormed, you can then help them label their ideas (e.g., Functional Decomposition). **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Think- Pair- Share is an instructional strategy you can use to maintain a high level of student engagement in the task. In the *Think-Pair-Share* strategy, firs students think on their own about what the article means to them, next they share their thoughts with their team members, finally as a team they would share their thoughts with the class. This strategy increases the sharing of student ideas and perspectives. As an instructor it is important to encourage all student ideas to be heard to help construct knowledge at a class level rather than just at an individual level. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking?**

Below are some questions that may be appropriate:

- What was Dyson's goal?
- How did Dyson go about problem solving?
- How did Dyson use science to help him improve his design?
- How did generating reasons for the problem that he was experiencing help Dyson to test his ideas?
- How are design and science related?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your learning goals?

You should begin this discussion with students sharing their thoughts about the article, and using this as a basis for shaping the rest of the discussion. You may want to use questions such as the example ones provided above, to guide the discussion. The goal of this lesson is to help students recognize that design is a way to solve a real-life problem.

Looking Ahead

What will you do in the next lesson that will build on this lesson?

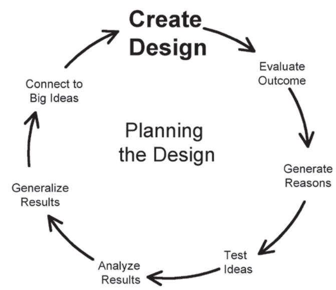
Tomorrow students will start brainstorming ideas for a heating or cooling (H/C) system based on their needs.

When you complete your journal entry, consider the following questions:

- What were the students' reactions to the lesson?
- What could you do next time to make this lesson more successful?
- Is there any additional information that would have been useful?
- Is the timing appropriate?
- What are your general comments?

Journal Space

Planning the Design. Lesson 2: Needs & New Ideas



Overview
Lesson Time: 1 day

Lesson Goal(s)

Teams brainstorm their need for a H/C system

Teams determine the type of H/C system they want to create to meet their need

Teams create a sketch of their ideal H/C system design

Student Activities

- Read *Planning Your Design* [2 min.]
- Brainstorm needs [20 min.]
- Create an H/C system sketch [10 min.]

Materials

- *Planning Your Design* (p. 10)
- *Brainstorming About Your Needs* (p. 11)
- Envisioning Your Design (p. 12)

Key Concept(s)

- Needs are problems that require a technological solution

Implementing This Lesson

This lesson is designed to allow students to brainstorm ideas about H/C systems that they would like to create. In teams, students should determine the need that they are trying to meet and come to a consensus about the type of system they want to create (either heating or cooling, not both!). In addition, teams should create a sketch of their ideal design.

Thinking Ahead

In what ways does the task build on students' previous knowledge?

This task encourages students to connect their knowledge of H/C systems to their own personal lives, and to think about how H/C systems can be personally useful. The purpose of this task is for students to brainstorm a number unique ideas. Please note, students may think that a need refers to what a design might require to work rather than a problem a design could solve. **What specific ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

This lesson is crucial to the success of the rest of the unit. Thus, students should be given ample time to explore their ideas and come to a team consensus about the system type and design they would like to create. Because ownership of their design is extremely important for the rest of the unit, you want to ensure that students consider all their options carefully. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

To ensure that students remain engaged with the task, you can use a *Think-Share* strategy. That is, students can complete the activity individually first, and then discuss their solutions within their design teams. This strategy will ensure that each student comes to the team discussion after thinking on their own about the question. Thinking on their own first increases student participation in the larger group. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What is your need for an H/C system?
- What problem are you really trying to solve?
- How might you use an H/C system to improve your life?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will refine those ideas and start to think about the essential parts of an H/C system.

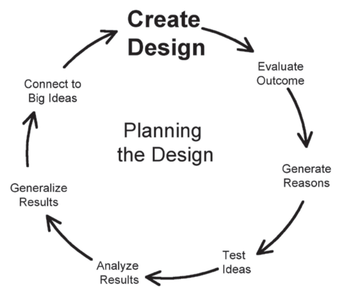
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections or form a generalization?

If you would like your students to do more formal research (e.g., library or Internet research) about H/C systems, this may be an appropriate time to do so.

Journal Space

Planning the Design. Lesson 3: Uses & Needs



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students determine the similarities and differences between various H/C systems

Student Activities

- Team Discussion: Uses & Needs of H/C systems [15 min.]
- Class Discussion: Uses & Needs of H/C systems [15 min.]
- Read: *Now That You've Thought About It ...* [2 min.]

Materials

- *Uses & Needs* Discussion (p. 13)
- *Now That You've Thought About It ...* (p. 14)
- Overheads and/or Chalkboard

Key Concept(s)

- Needs refer to problems that require a technological solution
- Energy levels in the surrounding environment can be increased or decreased
- Temperature is a reflection of the amount of energy in a system

Implementing This Lesson

This lesson uses students' prior knowledge and experience to think about how H/C systems work. In this lesson, students will work in their teams to begin to think about examples from their everyday life that could be considered an H/C system. Next, they will think about what need each of those systems meets (i.e., what problem does it solve?). Finally, students will consider the parts of H/C systems that are essential for making them work.

Note: If you finish this lesson early, then you should start the activities in the next lesson.

Thinking Ahead

In what ways does the task build on students' previous knowledge?

Students will have many of their own ideas about H/C systems and how they work. This task is designed to let students explore these ideas, and to relate what they have already experienced in their everyday life to the new ideas presented today (i.e. that H/C systems work to increase or decrease the energy levels in the surrounding environment).

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

Encourage students to think 'outside of the box' and to brainstorm a wide variety of H/C systems examples. Remind students that needs refer to a problem that requires a technological solution (e.g., what problem does the particular H/C system solve?). In addition, encourage students to list as many similarities and differences as they can. As you walk around the room, help students focus on the changing of energy levels in the environments as one of the ways that H/C systems function. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

One way to support student engagement is to assign roles within the teams. For example, one student might be assigned the role of recorder, while another student acts as the facilitator ensuring that all team members' ideas are considered. You want to encourage all team members to share their ideas during the team and class discussion. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- Why is "X" an essential part?
- What does "X" do?
- Does everyone agree that "X" is an essential part?

- What happens to energy levels in that system? How do we know that energy levels change?
- So, if energy levels change in the system, then what happens to energy levels in the surrounding environment?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your learning goals?

One goal of this discussion is that students have an opportunity to share their ideas with the class. As a consequence of this discussion, students should be able to identify the essential parts of H/C systems. Students will list various similarities and differences that may or may not relate to the lesson goal. As the discussion facilitator, your role is to shape the discussion using student ideas. First, encourage students to recognize the similarities and differences amongst H/C systems. Then, encourage students to think about the how these similarities or differences can be collapsed into larger/broader ideas that can be defined as essential parts. For example, students may think that electricity and chemical energy are different; however, energy is the underlying link between the two.

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will label the essential parts as subsystems, and relate one function to each subsystem. Students will recognize how each subsystem's function dictates how the system works as a whole.

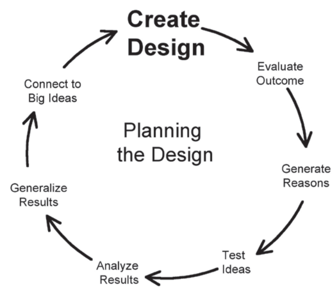
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections or form a generalization?

If you would like your students to do more formal research (e.g., library or Internet research) about H/C systems, this may be an appropriate time to do so.

JOURNAL SPACE

Planning the Design. Lesson 4: System Decomposition & Requirements



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will learn about systems and how they work

Students will define the essential parts as subsystems

Students will define the function of each subsystem

Students will be able to distinguish between 'must-have' and nice-to-have' requirements

Student Activities

- Define subsystems and functions [15 min.]
- Read *Now That You've Thought About It ...* [2 min.]
- Determine requirements [15 min.]

Materials

- *Decomposing Your System* (p. 15)
- Read *Now That You've Thought About It ...* (p. 16)
- *Your System Requirements* (p. 17)

Key Concept(s)

- Systems can be decomposed into their essential parts called subsystems
- Each subsystem has one function
- Some requirements are necessary and others are not necessary

Implementing This Lesson

This lesson is one of the most important lessons for setting the stage for how students are going to develop their designs.

Firstly, students will learn about systems and how they work. Secondly, students will recognize that functional decomposition is an approach that will be useful in creating their systems. All H/C systems can be broken down into their subsystems. Two subsystems that are significantly important for the designs are the Reaction Subsystem and the Container Subsystem. Students will need to have a clear understanding of the functions of each of these subsystems, and how they will influence their design. Finally, students will refine their design ideas by thinking about the 'must-have' and 'nice-to-have' requirements for their systems.

With regards to functions of H/C systems – through the class discussion it is important to help students understand that H/C systems function to increase or decrease the energy levels in the surrounding environment. Consequently, this change is felt (observed) as an increase or decrease in temperature. Teasing apart the difference between temperature and energy may also require some special attention in this lesson.

- The function of the Reaction Subsystem is to release or absorb enough energy to meet the design requirement.
- The function of the Container Subsystem is to allow for sufficient transfer of energy from the reaction to the object that will be heated or cooled.

Note: This lesson may take more than 1 class period.

Thinking Ahead

In what ways does the task build on students' previous knowledge?

From their prior everyday experience, students may have many of their own ideas about H/C systems. This lesson also builds on students prior knowledge of the idea of Functional Decomposition, allowing them now to consider how functional decomposition idea can be applied to their own system. Students may have difficulty determining what is required for their system to work and defining these requirements in a way that they can test while they design their system. **What specific ideas, knowledge or misconceptions do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

Remind students about the essential parts discussion from Lesson 3 and say that the purpose of today's lesson is to continue planning their design. Instruct students to use the essential parts and their features to define the subsystems and the functions of those subsystems. After students have determined the function of each subsystem, then they can define the requirements for their system. These requirements should be clarified as must-have or nice-to-have. During this lesson, encourage students to complete these activities on their own without giving them specific definitions of functions and requirements. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Students will complete the tasks within their teams. Some teams may find it difficult to start defining their requirements. Refer to the Asking Assessing/Advancing Questions section for ways to prompt their thinking. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What do you want your design to do?
- How does each subsystem work?
- What would an ideal outcome of your design look like? How would the ideal design work?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

Tomorrow your students will present their design ideas and get feedback from their peers about ways to improve their design. This presentation is an opportunity for you to push student thinking about their design and their requirements. By the end of the next lesson, all students should know that one must-have requirement for their system is that their Reaction Subsystem produces enough energy to heat or cool their desired object (this can be stated as a temperature requirement e.g., 'must reach 50 degrees Celsius'). The second must-have requirement that students should state is that their container material must allow for sufficient transfer of energy to heat or cool their desired object. This could be stated as a container material requirement, e.g. 'The heat must transfer to my object'.

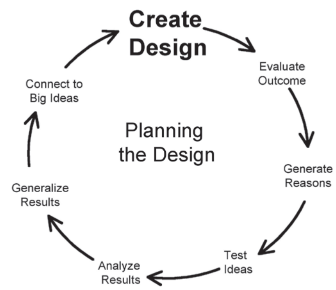
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections or form a generalization?

You may want to have students start thinking about ways that they would measure if their requirements have been met.

JOURNAL SPACE

Planning the Design. Lesson 5: Team Presentations



Overview
Lesson Time: 2 days

Lesson Goal(s)

Students receive and provide appropriate and constructive critiques about their design ideas

Students should synthesize needs, subsystems, functions, and requirements in their design

Student Activities

- Plan Presentation [30 min.]
- Present Design Ideas [30 min.]
- Homework: *Reflection I*

Materials

- *Preparing Your Presentation* (p. 18)
- Presentation Overheads
- Overhead markers (various colors)
- *Reflecting on Your Ideas & the Process* (p. 19)

Key Concept(s)

- Scientists and engineers share their ideas to get feedback
- Needs, subsystems, functions and requirements are the foundation for good designs
- Planning in a critical component for good designs

Implementing This Lesson

For this lesson students will prepare and present their initial designs for their H/C systems. The purpose of the presentations is for students to receive feedback about their own design and to give constructive critiques of other teams designs. Giving critiques and incorporating feedback is an important part of the design process, and is essential for improving the design. Students should present their design sketches, explain how their design has evolved as they have learned more about how engineers plan designs, and students should describe their must-have and nice-to-have requirements.

By the end of the lesson, all students should know that one must-have requirement for their system is that their Reaction Subsystem produces enough energy to heat or cool their desired object. This can be stated as a temperature requirement e.g., 'must reach 50 degrees Celsius'.

The second must-have requirement that students should state is that their container material must allow for sufficient transfer of energy to heat or cool their desired object. This could be stated as a container material requirement, e.g. 'The heat must transfer to my object'. Specifying these requirements now (temperature and energy transfer) will make it easier for students to successfully meet their requirements successfully later.

Please note that this lesson will likely take 2 class periods.

Thinking Ahead

In what ways does the task build on students' previous knowledge?

This lesson is the culmination of the previous four lessons, allowing students to synthesize all that they have learned about needs, subsystems, functions, and requirements. **What other ideas or knowledge do you think your students will bring to the task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

Briefly talk with students about why scientists and engineers present their ideas to each other. Scientists and engineers use presentations to communicate their ideas and receive appropriate and constructive critiques about their designs. As students prepare their presentation, encourage them to think about the most effective way to tell their design story. This presentation should document the evolution of their design and identify any weaknesses in their design.

Students play an important role in developing each others designs by providing appropriate and constructive critique. The goal of these critiques is to support improvement of student designs, rather than merely commenting about aesthetic features. Students should identify ways to improve the weaknesses in each others' designs, including weaknesses that the presenting team has not identified. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Students should actively participate in the presentations, providing feedback and constructive criticism to other teams, as well as being an active contributor to their own teams presentation. During their presentation, teams should record the critiques given to them by other students in a different color overhead marker. After the presentation, teams should incorporate the critiques to improve their design.

You may want to consider assigning roles for the presentations to ensure that all students are engaged. In addition, you may want to consider assessing students performance based not only on their team's presentation but also on the quality of feedback and critique they provide to other teams. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. Use the presentations to formally ask teams questions that you may have asked informally during group work. In addition, encourage students to think about how they will meet their requirements. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What do you want your design to do?
- How does each subsystem work?
- What would an ideal outcome of your design look like? How would the ideal design work?
- What is your need for an H/C system?
- What problem are you really trying to solve?
- What are some key steps to get you from where you are now to where you want to be with your design?
- What changes can you make to your design based on the feedback you received from your classmates?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your learning goals?

You may find that the discussion will be more productive if you order the presentations strategically, so that students can build on each other's ideas and designs. One strategy might be to use presentation(s) that have obvious strengths and/or weaknesses first because they encourage students to voice both appropriate and constructive critiques. For example, a strength could be a clear requirement that meets a goal; a weakness could be no requirement for the Reaction or Container Subsystem. Later presentations could build on the discussions and critiques from earlier presentations.

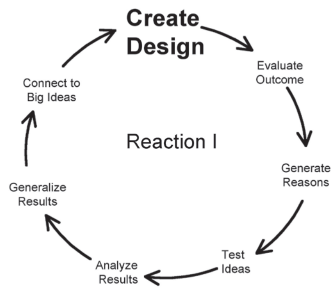
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will start to create their design by focusing on the Reaction Subsystem. Students will use their requirements to guide their progress.

Journal Space

Reaction I. Lesson 1: Exploring the Chemical Space



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will categorize chemicals by their properties

Student Activities

- Read *Creating Your Design* [2min.]
- Categorize Chemicals [20 min]
- Class Discussion: Chemical and Lab Safety [10 min.]

Materials

- *Creating Your Design (p. 20-21)*
- *Chemical Categorization* (p. 22-23)
- *Chemical Sheets*
- Safety page
- Chemicals

Big Idea

- Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation

Key Concept(s)

- Matter is made up of tiny particles that have mass and occupy space
- Particles have a unique composition
- The composition of particles determines their chemical and physical properties

Implementing This Lesson

Today students will engage in a categorization activity including the different chemicals that are available during this unit. Students will have an opportunity to think about the properties of these chemicals. The rationale for this task is to put students in a position to consider the particulate nature of matter, characteristic properties of matter, and structural differences.

Safety is paramount when working with chemicals. Take time during today's lesson to review the safety page with students and reiterate the importance of following best practices for lab safety. Introduce students to the materials in their resource packets including the *Chemical Sheets* (yellow) and *Material Safety Data Sheets* (MSDS) (blue). In this task, students primarily will use the Chemical Sheets to gather information about the properties of the chemicals they will use for their design. They can use the MSDS as an additional source of information about the chemicals. Students may not be familiar with an MSDS, so it should be made clear that chemists and engineers use MSDS to gather information about the properties and hazards of using various chemicals.

Thinking Ahead

In what ways does the task build on students' previous knowledge?

Many of the available chemicals for the Reaction Subsystem are chemicals that students may have encountered in their everyday lives. This lesson builds on students' previous knowledge about these chemicals (e.g., table salt, baking soda, and calcium chloride), and provides new experiences with chemicals that students may not have encountered before (e.g., acids). Students will have a variety of ideas to the table such as 'acids make things hot', or 'mixing vinegar with baking soda makes bubbles'. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

This task will give students their first opportunity to explore the chemicals that they will use to create their H/C systems. The goal of this task is that students will differentiate between matter at the macroscopic level (e.g., color, grain size, etc.) while inferring about the microscopic level. Rather than telling students which chemicals share similar properties, allow students to categorize the chemicals into grouping that make sense to them using their *Chemical Sheets*, keeping in mind that they have a design goal of determining which chemicals would be good sources of energy for their H/C system.

What will you hear that lets you know that students understand and are engaged with the task?

As you walk around you should hear students making claims about what chemical property may impact their ability to meet their energy requirement. You may hear students asking each other what certain properties mean. You may also hear students discussing the similarities and differences between the chemicals. This is really the opportunity for students to explore. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

For this task, students will work in their design teams. All students should be engaged and actively contribute to helping their team complete this task. However, maintaining engagement of all students can be a challenge. One strategy that you might employ would be to have students take-on different roles. For example, one student could be responsible for taking notes about each chemical, another student could be responsible for sorting the chemical sheets, and another student could be responsible for analyzing the chemicals. Rotate roles so that each member has an opportunity to try each role. This strategy may keep students focused on the scientific aspects of the task. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. Students should be focused on some properties while categorizing their chemicals: melting point, boiling point, types of bonding, ionic radius, states of matter, molecular weight, chemical formula, chemical structure and elements. **What kinds of questions do you think you can ask to focus their thinking on these features? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What similarities do you notice between the different samples?
- What differences do you notice between the different samples?
- Are there elements that are the same across samples? How are these samples similar? Different?
- What makes a cation? What makes an anion?
- Each sample has "X" grams of material in it but not all samples look like they have the same amount in them? Why?
- These two samples look the same, but are they the same? E.g., If this has lithium (LiCl) and this one has sodium (NaCl), are they the same?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

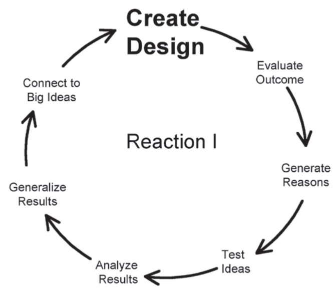
In the next lesson, students will build on what they have discovered today, using this new knowledge to help guide them in their decisions about what chemical combinations will give them a hot or cold reaction.

JOURNAL SPACE

When you complete your journal entry, consider the following questions:

- What were the students' reactions to the lesson?
- What could you do next time to make this lesson more successful?
- Is there any additional information that would have been useful?
- Is the timing appropriate?
- What are your general comments?

Reaction I. Lesson 2: Create Design



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will recognize that chemicals are a source of energy

Student Activities

- Conduct trials of chemical groupings [30 min.]

Materials

- *Chemical Categorization* (p. 22-23)
- *Reaction Trials* (p. 24)
- *Chemical Sheets*
- Chemicals
- Condiment cups
- Small scoop or spatula (<2 grams)
- Thermometer
- Balance (optional)

Big Idea

- Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation

Key Concept(s)

- Particles interact with each other; this interaction may result in an increase or decrease in temperature

Implementing This Lesson

Today, students will start working with the chemicals that they would like to use in the H/C system. Students will try a number of chemical combinations (in small amounts) to see if they can meet the temperature requirement for their system.

You may distribute chemicals in a way that works best in your classroom. For example, you may want to give each team a specific amount of chemicals or you may want to have a central location for chemicals. In addition, you may want to reiterate chemical safety procedures.

Thinking Ahead

In what ways does this task build on students prior knowledge?

This task will encourage students to build on the knowledge they gained from the previous task by giving them an opportunity to test how the chemicals will interact with each other. Students may want to combine many chemicals together. You might allow this at first (in small quantities) as it provides an opportunity for later discussion about why combining too many chemicals together may not be useful. **What other knowledge do you think your students will bring to this task?**

Students may have misconceptions about what will happen when they combine chemicals (e.g., 'acids make things hot'). **What other misconceptions might students have?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced?

This task is designed so that students will have the opportunity to explore some of their ideas from the *Chemical Categorization.* Allow students a bit of room to decide which ideas and chemicals they would like to explore, as this is an opportunity for students to begin to develop understanding about how different chemicals react when combined. Instruct students to use no more than a scoopful of each chemical (i.e. less than 2 grams) when conducting their tests. The goal is for students to collect quantitative evidence (taking temperature readings), to determine whether different chemical combinations produce endothermic or exothermic reactions.

How will you ensure that students will engage important scientific ideas or practices?

One way to ensure that students are engaging in important scientific ideas, is to ask them to make 'predictions' about the trials that they are conducting. That is, students should be connecting the trials that they are conducting with the categories they created in the *Chemical Categorization* task from the previous lesson. This will put students in the space of thinking about chemical ideas rather than having them do random trails. You will get some indication of how well your students understand the task as you walk around the classroom listening to students' discuss their reasons for testing various chemicals and the results that they are observing (e.g., whether the temperature increased, decreased or remained the same). **What else might you expect to hear your students saying?**

Supporting Student Engagement

Students will work in their teams to complete this task. You should expect that students will record their observations, using the information from their *Chemical Sheets* as a point of reference. To ensure that the whole group is engaged, more than one student should help combine and mix chemicals. For example, two students could be responsible for combining and mixing the chemicals, while the other two students could be responsible for recording the results. Students could rotate roles, to ensure that everyone has an opportunity to record results and combine chemicals. **What are other strategies that can ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. Students should be focused on some properties while conducting trials of their chemical groupings: melting point, boiling point, types of bonding, ionic radius, states of matter, molecular weight, chemical formula, chemical structure and elements. **What kinds of questions do you think you can ask to focus their thinking on these features? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What were your results?
- Were your groupings useful for meeting your requirement? For understanding the chemicals?
- What do you think your results say about the chemicals that you tested?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will evaluate their outcomes from this lesson.

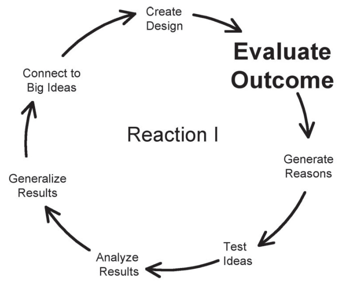
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections or form a generalization?

Challenge students to think about how their results are related to the information on the MSDS sheets.

JOURNAL SPACE

Reaction I. Lesson 3: Evaluate Outcomes



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will articulate the outcomes from their trials in terms of their temperature requirement

Students will connect their outcome to possible chemical ideas that may affect it

Student Activities

- Conduct chemical grouping trials [10 min.]
- Class Discussion: Evaluate outcomes [20 min.]
- Homework: *Individual Think Time*

Materials

- *Evaluating Your Trials* (p. 25)
- Homework: *Individual Think Time* (p. 26)
- *Reaction Trials* (p. 24)
- *Chemical Sheets*

Big Idea

- Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation

Key Concept(s)

- Exothermic reactions are measured by an increase in the temperature of the system

Implementing This Lesson

In today's lesson, students will evaluate the outcomes of their trials by addressing the question "Did you meet your temperature requirement?" After a brief sharing of results, students will engage in a class discussion about why they believe they saw the outcomes they did.

Note: If you complete this lesson early, then you should start the activities in the next lesson.

Thinking Ahead

In what ways does the task build on students prior knowledge?

The goal of the team and class discussions is to encourage students to consider their outcomes so that they will be able to consider the reasons for their outcomes in the next lesson. Good organization of the data from all teams will help students see an informative pattern of results. **What other knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced?

As students present their results, encourage them to link their hypothesis with their outcomes. For example, one team may have decided that pH would influence the temperature of their system. When discussing their findings, this team should state their hypothesis (e.g., chemicals with higher pH values will result in reactions that have greater temperature changes) and the outcomes they observed (e.g., it seemed that there was no relation between with the pH of a chemical and the resultant temperature of the system). **What ideas might you expect to hear your students share?**

Supporting Student Engagement

Students will complete *Evaluating Your Trials* in their teams, and then will participate in a class discussion. During the class discussion, encourage all teams and all students within each team to share their ideas. **What other strategies can you use to ensure that all students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- Did you meet your requirement? What is your evidence?
- Were your groupings useful for meeting your requirement? For understanding the chemicals?

Overview (continued.)

- Endothermic reactions are measured by a decrease in the temperature of the system
- Particles interact with each other; this interaction may result in an increase or decrease in temperature.

- What do you think your results say about the chemicals that you tested?
- What do you think are the pieces (elements) of each compound?
- How do you think the elements of each chemical behave during reactions?
- What do you think is going on with the particle interactions if one component is similar and the other component is not?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

The science learning goal for today is to begin to help students understand what is happening at the microscopic level in their reactions. That is, particles interact with each other and result in increases or decreases in temperature.

At the beginning of the class discussion have each team present their data (very quickly). This presentation of their data should include a discussion of their reason(s) for testing the reactions their hypotheses. Students should state the specific reactions they tested and the results of those trials.

You will likely find that students will provide you with multiple opportunities to assert the key concept for today's lesson. For example, students may say things such as "When I mixed the water with the LiCl the temperature increased." You should probe what the student means by 'mixed,' encouraging other students to help expand and clarify the ideas. In addition, this is an opportunity to label reactions as exothermic or endothermic.

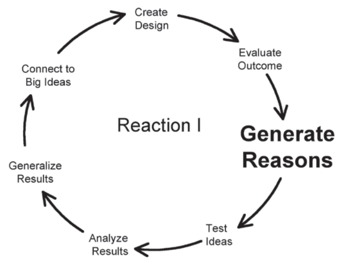
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will start to focus on the scientific reasons that can be used to explain the results they observed.

Journal Space

Reaction I. Lesson 4: Generate Reasons



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will link chemical ideas to reasons for their outcome

Students will brainstorm ways to test their reasons for their outcome

Student Activities

- Team Discussion: Review *Individual Think Time* Homework [5 min.]
- Class Think Time: Generate reasons [15 min.]
- Class Discussion: Plan how to test ideas [10 min.]
- Read *Now That You've Thought About It ...* [2 min.]

Materials

- *Individual Think Time* (p. 26)
- *Generating Reasons for the Outcome* (p. 27)
- Read *Now That You've Thought About It ...* (p. 28-29)
- *Chemical Sheets*

Big Idea

- Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation

Key Concept(s)

- The composition of particles determines how they interact with each other

Implementing This Lesson

Today students will continue to brainstorm reasons for why they believe their reactions did or did not meet their temperature requirement. Encourage the students to consider the idea that "the composition of the reactants (i.e., cation vs. anion) affects the final temperature of the system" Also, by the end of the class today, students will have begun to consider the features of a 'good test', including independent and dependent variables, and units of measure (e.g., the Mole).

Thinking Ahead

In what ways does the task build on students' prior knowledge?

This lesson builds on students prior knowledge about chemical transformations (also called chemical reactions). Students will have a number of ideas or misconceptions that may become apparent throughout this discussion. For example, students may think that when they do not see a change, then a reaction has not occurred (e.g., dissolved NaOH in water does not look different from water alone). **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

Students will struggle to generate scientific reasons for why they observed particular outcomes; however, you should encourage them to express a wide variety of possible reasons. The purpose of the discussion today is to brainstorm student ideas. Allowing students to express all their ideas, without evaluating them immediately, is very important to this task.

Finally, by the end of the lesson, students will decide (as a class) the best way to test one of their generated reasons. **What might you expect to hear your students saying during this discussion?**

Supporting Student Engagement

During the class discussion encourage all teams, and all students within each team, to share their ideas, and all students to share their ideas. It may be valuable to set some 'ground rules' for the class discussion that encourage the sharing of multiple ideas without immediately evaluating those ideas. Encourage constructive criticism of ideas, for the purpose of improving the ideas rather than just dismissing them. **What other strategies can you use to ensure that all students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- Were your groupings useful for understanding the chemicals?

- What do you think happens to chemical compounds during reactions?
- What do you think your results say about the chemicals that you tested?
- What do you think are the pieces (elements) of each compound?
- How do you think the elements of each chemical behave during reactions?
- What do you think is going on with the particle interactions if one component is similar and the other component is not?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

The science learning goal for today builds on the ideas from the previous lesson (particles interact with each other and result in increases or decreases in the temperature of the system). Through the discussion today, students should recognize that when they observed temperature changes in their systems it was because particles were interacting resulting in a transformation (reaction). In addition, students should begin to recognize that the composition of the particles determines how they interact with each other, and thus whether there will be a transformation.

Students will likely provide you with multiple opportunities to assert the key concept for today's lesson. For example, students may say things such as "It depends on how the elements interact" or "There is a reaction". These statements indicate that students are beginning to think about the particles, and can be pushed to start articulating their ideas using more precise scientific terms.

When the discussion gets to the point where you are beginning to think about the best ways to test their ideas, you do not want to dictate to the students how to design their experiments. However, you might want to have a brief discussion with the students about experimental design in general (e.g., independent and dependent variables; constants). For example, the independent variable is the thing you will modify and the dependent variable is the thing you will measure to see how it changes. The constant(s) is/are the thing(s) you hold constant to ensure that you are comparing apples to apples, (e.g., we held the number of particles the same by using one teaspoon/scoop of each substance/matter). Help students recognize that considering the variables and constants allows you to notice patterns and relationships.

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will test the idea(s) that they generated in this lesson.

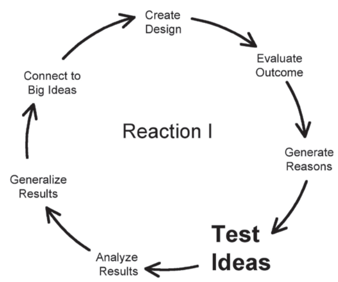
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections or form a generalization?

Encourage students to think more deeply about what is happening in their reactions by introducing the concepts of reactants and products.

JOURNAL SPACE

Reaction I. Lesson 5: Test Ideas



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will test how their ideas might be responsible for the outcomes they observed

Student Activities

- CSI I: Considering Shape & Structure [30 min.]

Materials

- *CSI I: Considering Shape & Structure* (handout)
- *Systematically Testing Your Ideas* (p. 30)
- *Chemical Sheets*
- *Periodic Table*
- Balance
- Thermometers
- Small scoop or spatula
- Graduated cylinder or 10ml syringe
- Condiment cups
- Chemicals

Big Idea

- Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation

Implementing This Lesson

Today, students will test their ideas about how chemical properties influence the outcome. This is the first opportunity for students to engage in a guided inquiry experience that will allow them to systematically analyze their data. The activity will need to be jigsawed between teams so that students can make comparisons across group data can be made. *CSI I: Considering Shape & Structure* will introduce students to different representations of chemical transformations (e.g., in the form of a chemical equation); a brief discussion of transformations may be necessary before to students begin the task.

On the *CSI I: Considering Shape & Structure* handout, there are questions that students should complete before the start conducting *CSI I: Cations & Anions*.

Note: If you have not completed *CSI I: Considering Shape & Structure* yourself, please do so. You should be aware of the results and patterns that arise from the experiments.

Thinking Ahead

In what ways does this task build on students prior knowledge?

In this task students will have the opportunity to use their knowledge of independent and dependent variables; the Mole; laboratory skills (e.g., weighing; reading temperature). Students may need prompting and reminding about how to use a balance, how to read a thermometer, and the conversion of Fahrenheit to Celsius. **What other knowledge or skills will your students bring to this task that you will be able to build upon?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

When distributing handouts, remind students that the handouts were created based on their ideas from the Generate Reasons discussion. When introducing this task to students, do not foreground the expected results. Do not provide students with too much background information about the concepts they will be encountering as they engage in this task. Rather, let students bump up against some of these difficult concepts before providing guidance. Your role is to facilitate the procedural aspects of the task, the conceptual aspects should be discussed with students either in small groups or during a class discussion. It is best to provide students with the handout and allow them to complete the *CSI* in their teams. Before students begin experimenting with the chemicals, they should complete the first part of the *CSI I: Considering Shape & Structure* handout. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Ensure that all students in each team are engaged with a part of the CSI. You may want to consider assigning student roles to facilitate efficient completion of this task. If teams are not efficient, then they will not be able to complete the task in time. As you walk around the classroom talking to the teams, you may want to engage the teams in a brief discussion about their ideas. This discussion will give you with an opportunity

Overview (continued.)

Key Concept(s)

- Interactions may between particles result in transformations
- Interactions are the attraction between particles
- Transformations involve changes in attractions between particles

to informally assess students are. In addition, this discussion will provide an opportunity for you to identify whether all students understand the task (i.e., they are able to articulate the hypothesis that they are testing). **What other strategies can you use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- Why do you think the same molar amounts weigh different grams?
- What do yo think is happening when substances interact and you see an increase, decrease or no change in temperature ?
- How do you think chemical structure affects interactions?

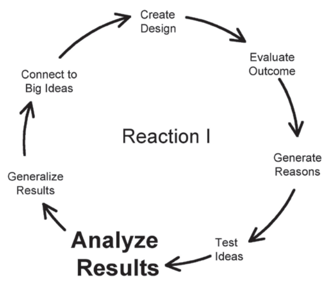
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will analyze the data they collected during this lesson.

Journal Space

Reaction I. Lesson 6: Analyze Results



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will plot their data and interpret their results using graphical formats

Students will evaluate whether their data support the idea they tested

Student Activities

- Analyze Results [25 min.]
- Prepare for Presentations: Temperature vs. Ionic Radius Transparencies [5 min.]

Materials

- *Analyzing Your Data* (p. 31)
- *CSI I: Considering Shape & Structure* (handout)
- *Systematically Testing Your Ideas* (p. 30)
- *Temperature and Ionic Radii Handout* (p. 33)
- *Periodic Table* (p. 32)
- *Chemical Sheets*
- Graph paper
- Transparencies
  - Periodic table
  - Graph
- Transparency markers

Big Idea

- Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation

Implementing This Lesson

Today your students will plot their data from *CSI I: Considering Shape & Structure* and use these data to interpret their results. Students will need to make claims about whether their data supports or disproves the idea they tested. In addition, students will plot their results on a copy (e.g. transparency) of the periodic table. This activity will highlight the cation/anion trend, and focus students on the elemental properties of the ions, such as charge, valence electrons (as a important factor for bonding), ionic radius (as a measure of size), and atomic mass (as a measure of the number of electrons, protons and neutrons). Finally, teams will complete a prediction task based on their results, examining how ionic radii influences their outcome.

Thinking Ahead

In what ways does the task build on students' prior knowledge?

This task requires students to represent their knowledge in a new way (i.e., graphically) and helps them build their understanding of their data. Students will need to use their prior knowledge about graphing (e.g., independent & dependent variables; X & Y axes). Students will use their prior knowledge and skills of reading and interpreting graphs. They may make mistakes, incorrectly plotting data or labeling the axes on the graph. These mistakes may make it difficult for students to interpret their results, but may provide you with a good opportunity to engage the class in a discussion about the appropriate methods for plotting. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

You should to give students clear goals and expectations for this task but do not tell them what they should think. For example, students should determine for themselves how to plot their data (i.e., on the correct axes). As a facilitator, you should wander around the classroom monitoring student progress. If necessary, a class discussion could be utilized to highlight the different ways that students represent their data and whether there is a best way to represent these data.

In addition, students should discover what is the same and what is different between the ions and their attractions to water or other solvents. Therefore, rather than telling students about the relative bond strengths of different ions and water or other solvent molecules, students should use the periodic table and elemental data to begin to explore these ideas on their own.

When introducing the periodic table, inform students that the periodic table is a way that chemists have organized the elements, just like they organized their chemicals during the categorization task. Students should begin to make links between other characteristics from the periodic table and their results. You should expect to hear them moving away from only talking about their temperature data and hear more discussion about charge, number of electrons, radius/size, energy levels etc. **What do you expect to hear your students saying that lets you know that students understand and are engaged with the task?**

Overview (continued.)

Key Concept(s)

- Generally, as the size of the cation / anion increases the final temperature of the reaction involving the rearrangement of these ions will be lower
- Higher energy levels are related to the size of the cation / anion

Supporting Student Engagement

Students will complete these activities individually, although they can work with their teams. Each student will complete their own graph to represent the data their group collected. This task will ensure that students remain engaged with the task, and provides every student an opportunity to practice and solidify their graphing and analysis skills. **What other strategies can you use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking.**What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What are the trends on the graph?
- What do the trends on the graph represent?
- How does the trend on the graph relate to the trend on the periodic table?
- What do you think will happen when you mix CsCl and water? RbCl and water? FrCl and water? LiAt and water? NaAt and water? KAt and water? RbAT and water? CsAt and water? FrAt and water? Etc.

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will create general statements about how their data relate to the ideas they discussed during Generate Reasons.

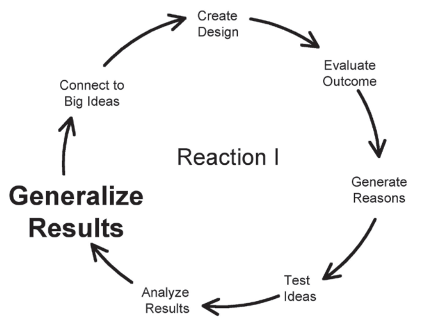
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections or form a generalization?

Challenge students to make predictions about Group II cations and Group VII anions.

Journal Space

Reaction I. Lesson 7: Generalize Results



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will draw conclusions about the data

Student Activities

- Teams Present *CSI I* data [15 min.]
- Students draw conclusions about the data [15 min.]

Materials

- *Generalizing Your Data* (p. 34)
- *Chemical Sheets*
- Temperature and Ionic Radii transparencies
- Transparency markers

Big Idea

- Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation.

Key Concept(s)

- Interactions are the attraction between particles
- Transformations involve changes in attractions between particles
- Higher energy levels are related to the size of the cation / anion
- The size of the cation / anion is directly related to the distance to the nucleus and the attraction of the valence electrons of one nucleus to another nucleus

Implementing This Lesson

Today the teams your students will present their *CSI I* data to the class. Following this, you will facilitate a class discussion about these results, helping students begin to generalize the results presented by each team; addressing the question "what trends or patterns do you notice in your data?".

Thinking Ahead

In what ways does the task build on students' prior knowledge?

There are a number of science learning goals for today that have been built up through students' experiences in previous lessons. Through the discussion today, students should recognize that the properties of cations and anions (e.g., charge, size, attractive forces) relate to their temperature data. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the requirements are clear? So that students are likely to engage in important scientific ideas or practices?

Students will start today's lesson presenting and thinking about the data their teams collected during the *CSI*. Ask students to present the results from the *CSI*. Students will present their Temperature and Ionic Radii transparency to illustrate the trends in their data. The presentation should include the reactions that they tried and resultant temperatures.

As a class, identify patterns in the data across the various *CSI* investigations and draw conclusions about those patterns. As students see the results from other teams, they should be able to see how their own data are the same or different from the other data. By the end of the discussion, students should realize that the shape and structure of particles are related to the way they interact with each other. **What do you expect to hear your students saying that lets you know that students understand and are engaged with the task?**

Supporting Student Engagement

Encourage all teams to share their ideas, and all students to participate in both the team presentations and class discussion. If you set 'ground rules' for previous class discussions, remind students of these ground rules before beginning this discussion. **What other strategies can you use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- Does that work for all cases?

- I wonder what would happen if you used something further down the Periodic Table?
- How might the data trends help you improve your design?
- What are the trends on the graph?
- What do the trends on the graph represent?
- How do the trends on the graph relate to the trend on the periodic table?
- What do you think will happen when you mix CsCl and water? RbCl and water? FrCl and water? LiAt and water? NaAt and water? KAt and water? RbAT and water? CsAt and water? FrAt and water? Etc.

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

During the team presentations, the relation between to cation/anion size trend and temperature changes should become apparent to students. Ultimately, through the class discussion, students should recognize that the properties of dissociated ions are important for predicting how particles interact (assuming everything else is held constant). That is, the dissociated ions have different levels of attraction to the water particles, and these attractions result in new bonding with different strengths. Students should now see that their ideas can be generalized to make predictions about how other chemicals might be used in their system. By the end of the class, students should think about temperature changes as representative of energy changes due to changes in bonding. During the class discussion, you should facilitate the connection between the appropriate scientific terms and the ideas that students are expressing.

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will connect conclusions to the big idea that energy released/absorbed during transformation is dependent on the shape and structure of the particles involved in the transformation.

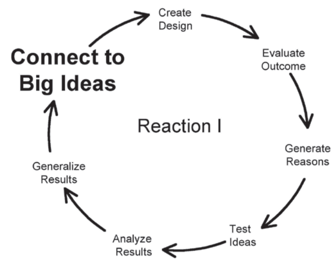
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections or form a generalization?

Introduce the concept of lattice energy levels and their relationship to the size of anions and cations.

Journal Space

Reaction I. Lesson 8: Connect to the Big Idea



Overview
Lesson Time: 2 days

Lesson Goal(s)

Students will see how the results of their CSIs relate to the big idea that energy released/absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation

Students will begin to think about how they can use the big idea to improve their design

Student Activities

- Read *Now That You've Thought About It ...[2 min.]*
- Class Discussion: Atomic/Ionic Radius; Attractive Forces; Particle Arrangement [15 min.]
- Make predictions based on the generalized results [15 min.]
- Read *Now That You've Thought About It ...[2 min.]*
- Class Discussion: Principles of Delta- H [15 min.]
- Homework: Reflection II (p. 37)

Materials

- *Now That You've Thought About It ...(p. 35-36); (p. 38-39)*
- *Predicting From Your Generalizations* (p. 37)
- Homework: *Reflecting On Your Ideas and The Process* (p. 39)

Implementing This Lesson

Today, you will reinforce the ideas encountered previously in the Reaction I Subsystem and tie them all together so that students start to recognize that energy released or absorbed during transformations is dependent on factors related to the shape and structure of the involved chemicals. You have spend a lot of time building students ideas about atomic structure and bonding changes as they relate to their temperature requirement. During this lesson, you should encourage students to begin thinking about their temperature changes as energy changes and about how temperature is a measure of the energy in the system. Understanding this big idea can help students determine how to design their H/C systems by thinking about the properties (particularly shape and structure) of the chemicals that they have and how the shape and structure of these chemicals impacts how they react with different solvents.

Thinking Ahead

In what ways does the task build on students' prior knowledge?

This task builds on all the knowledge that students have learned and the experiences that students have gained throughout this subsystem. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

Learning is most effective when students have experiences that they can connect with new information. Start today's discussion with students' experiences with the CSIs and build on those experiences to get students to see the Big Idea. **What do you expect to hear your students saying that lets you know that students understand and are engaged with the task?**

Supporting Student Engagement

During the class discussion, encourage all teams and all students within each team to share their ideas. It may be valuable to set some 'ground rules' for the class discussion that encourage the sharing of multiple ideas without immediately evaluating those ideas. Encourage constructive criticism of ideas, for the purpose of improving the idea rather than just dismissing it. **What other strategies can you use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- How do you think the energy level relates to size?
- How do you think the number of electrons relates to size?
- How does losing/gaining electrons affect the size of the ion?

Overview (continued.)

Big Idea

- Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation

Key Concept(s)

- Review all previous key concepts to get to the big idea

- How do you think atomic mass relates to size?
- What factors do you think affects the attractions (bonding)?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

The goal of this discussion is to help students begin to understand how ideas about bonding and rearrangement can be used to improve the design of their H/C system. It may be beneficial to begin the class discussion by focusing on atomic radius first because students will likely connect with this idea. Next you should address ideas about attraction due to charge differences, which will lead to ideas about bonding. However, you can address these ideas in whatever order you feel will be most appropriate for your students, so long as you make connections between all the concepts. **What do you think you will see or hear that lets you know students in the class understand the scientific ideas that you intended for them to learn?**

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will use the Big Idea to improve their design.

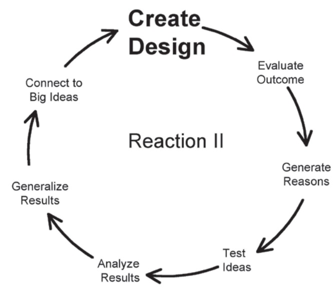
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections or form a generalization?

Challenge students to do quantitative calculations for Heat of Formation.

Journal Space

Reaction II. Lesson 1: Create Design



Overview
Lesson Time: 1 day

Lesson Goal(s)

Based on their findings from Reaction I, students will select and test new reactions for their design

Student Activities

- Conduct trials to select a reaction for Reaction II Subsystem [30 min]

Materials

- *Selecting Your Reaction Subsystem Handout* (p. 40-41)
- *Chemical Sheets*
- Balance
- Thermometers
- Small scoop or spatula
- Graduated cylinder or 10ml syringe
- Condiment cups
- Chemicals

Big Idea

- Energy released / absorbed during transformations is dependent on the mass and temperature of the system

Key Concept(s)

- Energy released/absorbed during transformations are dependent upon shape/structure

Implementing This Lesson

Today students will select and test new reactions to use as the energy source for their design. They should select these new reactions based on what they have learned from their Reaction I investigations. Each team member will collect data on each reaction. Multiple measures of the same reaction will allow students to see whether they were able to replicate their outcome.

Thinking Ahead

In what ways does the task build on students' previous knowledge?

This task builds on all the experiences students have had throughout the unit, and allows them to synthesize this new knowledge and put it to use in the creation of their design. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

This is students opportunity to utilize their new knowledge. Students will the Reaction Approval form, justifying their reaction choices. While students are completing this form you should expect to hear them referring back to some of the ideas they learned in Reaction I (e.g., anion and cation size) and to see them using these ideas to make informed decisions about what reactions to try next. **What else might you expect to hear your students saying that lets you know that students understand and are engaged with the task?**

Supporting Student Engagement

For this task students will work in their design teams to determine which reactions they would like to try. Each team member will test the selected reactions. All students should be actively engaged and contributing to the completion of this task. Now that teams have spent a significant amount of time working together, they should have worked out a system within their team for completing group activities. However, it may be helpful to remind students about effective group work strategies (e.g., the division of tasks; rotating team roles; etc.). **What other strategies can you use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- Why do you want to use that reaction for your design?
- How are you using what you learned in the last few days to improve your design?

- Remember the CSIs? What did those results say that could help you improve your design?
- How has your design improved since you started?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

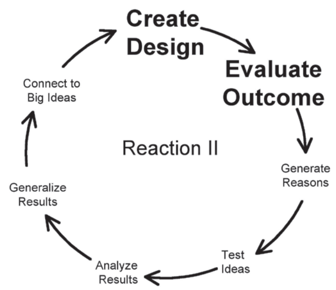
In the next lesson, students will continue to improve their Reaction Subsystem and evaluate their outcomes from this lesson.

Journal Space

When you complete your journal entry, consider the following questions:

- What were the students' reactions to the lesson?
- What could you do next time to make this lesson more successful?
- Is there any additional information that would have been useful?
- Is the timing appropriate?
- What are your general comments?

Reaction II. Lesson 2: Create Design & Evaluate Outcome



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will articulate the outcome of their trials in terms of their requirement

Students will connect their outcome with possible chemical ideas that may have affected it

Student Activities

- Finish conducting trials and calculate average outcomes [20 min.]
- Evaluate Outcomes [10 min.]
- Homework: *Individual Think Time*

Materials

- *Selecting Your Reaction Subsystem* (p. 40-41)
- *Evaluating Your Trials* (p. 42)
- *Homework: Individual Think Time (p. 43)*
- *Chemical Sheets*
- *Periodic Table*
- Balance
- Thermometers
- Small scoop or spatula
- Graduated cylinder or 10ml syringe
- Condiment cups
- Chemicals syringe
- Balance
- Thermometer
- Stirrer

Implementing This Lesson

In today's lesson, students will continue to test new reactions that they might use as the energy source for their design. After completing their tests, students will calculate the average outcome for each reaction (i.e. initial and final temperature). Also, students will evaluate the outcomes of their trials and address the question "Did you meet your temperature requirement?"

Thinking Ahead

In what ways does the task build on students' previous knowledge?

Based on their experiences during Reaction I, students should be proficient at setting up equipment and designing good experiments. Students will have some experience observing and evaluating outcomes and consequently, generating reasons for those outcomes. This task is designed to build on those prior experiences and to provide students with an opportunity to engage in these same activities and further develop their skills. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

Because students have had prior experience with both activities that they will complete today, you may not need to provide as much guidance as when these activities were introduced the first time. When students begin evaluating their outcomes, encourage them to link their hypotheses with their outcomes. Students may struggle to generate scientific reasons for why they observed particular outcomes, however, once again you should encourage them to express a wide variety of possible outcomes. **What do you expect to hear your students saying that lets you know that students understand and are engaged with the task?**

Supporting Student Engagement

For this task, students will work in their design teams to determine which reactions they would like to try. Each team member will test the selected reactions. All students should be engaged and contributing to the completion of this task. Now that teams have spent a significant amount of time working together, they should have worked out a system within their team for completing group activities. However, it may be helpful to remind students of effective group work strategies (e.g., the division of tasks; rotating team roles; etc.). **What other strategies can you use to ensure that students remain engaged and focused on the task?**

Overview (continued.)

Big Idea

- Energy released / absorbed during transformations is dependent on the mass and temperature of the system

Key Concept(s)

- Mass effects the amount of energy in the system

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- Were you able to replicate the outcome across team members? If not, why?
- Were you able to meet your temperature requirement?
- If you have not yet met your requirement, are you closer now than you were before?
- What is an average?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will start to focus on the scientific reasons that can be used to explain the results they observed in this lesson.

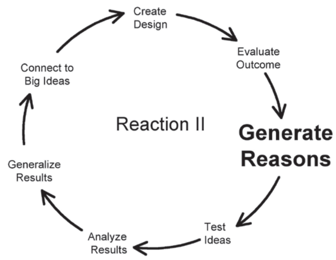
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections, or form a generalization?

If time permits, add a second day to this lesson.

Journal Space

Reaction II. Lesson 3: Generate Reasons



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will generate ideas for reasons for their observed temperature changes

Students will brainstorm ways to test their reasons for the outcome

Student Activities

- Team Discussion: Review *Individual Think Time* [5 min.]
- Class Think Time: Generate Reasons [15 min.]
- Class Discussion: Determine how to test ideas [10 min.]

Materials

- *Selecting Your Reaction Subsystem* (p. 40-41)
- *Evaluating Your Trials* (p. 42)
- Homework: *Individual Think Time (p. 43)*
- *Generating Reasons for the Outcomes* (p. 44)

Big Idea

- Energy released / absorbed during transformations is dependent on the mass and temperature of the system

Key Concept(s)

- An increase in mass results in more particle interactions, and consequently increases the energy of the system

Implementing This Lesson

Today, in Generate Reasons, students will make connections between their observations (at the macroscopic level) and the scientific explanations for those observations (at the microscopic level). In their teams students will discuss why they believe they saw their outcomes (i.e., what variables affected their outcome). In a class discussion, students will continue to brainstorm ideas about reasons for why they believed their reactions did or did not generate enough energy to meet their temperature requirement. Refer back to the 'Generate Reasons List' that you created in Reaction I. Now students should pursue the idea that more is better. This will include "an increase in mass will increase the amount of temperature change" or that "an increase in solvent will increase the amount of temperature change." Also, by the end of the class today, students will have decided the most appropriate way to test their ideas.

Thinking Ahead

In what ways does the task build on students' previous knowledge? What definitions, concepts, or ideas do students need to know in order to begin to work on the task? What are all the ways the task can be solved?

This task is designed to build on students prior experiences in Reaction I and to provide students with an opportunity to engage in these activities and to develop their skills further. Students should be familiar with the task, first brainstorm ideas, second consider those ideas more closely, and third, determine a single idea to test. In addition, students will have gained a wealth of knowledge about what constitutes a good experimental design and test. Thus students should have many thoughts about how to test their ideas that they can contribute to the discussion. Students learned that matter is made up of particles in Reaction I. Use their experiences with particles to get them to think about how more matter is related to an increase in particles, and how having more matter might influence the outcome. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

Again, you should encourage students to share and express a wide variety of ideas. As you begin to narrow down ideas, push students to clarify and support their ideas with evidence (e.g., data from previous trials or tests). As students suggest a reason, ask them to provide evidence for their reason, and to suggest variables that could be manipulated or controlled to test this idea. Encourage students to provide as much detail and support for their ideas as possible. Note, students may be inclined to voice reasons based on what they learned in Reaction I. This is a great place to start, but push them to think more deeply about the idea that they will test in the next lesson. **What do you expect to hear your students saying that lets you know that students understand and are engaged with the task?**

Supporting Student Engagement

During the class discussion, encourage all teams, and individual students within the teams, to share their ideas. It may be valuable to remind students of the 'ground rules' you set as a class during Reaction I when you had a similar discussion. Encourage constructive criticism of ideas, for the purpose of improving the ideas rather than just dismissing them. **What other strategies can you use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What does more mass mean?
- How would an increase in mass affect the particle interactions?
- How does having more particles influence the outcome?
- How is testing "x" idea different from the test you conducted in Reaction I?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

The science learning goal for today is to build on the ideas from the Reaction I Subsystem. Before the discussion today, students should recognize that observed temperature changes in their systems, are related to the interactions of particles, resulting in a transformation (reaction). In addition, students should see that the composition of particles determines how they interact with each other and whether there will be a transformation.

Through the discussion today, students should begin to think about how an increase in mass reflects more particles, producing more interactions and more temperature change. There will be multiple opportunities to assert the key concept for today's lesson. For example, students may say things such as "more is better." Students may think that if they have used NaCl and did not see a temperature change, then perhaps adding more NaCl will produce different results. Additionally, students may think that an exothermic reaction will get hotter if they add more chemicals.

When the discussion gets to the point where you are beginning to think about the best ways to test their ideas, you should not dictate how students should design their experiments. However, you might remind students about experimental design in general. As a class, determine what molar amounts of each chemical will be tested. Agree with the students that reactants with masses greater than 20g will be tested by you (the teacher) because of the cost.

What do you think you will see or hear that lets you know students in the class understand the scientific ideas that you intended for them to learn?

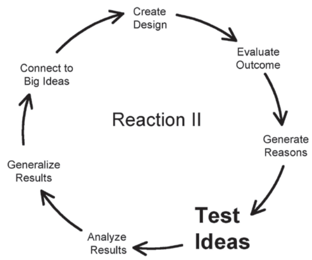
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will test the idea(s) that they generated in this lesson.

Journal Space

Reaction II. Lesson 4: Test Ideas



The lesson overview
Lesson Time: 2 days

Lesson Goal(s)

Students will test how their ideas might be responsible for the outcomes they observed

Student Activities

- Complete CSI II: *Considering Mass & Volume* [60 min.]

Materials

- *CSI II: Considering Mass & Volume* (handout)
- *Considering Mass* (p. 45)
- *Collecting Your Mass Data* (p. 46)
- *Considering Volume* (p. 47)
- *Collecting Your Volume Data* (p. 48)
- *Chemical Sheets*
- *MSDS Sheets*
- *Periodic Table*
- Balance
- Thermometers
- Small scoop or spatula
- Graduated cylinder or 10ml syringe
- Condiment cups
- Chemicals

Big Idea

- Energy released / absorbed during transformations is dependent on the mass and temperature of the system

Implementing This Lesson

In today's lesson, students will complete *CSI II: Considering Mass & Volume*. In this *CSI,* students will explore how mass and volume affect temperature changes in their system. **Note: Most likely, this lesson will take 2 class periods.**

Thinking Ahead

In what ways does this task build on students' prior knowledge?

This task builds on students prior knowledge about conducting good experiments. It gives students a chance to explore their conception of 'more is better'. Students will have the idea that more mass will result in more temperature; this idea correct, but only to a certain extent. Students might believe that if they double the mass, then it will result in a doubling of the temperature change; this idea is incorrect. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

Do not provide students with too much background information about the concepts they will encounter as they engage in this task. Rather, let students bump up against some of these difficult concepts before providing guidance. Your role is to facilitate the procedural aspects of the task. The conceptual aspects should be discussed with students in small groups or during a class discussion. **What will you hear that lets you know that students understand and are engaged with the task?**

Supporting Student Engagement

Students will complete this task in their teams. Now that teams have spent a significant amount of time working together, they should have worked out a system within their team for completing group activities. There is enough work involved in this CSI for each team member be engaged throughout the majority of the task. Expect students to be more proficient at measuring and collecting temperature data, because they have practiced these skills in the unit. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Overview (continued.)

Key Concept(s)

- An increase in mass results in more particle interactions, and consequently increases the energy of the system

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What trends did you notice?
- What happens when you add more mass? Is that the same as when you increase the volume?
- What is happening to the particles in your reaction?
- If you continue to add more will your temperature change continue to increase?
- How can you use this information for your design?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will analyze the data they collected during this lesson.

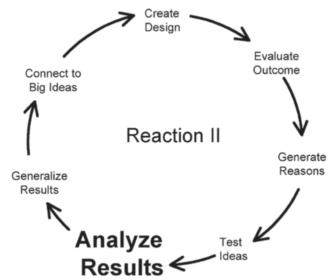
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections, or form a generalization?

Students could conduct additional tests using displacement or double displacement chemical reactions (or other reaction types). The results of these tests can be used to introduce students to limiting reagents.

Journal Space

Reaction II. Lesson 5: Analyze Results



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will plot their data and interpret their results using graphical formats

Students will evaluate whether their data support the idea they tested

Student Activities

- Analyze Results [20 min.]
- Prepare for Presentations [10 min.]

Materials

- *Analyzing Your Mass Data* (p. 49)
- *Analyzing Your Volume Data* (p. 50)
- *CSI II: Considering Mass & Volume* (handout)
- *Considering Mass* (p. 45)
- *Collecting Your Mass Data* (p. 46)
- *Considering Volume* (p. 47)
- *Collecting Your Volume Data* (p. 48)
- Graph transparencies (p. 51-52) & markers

Big Idea

- Energy released / absorbed during transformations is dependent on the mass and temperature of the system

Key Concept(s)

- The mass of a reactant affects the change in temperature (ΔT) of the system

Implementing This Lesson

Today, students will analyze their results. Students will need to make graphs to represent their data, and use those graphs to draw conclusions about whether their data support their initial hypotheses. By the end of this lesson, students should realize that the amount (mass) of reactants affects temperature changes the change in their system. They may realize that all reactions have only a specified amount of energy associated with them.

Thinking Ahead

In what ways does this task build on students' prior knowledge?

This task helps students build on their prior knowledge about graphing and particle interactions (i.e., adding more mass [particles] to a system). Students should understand important concepts for graphing (e.g., independent and dependent variables). Students may make typical graphing errors such as mixing up the axes. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

Give students clear goals and expectations for the task, but do not want to tell them what they should think. For example, students should determine for themselves how to plot their data (i.e., on the correct axes). As a facilitator, you should wander around the classroom monitoring student progress on this activity. If necessary, a class discussion might be utilized to highlight the different ways that students represent their data, and the best ways to represent these data.

In addition, students should discover what is the same and what is different between varying mass and varying volume. Rather than telling students about the concept of limiting reagents, students should be able to see from their data that adding mass or volume increases the temperature change, but only to a point. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Students will complete this task in their teams. Because each student will be responsible for constructing their own representation of the data (graph), all students should be engaged with the task. If a student has difficulty beginning this task, then direct him/her to review the graph that he/she made while completing Reaction Subsystem. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Overview (continued.)

- All reactions have a specific maximum amount of energy

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What happens when you add more mass? Is that the same as when you increase the volume?
- What happened to the particles in your reaction?
- If you continue to add more will your temperature change continue to increase?
- Is the amount of energy released or absorbed related to the amount of reactants added?
- What happened to the reactants during the reaction?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will create general statements about how their data relate to the ideas they discussed during Generate Reasons.

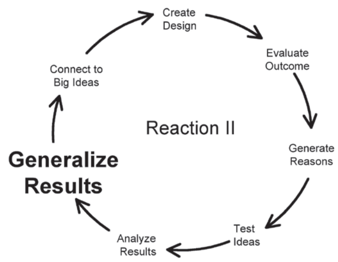
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections, or form a generalization?

Students could conduct additional tests using displacement or double displacement chemical reactions (or other reaction types). The results of these tests could be used to introduce students to limiting reagents.

Journal Space

Reaction II. Lesson 6: Generalize Results



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will draw conclusions about the data

Student Activities

- Team Presentations [10 min.]
- Class Think Time: Generalize Results [20 min.]

Materials

- *Generalizing Your Data* (p. 53)
- Graph transparencies & markers

Big Idea

- Energy released / absorbed during transformations is dependent on the mass and temperature of the system

Key Concept(s)

- Increases / decreases in mass are not directly proportional to increases / decreases in temperature
- Changes in temperature are directly proportional to changes in energy

Implementing This Lesson

Today, you will facilitate the class discussion by encouraging students to generalize the results of their individual experiments addressing the question "what trends or patterns do you notice in your data?"

Thinking Ahead

In what ways does this task build on students' prior knowledge?

This lesson builds on students prior experiences generalizing results during the Reaction I Subsystem. This task is designed to build on those prior experiences and to provide students with an opportunity to engage with these new activities to develop their skills further. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

Start today's lesson thinking about the data that students have collected. Ask students to present the results from the CSI. Students will present their Temperature Change Graph transparency to illustrate the trends in their data. Their presentation should include the reactions that they tried, the molar amounts that they used, and the resultant temperatures that they observed.

As a class, identify patterns in the data across various CSI investigations and draw conclusions about those patterns. As students see the results from other teams, then they will be able to see how their own data are the same or different from other investigations. By the end of the discussion, students should realize that mass is not directly proportional to increases/decreases in temperature. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Encourage all teams, and all students within each team, share their ideas and to participate during the team presentations and the class discussion. If you have set 'ground rules' for previous class discussions, then you should remind students about these ground rules before you start this discussion. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What happens when you add more mass? Is that the same as when you increase the volume?
- What happened to the particles in your reaction?
- If you continue to add more, will your temperature change continue to increase?
- Is the amount of energy released or absorbed related to the amount of reactants added?
- How is the amount of energy released or absorbed related to temperature?
- What happened to the reactants during the reaction?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

Each team should present their data during the first part of the class. Each team does not need to present each data point. Instead, students should plot the general trend of their data on a transparency. Each group should use a different colored marker, so that you can overlay each teams graph at the same time. Presenting all team data at once will allow for students to see clearly that their individual data fits a trend that generalizes across all groups data.

There are a number of science learning goals for today that have been built up to through students' experiences in previous lessons. The discussion during this lesson should align with the two key concepts. Through the discussion, students should recognize that increases/ decreases in mass are **not** directly proportional to increases/decreases in temperature. In addition, students should recognize that changes in temperature **are** directly proportional to changes in energy. During the discussion, use the questions in the Team Guide to press students' reasoning forward and to connect students' ideas to the appropriate scientific terms. **What do you think you will see or hear that lets you know students in the class understand the scientific ideas that you intended for them to learn?**

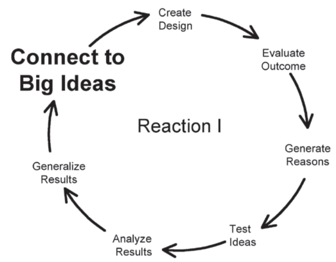
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will connect their generalized results conclusions to the big idea that energy released or absorbed during transformations is dependent on the mass and temperature of the system.

Journal Space

Reaction II. Lesson 7: Connect to the Big Idea



Overview
Lesson Time: 2 days

Lesson Goal(s)

Connect students general ideas to scientific ideas about energy

Student Activities

- Read *Now That You've Thought About It ...* [5 min.]
- Class Discussion: Temperature and energy changes in the system [20 min.]
- Complete *Energy Problems* [30 min.]
- Homework: *Reflection III*

Materials

- *Now That You've Thought About It ...*(p. 54)
- *Energy Problems* (p. 55)
- *Reflecting on Your Thinking* (p. 56)

Big Idea

- Energy released / absorbed during transformations is dependent on the mass and temperature of the system

Key Concept(s)

- Review all previous key concepts to get to the big idea

Implementing This Lesson

In today's lesson, you will facilitate a class discussion that guides students see the connection between their generalized results and the big idea that Q of a system is dependent upon mass and the temperature change of a system. At the end of the discussion, students will use this idea to calculate Q for their own reaction. In addition, students will identify calculate the energy released or absorbed by various systems. Understanding this big idea can help students determine how to design their H/C systems by thinking about how mass and temperature relates to the energy released or absorbed by their system.

Thinking Ahead

In what ways does this task build on students' prior knowledge?

This task builds on the knowledge students have learned throughout this subsystem. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

Learning is most effective when students have experiences that they can connect with new information. Start today's discussion with students' experiences with the CSIs and build on those experiences to get students to see the Big Idea. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

In this lesson students will work in teams to complete their assigned energy problems, and then present their results to the class for discussion. Encourage students to work as a team to solve their assigned energy problem, ensuring that every team member understands their teams' solution. If teams finish their assigned problem quickly, encourage them to attempt to solve additional problems. During the class discussion, remind students that the goal of the discussion is to engage with constructive criticism of ideas in order to improve the ideas and everyone's understanding. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- How is the mass of the reactants in the system related to the energy released or absorbed?
- How is mass of the reactants in the system related to temperature changes?

- How is the amount of energy released or absorbed related to temperature?
- How does the mass of reactants change during the transformation?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

At this point in the unit, you want students to begin to focus on what the trends and patterns mean in terms of the energy in their system. In this lesson you will introduce the mathematical equation $Q = mc\Delta T$. You might introduce this equation by stating that this is an equation that scientists use, and often 'Q' is a value that is derived experimentally. However, this equation determines a theoretical value.

This discussion is builds on the key concepts that students have learned in this subsystem; that is that mass and temperature changes are directly proportional to energy changes. With the introduction of $Q=mc\Delta T$, you will have to introduce 'c'. Simply state that for their systems 'c' can be thought about as a property of water and it is an experimental constant. **What do you think you will see or hear that lets you know students in the class understand the scientific ideas that you intended for them to learn?**

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will use the Big Idea to improve their design.

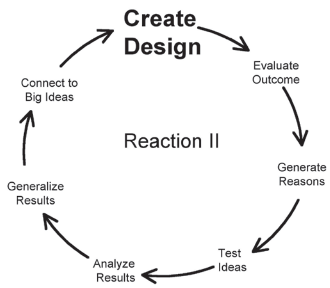
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections, or form a generalization?

Challenge your students to think about how specific heat and/or heat capacity might work in their system.

JOURNAL SPACE

Reaction II. Lesson 8: Create Design



Overview
Lesson Time: 1 day

Lesson Goal(s)

Based on their findings from Reaction I and II, students will select and test new reactions for their final design

Student Activities

- Test and select reaction for final design [30 min.]

Materials

- *Selecting Your Reaction Subsystem* (p. 57-58)

Big Idea

- Energy released / absorbed during transformations is dependent on the mass and temperature of the system
- Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation.

Key Concept(s)

- Review all previous key concepts from Reaction I and Reaction II

Implementing This Lesson

Today, students will test and select the reaction that will be part of their final design. Using the knowledge that they have gained from both Reaction I and Reaction II, students will create a reaction that meets their requirements.

Thinking Ahead

In what ways does the task build on students' previous knowledge? What definitions, concepts, or ideas do students need to know in order to begin to work on the task?

This task builds on the experiences students have had throughout the Reaction I and Reaction II Subsystems, and allows them to synthesize this new knowledge by using it to create their design. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so that the demands of the task are not reduced? That the goals and expectations are clear? That the students are likely to engage important scientific ideas or practices?

While students are engaged with this activity you should expect to hear them refer back to some of the ideas that they learned during Reaction I and Reaction II (e.g., anion and cation size; $q = mc\Delta T$) and use these ideas to make informed decisions about what reactions to try next. **What will you hear that lets you know students understand the task?**

Supporting Student Engagement

How will the students work independently, in small groups, or in pairs? How will you ensure that students remained engaged with the task? What are your expectations for students as they work on and complete this task?

For this task students will work in their design teams to determine which reactions they would like to try. All students should be actively engaged and contributing to the completion of this task. Now that teams have spent a significant amount of time working together, they should have worked out a system within their team for completing group activities. However, it may be helpful to remind students about effective group work strategies (e.g., the division of tasks; rotating team roles, etc.). **What other strategies can you use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- Why do you want to use that reaction for your design?
- How are you using what you learned in the last few days to improve your design?
- Remember the CSIs? What did those results say that could help you improve your design?
- How has your design improved since you started?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

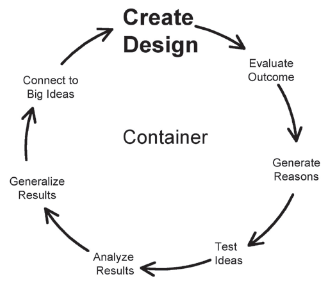
In the next lesson, students will begin to consider the Container Subsystem.

Journal Space

When you complete your journal entry, consider the following questions:

- What were the students' reactions to the lesson?
- What could you do next time to make this lesson more successful?
- Is there any additional information that would have been useful?
- Is the timing appropriate?
- What are your general comments?

Container. Lesson 1: Explore the Container Space



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will organize the container materials by their properties

Student Activities

- Read *Container Subsystem* [2 min.]
- Categorize container materials [20 min.]
- Class discussion: Container groupings [10 min.]

Materials

- *Container Subsystem* (p. 59)
- *Container Categorization* (p. 60-61)
- *Material Sheets*
- Container material samples

Big Idea

- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions

Key Concept(s)

- The container is made up of particles that have unique composition which determines how they interact with the environment

Implementing This Lesson

Today students will begin to explore the materials available for their design, and consider issues related to the Container Subsystem. To help students begin to understand the key concept for the day, students will complete a categorization activity similar to the categorization activity in the Reaction I Subsystem. After students complete the categorization task, you will facilitate a class discussion to highlight the key points.

Thinking Ahead

In what ways does this task build on students' prior knowledge?

This task will build on students prior knowledge that chemicals are made up of particles and that each chemical is a unique combination of particles. This activity will help students extend their understanding of this concept from the Reaction Subsystems to realize that these ideas apply to all matter. Students may need some clarification of the terms included on the *Material Sheets* (e.g., heat capacity).

Students can solve this task in many ways, categorizing materials on a number of dimensions (e.g., heat capacity; structure; thermal conductivity, etc). No one way is correct. Rather this is an opportunity for students to explore the similarities and differences between the container materials. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

When introducing students to the task, encourage them to take some time to examine the *Material Sheets*, thinking about what may be the same or different across materials. Do not provide too many explanations about what terms mean. Encourage students to try many different ways of categorizing their cards, focusing on the dimensions outlined in the cards.

While students are engaged with the task, you should hear them discussing the various dimensions on *Material Sheets* and grappling with the ideas related to these dimensions. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Students will work in their teams for this activity. To ensure that students remain engaged with the task, encourage all students to express their ideas and try to explore the connections between the different materials. Students should explore various ways of categorizing the different materials. If students are have difficulty beginning the task, then encourage them to focus on a particular feature of the materials (e.g., thermal conductivity). **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of**

questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?

Below are some questions that may be appropriate:

- What similarities do you notice between the different materials?
- What differences do you notice between the different materials?
- Are there elements that are the same across samples? How are these samples similar? Different?
- How are these materials similar to the chemicals you have been using? Different?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your learning goals?

The goal of this discussion is for students to share how they grouped their container materials. Different teams will have different groupings. Once these groupings have been shared, students can discuss how their groupings are the same and/or different from other teams' groupings. Throughout this discussion, use the teams' groupings to highlight the idea that the container materials are made up of a unique set of particles. **What do you think you will see or hear that lets you know students in the class understand the scientific ideas that you intended for them to learn?**

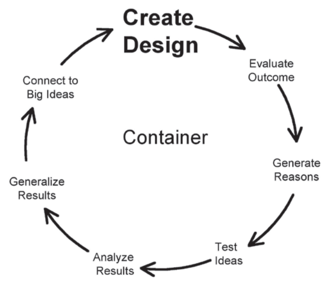
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will build upon what they have discovered today, using this new knowledge to help guide them in their decisions about what materials will work best for their design.

Journal Space

Container. Lesson 2: Create Design



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will create designs that will allow energy to transfer between target object and environment

Student Activities

- Conduct trials of container groupings [30 min.]

Materials

- *Experimenting with Containers* (p. 62)
- Kettle or Hot Plate
- Ice

Big Idea

- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions

Key Concept(s)

- Conduction is the mechanism by which energy is transferred when two objects are in contact
- Energy transfers from particles with more kinetic energy to particles with less kinetic energy

Implementing This Lesson

Today students will explore the various container materials using hot or cold water to simulate the temperature of their reactions. Students will take qualitative measures of how well the various container materials allow for the transfer of energy between their reaction and the object they desire to heat or cool. In essence, students will be testing their ideas about how the properties of different materials influence how they behave (i.e., how well they allow for the transfer of energy; how well they conduct energy). By the end of today's lesson, students will have a better sense of how materials influence the transfer of energy.

Thinking Ahead

In what ways does this task build on students' prior knowledge?

Students will have had some previous experience with the transfer of energy based on their own life experiences. Students may have some prior understanding of conduction; kinetic energy; and/or potential energy. Students may solve the task in may different ways, basing their decisions about which materials to test with their reactions on their prior experience and their categorization activity.

Students may have some misconceptions about 'hot' and 'cold' energy and the direction that energy transfers. Rather than thinking that energy transfers from areas of high energy to low energy students may think of energy as distinctly 'hot' energy and 'cold' energy and that they both transfer to opposite areas until equilibrium is reached. Students may also have misconceptions about insulators versus conductors, either confusing the two terms or not understanding that they are representative of a continuum. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

This should be a time where students are able to explore their ideas freely and design their own investigations for how to determine which material will work best for their design. The goal of today's task is for students to investigate how different materials allow them to transfer energy between their reactions and their target object. You will know that students understand this task if you hear them talking about different ways to manipulate the materials that promotes more efficient transfer of energy between their reaction and their object. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Students will complete this task in their teams. Teams can divide up the work so that they complete more tests in the time provided. Students should be expected to complete all their testing in this one class period, and to begin to develop some ideas about how materials differently affect energy transfer via conduction. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What were your results?
- Were your groupings useful for meeting your requirement? For understanding the materials?
- What do you think your results say about the materials that you tested?
- What direction is energy flowing in your system? What variables drive the flow of energy?
- Is the energy that was transferred between the water and the object the same or different as the energy that was in each system? Would the same be true if energy transfer between your reaction and the object?
- Where did the energy that is transferred come from?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

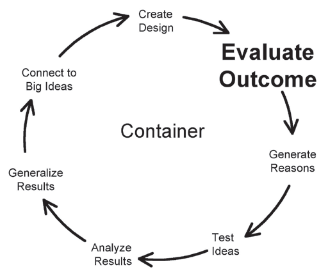
In the next lesson, students will evaluate their outcomes from this lesson. The key concepts will be covered in greater depth during the next lesson.

When you complete your journal entry, consider the following questions:

- What were the students' reactions to the lesson?
- What could you do next time to make this lesson more successful?
- Is there any additional information that would have been useful?
- Is the timing appropriate?
- What are your general comments?

Journal Space

Container. Lesson 3: Evaluate Outcomes



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will articulate the outcome of their trials in terms of their requirement

Students will connect their outcome to possible chemical ideas that may affect it

Student Activities

- Evaluate Outcomes [10 min.]
- Class Discussion: *Evaluate Outcomes* [20 min.]
- Homework: *Individual Think Time*

Materials

- *Evaluating Your Trials* (p. 63)
- Homework: *Individual Think Time: Generate Reasons* (p. 64)

Big Idea

- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions

Key Concept(s)

- Conduction is the mechanism by which energy is transferred when two objects are in contact
- Energy transfers from particles with more kinetic energy to particles with less kinetic energy

Implementing This Lesson

In today's lesson, students will evaluate the outcomes of their trials by completing *Evaluating Your Trials* and addressing the question "Did the selected material allow for sufficient energy transfer?" Students will share their results with the class allowing students to compare their results with other teams and providing them insight about how the container materials behaved under different conditions.

Thinking Ahead

In what ways does this task build on students' prior knowledge?

This task builds on students prior knowledge about insulators and conductors and the various properties of materials. This task allows students to express all their prior knowledge and what they observed while trying to solve the design challenge of finding a container material that would allow for energy to transfer. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

As students present their results, encourage them to link their hypothesis with their outcomes. For example, one team may have decided that Styrofoam would allow significant energy transfer. When discussing their findings, teams should state their hypothesis (e.g., "Styrofoam would allow the greatest energy transfer") and the outcome they observed (e.g., "it seemed that there was little or no energy transfer when Styrofoam was used"). **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Initially, students will work in teams to evaluate the outcomes of their trials. Next, students will engage in a class discussion. Encourage all students/ teams to share their ideas so that everyone in the classroom is engaged. Students should actively participate in the discussion and contribute to the development of class-level knowledge about how different materials affect energy transfer. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- Did you meet your requirement? What is your evidence?

- What do you think your results say about the materials that you tested?
- What do you think are the properties of the material for allowing energy transfer?
- What direction does energy flow in your system? What variables drive the flow of energy?
- Is the energy that was transferred between the water and the object the same or different as the energy that was in each system? Would the same be true if energy transferred between your reaction and the object?
- Where did the energy that is transferred come from?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

The science learning goal for today is for students to begin to see what happens at the microscopic level when energy transfers between materials. That is, particles interact with each other and energy transfers from particles with more kinetic energy to particles with less kinetic energy.

At the beginning of the class discussion, teams should present their data (very quickly). This presentation of data should include a discussion of the reasons for testing the materials, the hypothesis they were testing. It may be helpful to have students state the specific methods that they used to test their materials and the results of those trials. **What do you think you will see or hear that lets you know students in the class understand the scientific ideas that you intended for them to learn?**

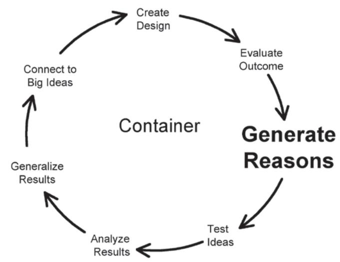
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will start to focus on the scientific reasons that can be used to explain the results they observed.

Journal Space

Container. Lesson 4: Generate Reasons



The lesson overview
Lesson Time: 1 day

Lesson Goal(s)

Students will generate ideas for reasons for their observed temperature changes

Students will brainstorm ways to test their reasons for the outcome

Student Activities

- Team Discussion: Review *Individual Think Time* [5 min.]
- Class Think Time: Generate Reasons [15 min.]
- Class Discussion: Determine how to test ideas [10 min.]

Materials

- *Individual Think Time: Generate Reasons* (p. 62)
- *Generating Reasons for the Outcomes (p. 65)*

Big Idea

- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions

Key Concept(s)

- Thermal conductivity is the transfer of kinetic energy by conduction
- Thermal conductivity is a unique property of a material

Implementing This Lesson

Today is the class discussion for Generating Reasons. Students will articulate their ideas for why they believe that the different materials allowed or did not allow effective transfer of energy between their system and their target object. By the end of this discussion, the class should come to a consensus about which idea (reason) they want to test systematically in the next lesson. Steer your students towards testing the idea that thermal conductivity is an important factor that will have the most implications for their designs. Once the class has come to a consensus about the idea to test, the discussion should turn briefly to considering how best to test that idea (e.g., what is a good test?).

Thinking Ahead

In what ways does this task build on students' prior knowledge?

This task builds on students prior knowledge about how to generating reasons and about insulators and conductors. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

Remind students that the purpose of the Generate Reasons discussion is to consider a variety of ideas after all of the ideas have been shared, then they can evaluate the ideas to decide which one to test during the next lesson. Also, remind students that it is important to get to the core of the ideas, by expanding defining and clarifying each one. Finally, decide which idea will be most useful to improve the designs. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

This will be a whole-class discussion. Encourage all teams and students to share their ideas. Do your best to engage students who do not participate typically in class discussions. Students should question each other so that ideas can be clarified. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- How do you think energy is transfers between materials?
- Is the energy that is transferred the same or different as the energy that was part of the reaction?
- Where does the energy that is transferred come from?
- What do you think your results say about the materials that you tested?
- What do you think are the important properties of a material that relate to how well or poorly it allows for the transfer of energy?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

Through the discussion today, students should begin to think about thermal conductivity as a unique property of matter. In addition, students should start to think about thermal conductivity as the concept that describes the transfer of kinetic energy through conduction. It may be effective to encourage students to think about their everyday experiences with different types of materials. For example, when a piece of metal and a piece of wood are placed in a refrigerator only the metal feels cold.

By the end of this discussion, the class should come to a consensus about which idea (reason) they want to test systematically in the next lesson. Steer your students towards testing thermal conductivity.

When the discussion gets to the point where you are beginning to think about the best ways to test their ideas, do not dictate how they should perform their test. However, you may need to remind students about experimental design in general. **What do you think you will see or hear that lets you know students in the class understand the scientific ideas that you intended for them to learn?**

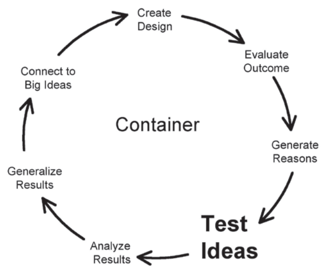
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will test the idea(s) that they generated in this lesson.

JOURNAL SPACE

Container. Lesson 5: Test Ideas



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will test how their ideas might be responsible for the outcomes they observed

Student Activities

- Complete: CSI: *Conductivity & Insulation* [30 min.]

Materials

- *CSI: Conductivity & Insulation* (handout)
- *Systematically Testing Your Ideas* (p. 66)
- Conductometer
- Timer/stopwatch
- Calorimetry materials

Big Idea

- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions.

Key Concept(s)

- Thermal conductivity is the transfer of kinetic energy by conduction
- Thermal conductivity is a unique property of a material

Implementing This Lesson

Today students will complete the CSI: Conductivity. The goal of today's CSI is that students will conduct a thermal conductivity experiment to calculate the relative thermal conductivities and insulation abilities of the container materials.

Thinking Ahead

In what ways does this task build on students' prior knowledge?

Students should have some preconceived ideas about which materials will best conduct or insulate energy. This CSI will help them systematically test these notions. Any misconceptions related to this CSI would likely relate to ideas about which materials are better insulators or conductors. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

Do not provide students with too much background information about the concepts they will be encounter during this task. Rather, let students bump up against some of these difficult concepts before providing guidance. Your role is to facilitate the procedural aspects of the task. The conceptual aspects should be discussed with students in small groups or during a class discussion. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Students will complete this task in their teams. Now that teams have spent a significant amount of time working together, they should have worked out a system within their team for completing group activities. There is enough work involved in this CSI for each team member be engaged throughout the majority of the task. Expect students to be more proficient at measuring and collecting temperature data, because they have practiced these skills in the unit. All students should be actively engaged and contributing to the completion of this task. Teams should focus on using good experimental procedures to ensure that they collect accurate data. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- Why do you think your results are different for the different materials?
- What do yo think is happening to the particles in each material as you heat them? Cool them?

- How do you think energy transfers between materials?
- What do you think your results say about the materials that you tested?
- What do you think are the important properties of a material that relate to how well or poorly it allows for the transfer of energy?

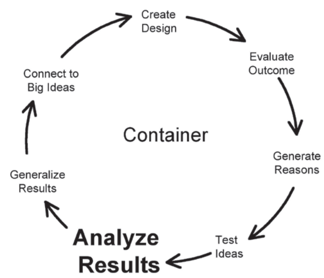
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will analyze the data they collected during this lesson.

Journal Space

Container. Lesson 6: Analyze Results



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will plot their data and interpret their results using graphical formats

Students will evaluate whether their data support the idea they tested

Student Activities

- Analyze Results [20 min]
- Prepare for Presentations [10 min.]

Materials

- *Analyzing Your Data* (p. 67)
- Graph transparencies & markers

Big Idea

- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions.

Key Concept(s)

- Thermal conductivity is a unique property of a material

Implementing This Lesson

Today students will analyze the results of the data they collected yesterday during their CSIs. First, students will plot their data. Next, students will interpret the graphs and draw conclusions about whether the data supported their hypothesis. By the end of this task, students should recognize that thermal conductivity varies across different materials; it is a unique property of matter. In addition, students should recognize that insulators are materials that are not good conductors.

Note: If you finish this lesson early, then you should start the activities in the next lesson.

Thinking Ahead

In what ways does this task build on students' prior knowledge?

This task allows students to use the graphing skills that they have developed through experience during the Reaction Subsystems. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

Try not to take the challenge away from the students by telling them how to plot their data. Encourage them to think about what they already know about dependent and independent variables and how they should be plotted on the graph. When students begin to interpret their data you should hear them discuss the values they recorded when they conducted the experiment and whether those values indicate more or less conductivity. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

For this activity, students should each complete their own graph. However, they can work with their team members to do so. This will ensure that all students are engaged with the task, and are given the opportunity to develop their graphing skills. If students have difficulty beginning the task, encourage them to review the other graphs that they have created as part of this unit to see if those graphs help them get started. They should also talk with their teammates about how best to proceed. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What are the trends on the graph?
- What do the trends on the graph represent?

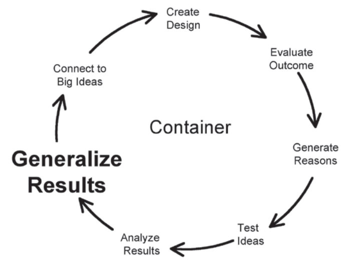
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will create general statements about how their data relate to the ideas they discussed during Generate Reasons.

Journal Space

Container. Lesson 7: Generalize Results



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will draw conclusions about the data

Student Activities

- Team Presentations [10 min.]
- Class Think Time: Generalize Results [20 min.]

Materials

- Graph transparencies & markers
- *Generalizing Your Data* (p. 69)

Big Idea

- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions

Key Concept(s)

- The mass and structure of a substance affects its ability to transfer energy between adjoining atoms
- Substances that transfer energy quickly are called conductors
- Substances that transfer energy slowly are called insulators

Implementing This Lesson

Today you will facilitate the class discussion by encouraging students to generalize the results of their individual experiments and addressing the question "what trends or patterns did you notice in your data?" Throughout this discussion, you should draw students attention to how the properties of materials influence whether they are insulators or conductors and how the mass and structure of a substance affects its ability to transfer energy via conduction.

Thinking Ahead

In what ways does this task build on students' prior knowledge?

This task will build on students previous knowledge by tapping into their previous conceptions about what materials are good insulators or conductors. Students need to understand about the kinetic motion of particles before beginning this task before they will see how conduction works to transfer energy quickly. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

Start today's lesson thinking about the data students have collected. Ask students to present the results from their CSI. As a class, identify patterns in the data across various CSI investigations and draw conclusions about those patterns. As students see the results from other teams, they will be able to see how their own data are the same or different from other investigations. By the end of the discussion, students should realize that the mass and the structure of a substance affects its ability to transfer energy between adjoining atoms. **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

This lesson will be a class discussion. To encourage students to remain engaged, invite all teams to share their results, analyses, and ideas about what their data might mean. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- How might the data trends help you improve your design?
- What are the trends on the graph?
- What do the trends on the graph represent?
- How does energy transfer through conductors? Insulators?
- How do you think the structure of materials influences whether they are conductors or insulators?

- What type of material, conductor or insulator, might be best for your design? Why?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

Start this lesson with very brief presentations of each team's data. Each team does not need to present each data point. Instead, students should plot the general trend of their data on a transparency. Each group should use a different colored marker, so that you can overlay each teams graph at the same time. Presenting all team data at once will allow for students to see clearly that their individual data fits a trend that generalizes across all groups data.

There are a number of science learning goals for today that have been built up to through students' experiences in previous lessons. The discussion during this lesson should align with the three key concepts for this lesson. Through the discussion, students should recognize that conductors are materials that have high thermal conductivities and easily allow for energy transfer; insulators have low thermal conductivities and do not allow for the transfer of energy. The ability of a material to transfer energy between adjoining atoms depends on the mass and structure of that material. During the discussion you may want to use the questions in the Team Guide to press students' reasoning forward and to connect students' ideas. **What do you think you will see or hear that lets you know students in the class understand the scientific ideas that you intended for them to learn?**

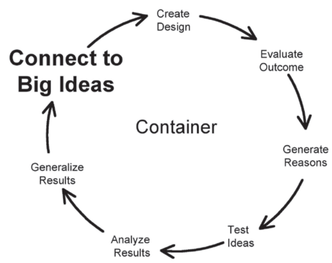
Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will connect conclusions to the big idea that energy transfers from particles with higher kinetic energy to particles with lower kinetic energy through collisions.

Journal Space

Container. Lesson 8: Connect to the Big Idea



Overview
Lesson Time: 1 day

Lesson Goal(s)

Connect students generalized ideas to scientific ideas about energy transfer

Student Activities

- Read *Now That You've Thought About It ...* [2 min.]
- Complete *Energy Transfer Problems* [20 min.]
- Class Discussion: Wrap Up [10 min.]

Materials

- *Now That You've Thought About It ...* (p. 68)
- *Energy Transfer Problems* (p. 70)

Big Idea

- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions

Implementing This Lesson

Today you will reinforce the ideas encountered already in this subsystem and tie them all together to help students recognize that energy transfer/flow always goes from regions of high kinetic energy to areas of lower kinetic energy through particle collisions. Help students see the connection between this big idea and conduction and insulation; these properties, and the property of thermal conductivity can be explained by this one big idea. This big idea can help students determine how to design their systems by thinking about the types and arrangement of material that will best meet their requirements.

Thinking Ahead

In what ways does this task build on students' prior knowledge?

This task builds on the knowledge students have learned throughout this subsystem. Students should have a good understanding of the kinetic motion of particles; conduction; insulators; particles and energy. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

Learning is most effective when students have experiences that they can connect with new information. Start today's discussion with students' experiences during the CSIs and build on those experiences to get students to see the Big Idea. Students should complete the Energy Flow Practice Problems without preempting their thinking. **What might you expect to hear that lets you know that students understand and are engaged with the task?**

Supporting Student Engagement

In this lesson, students will work in teams to complete their assigned energy problems and present their results to the class for discussion. Encourage students to work as a team to solve their assigned energy problem, ensuring that every team member understands their teams' solution. If teams finish their assigned problem quickly, encourage them to attempt to solve additional problems. During the class discussion, remind students that the goal of the discussion is to engage with constructive criticism of ideas in order to improve the ideas and everyone's understanding. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Below are some questions that may be appropriate:

- What direction does energy flow?
- How does energy transfer between different materials/ substances?
- How does understanding the direction of energy flow help you improve your design?

Facilitating Discussion

How will you orchestrate the class discussion so that you accomplish your science learning goals?

At this point in the unit, you want students to begin to focus on what the trends and patterns mean in terms of the how energy will transfer in their system. Students will complete the energy transfer problems in their teams and share their solutions with the rest of the class. You may find that the discussion will be more productive if you order the presentations strategically, so that students can build on each other's ideas and solutions. **What do you think you will see or hear that lets you know students in the class understand the scientific ideas that you intended for them to learn?**

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will construct their design.

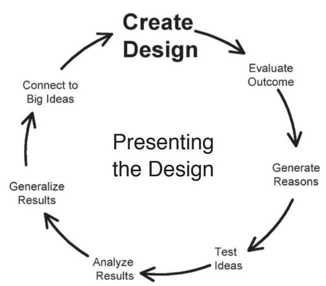
Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections, or form a generalization?

Challenge students to think about how particle arrangement and the space between particles influence how well a material conducts or insulates.

Journal Space

Presenting the Design. Lesson 1: Construction



Overview
Lesson Time: 1 day

Lesson Goal(s)

Students will draw sketches of their system and construct a design (model)

Student Activities

- Draw system sketches
- Construct model of design using basic materials to represent container materials

Materials

- All chemicals
- All container materials

Big Ideas

- Energy released / absorbed during transformations is dependent on the shape and structure of the particles involved in the transformation.
- Energy released / absorbed during transformations is dependent on the mass and temperature of the system
- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy through collisions

Implementing This Lesson

Today students will get to put together a model of their system. Students will create small models of their systems using basic materials (e.g., cardboard, Styrofoam, etc.) to represent other materials that they may want to use in their real system. Students can create sketches or actual models, whichever they prefer, to represent the knowledge they have gained throughout the unit.

Thinking Ahead

Students will use the knowledge they have gained in this unit to design and create a model of their system. Students' designs will vary in a number of ways; all of which are acceptable, as long as students can support their design decisions based on the scientific knowledge that they have gained (e.g., thermal conductivity of materials; energy flow diagrams; energy produced in reactions; etc). **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

While students are engaged with this activity, you should expect to hear them referring back to some of the ideas they learned during the Reaction I, and Reaction II, and Container Subsystems (e.g., anion and cation size; $Q = mc\Delta T$, etc.). **What else might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Students will complete this task in their teams. Now that teams have spent a significant amount of time working together, they should have worked out a system within their team for completing group activities.

To help students focus on the scientific aspects of the task, remind students to use their energy flow diagrams, and to create their design based on what they have learned about energy and particles throughout the unit. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Many of the questions presented earlier in the unit would be appropriate to use at this time. Below are some additional questions that may be appropriate:

- How do all of your subsystems work together so that your entire design works as you designed it?
- Does the design meet your needs and requirements?

Looking Ahead

What will you do in the next lesson that will build on this lesson?

In the next lesson, students will complete their Patent Application and prepare for their *Gallery Walk*.

Extending the Task(s)

What extensions to the task will you pose that will help students look for patterns, make connections or form a generalization?

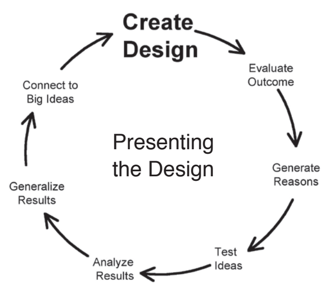
You may provide additional time for this lesson if you wish to do so.

Journal Space

When you complete your journal entry, consider the following questions:

- What were the students' reactions to the lesson?
- What could you do next time to make this lesson more successful?
- Is there any additional information that would have been useful?
- Is the timing appropriate?
- What are your general comments?

Presenting the Design. Lesson 2: Patent Application



Overview
Lesson Time: 1-2 day(s)

Lesson Goal(s)

Students should incorporate the key concepts and big ideas learned throughout this unit to complete their patent application

Student Activities

- Read *Presenting & Protecting Your Design* [2 min.]
- Class Discussion: What are patent applications [5 min]
- Prepare patent applications [1-2 class periods]

Materials

- *Presenting & Protecting Your Design* (p. 71)
- *Patent Application Guidelines* (p. 73-74)

Big Idea

- Energy released or absorbed during transformations is dependent upon the shape and structure of the particles involved in the transformation
- Energy released or absorbed during transformations is dependent upon the mass and temperature of the system
- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy

Key Concept(s)

- See all key concepts from previous lessons

Implementing This Lesson

Today, students will complete their Patent Application for their design. This patent application should describe how they developed their design, what their design does, and the science concepts underlying how their design functions. This lesson may take one to two class periods.

NOTE: This lesson may be completed simultaneously with the next lesson: Gallery Walk (please allot extra time if you decide to do both the Patent Application and preparation for the Gallery Walk simultaneously)

Thinking Ahead

In what ways does the task build on students' previous knowledge?

This task allows students to reflect and synthesize what they have learned throughout this unit. In addition, students will be able to practice their scientific writing skills. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

While students are engaged with this activity, you should expect to hear them referring back to some of the ideas they learned during the Reaction I, and Reaction II, and Container Subsystems (e.g., anion and cation size; $Q = mc\Delta T$, etc.). **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Students will complete this task in their teams. Now that teams have spent a significant amount of time working together, they should have worked out a system within their team for completing group activities. There is enough work involved in this activity for each team member be engaged throughout the majority of the task. To help students focus on the scientific aspects of the task, remind students to use their energy flow diagrams, and to create their design based on what they have learned about energy and particles throughout the unit. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

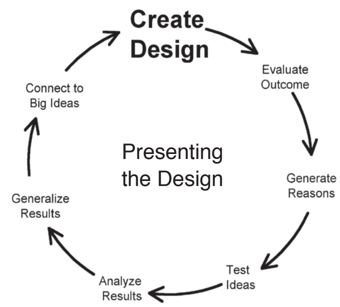
As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Many of the questions presented earlier in the unit would be appropriate to use at this time. Below are some additional questions that may be appropriate:

- How do all of your subsystems work together so that your entire design works as you designed it?
- Does the design meet your needs and requirements?
- If you had unlimited time and money, what improvements would you make to your design?

Journal Space

Presenting the Design. Lesson 3: Gallery Walk



Overview
Lesson Time: 2-3 days

Lesson Goal(s)

Students should incorporate the key concepts and big ideas learned throughout this unit to prepare their posters, and during their Gallery Walk presentations

Student Activities

- Read *Presenting Your Design* [5 min.]
- Prepare posters for Gallery Walk [1-2 class periods]
- Gallery Walk [1 class period]

Materials

- *Presenting Your Design* (p. 72)
- Gallery Walk Evaluation handouts
- Poster paper
- Poster markers
- Tape/ Sticky tack

Big Idea

- Energy released or absorbed during transformations is dependent upon the shape and structure of the particles involved in the transformation
- Energy released or absorbed during transformations is dependent upon the mass and temperature of the system
- Energy transfers from particles with high kinetic energy to particles with lower kinetic energy

Key Concept(s)

- See all key concepts from previous lessons

Implementing This Lesson

Today, students will prepare their posters for the Gallery Walk, and participate in a Gallery Walk to present their final designs. Their posters should describe how they developed their design, what their design does, and the science concepts underlying how their design functions. This lesson may take one to two class periods. NOTE: The preparation of their posters may be completed simultaneously with the previous lesson : Patent Application.

Thinking Ahead

In what ways does the task build on students' previous knowledge?

This task allows students to reflect and synthesize all that they have learned throughout this unit. In addition, students will be able to practice their scientific presentation skills in this activity. **What other ideas or knowledge do you think your students will bring to this task?**

Introducing the Task(s)

How will you introduce students to the activity so as not to reduce the demands of the task? That the goals and expectations are clear? So that students are likely to engage in important scientific ideas or practices?

While students are engaged with this activity, you should expect to hear them referring back to some of the ideas they learned during the Reaction I, and Reaction II, and Container Subsystems (e.g., anion and cation size; $Q = mc\Delta T$, etc.). **What might you expect to hear that lets you know students understand?**

Supporting Student Engagement

Before the Gallery Walk begins, teams should set up their posters around the room. Teams should divide up into pairs (or singles). One pair (or student) will act as the curator(s), while the other pair will act as the evaluator(s) for other posters. These roles will switch half-way through the Gallery Walk.

The evaluator(s) will visit two other posters. They should spend about 5 minutes at each poster, asking enough questions to be able to complete the Gallery Walk Evaluation form for each poster that they visit.

The curators present the team prototype and answer questions from the evaluator(s) from the other teams. **What are other strategies you can use to ensure that students remain engaged and focused on the task?**

Asking Assessing/Advancing Questions

As students work in their groups or participate in the class discussion, it is important that you facilitate and focus their thinking. **What kinds of questions do you think you can ask to focus their thinking? Assess or advance their understanding of key scientific ideas?**

Many of the questions presented earlier in the unit would be appropriate to use at this time. Below are some additional questions that may be appropriate:

- How do all of your subsystems work together so that your entire design works as you designed it?
- Does the design meet your needs and requirements?
- If you had unlimited time and money, then what improvements would you make to your design?

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