Studio STEM
Facilitators’ Handbook

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Studio STEM: Engaging Middle School Student in Networked Science and Engineering Projects

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Studio STEM Project web site
Http://studiostem.org

Find us on Twitter and Facebook.
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Overview of the Studio STEM Structure

Studio STEM is an after school and summer program for middle school youth in science, technology, engineering, and math education (STEM). This program is funded through the National Science Foundation and is a partnership among Virginia Tech, Temple University, and Auburn University. This program uses a technology rich context to help girls and boys learn about energy conservation.

Our primary goal is to motivate these students to develop the skills, critical knowledge, and interest in pursuing a career in STEM.

The structure of Studio STEM is based four principles:
• An interesting curriculum in energy sustainability,
• Design-based inquiry that integrates computers and technology,
• An after school design studio that fosters creativity, and
• Site leaders and facilitators who provide a caring and supportive learning environment.

Each 8-week unit consists of three components (above):
• Short demonstrations that illustrate key science concepts,
• An opportunity to work and tinker with materials, and
• Working in teams on a design problem or re-designing new solutions.

The studio uses an integrated STEM curriculum in fundamental concepts around energy resources, energy conservation, energy transfer, and sustainability. We engage youth through solving problems related to energy that impact animal populations.

The design studio is a learning environment where youth work in teams on an ill-structured problem (one without an obvious answer).
Working together in teams of 4-5 students, youth are challenged to find a novel solution to a problem related to energy transfer. Students are encouraged to think creatively, act purposefully, and communicate clearly as they design solutions.

At key moments in the design process, the Instructor (Site Leader) asks the girls and boys to pause, reflect, and record their emerging understandings on Edmodo, a social networking platform designed for educators and schools, and on a storyboard – a sequence of drawings with words and pictures that illustrates their new knowledge. The Site Leader also provides time to document their understandings with digital video cameras for later posting on Edmodo.

As they progress through the unit, youth test their solutions and present their designs to one another face to face and on Edmodo. This allows them to offer constructive feedback or ideas to one another through a critique that can improve their designs and understanding of science and engineering.

Each after school site consists of a Site Leader who leads the instruction and volunteer facilitators who work with middle school girls and boys enrolled in Studio STEM. The Studio STEM sites are managed with the assistance of the Studio STEM Project Coordinator. Volunteer facilitators report directly to Site Leader and the Studio STEM Project Coordinator.

Your Role: Facilitator

Your work with the middle school students is crucial to the success of Studio STEM. In many cases, your interactions with these girls and boys are the first time they’ve ever talked with someone who is a college student. Also, this might be their first real opportunity to meet an engineer or scientist. In our prior studies, we found that the middle school youth looked forward to their weekly interactions with the undergraduate volunteers and felt supported in their interactions with the facilitators.

Basic Protocols

- Attendance at both the facilitator and Studio STEM curriculum workshop are mandatory.
- Arrive on time and stay until the students leave the classroom.
- Understand the dress codes for the school in which you are located.
- Do not text or use your phone during Studio STEM. Please turn off your phone while in the studio classroom.
• Report immediately any problems you have with a student to the site leader.

**Remember – you are important role models for these young girls and boys!**

As a volunteer with Studio STEM, you have four roles as a facilitator:

• You will keep students progressing in their work and focused on their problem.
• You will provide effective praise and constructive feedback in small groups and on Edmodo.
• You act as a “sounding board” for students’ ideas.
• You will ask “productive questions” that encourages reflection.

In education we speak about the work you do as a facilitator as providing the **scaffolding** for learning. Scaffolding “helps learners perform tasks that are outside their independent reach” – a support structure or a framework as you talk with students about their design process.

Research shows that praise is most effective when it is aimed at an individual and highlights their accomplishments. For example:

> Jill, you explained very clearly your reasoning behind this design. Good work!

> Your connections to the principles of energy transfer on your storyboard are very accurate, Randy!

You will use language strategies in supporting students as they construct understanding. The facilitator is guiding their construction of knowledge.

In the following pages, this handbook will introduce the ways you can provide scaffolding during the inquiry process through productive questions in your discussions with your group. Our goal is to establish a climate of curiosity and questioning that is conducive to question asking by students. Before describing the kinds of questions to ask, we begin by briefly providing an overview of science inquiry and the 5E model of STEM instruction.

![Designing and constructing a penguin shelter](image)

As you begin to facilitate discussion, also be aware of:

• Asking open-ended questions (as opposed to closed-ended questions that can be answered with yes-no).

• Asking students to describe their thinking about design choices and their understanding at key moments.
• Sharing your interests in science and engineering. Students want to connect with you as a person. You are an important role model for these youth.

5E Model of STEM Instruction

The Studio STEM curricula are organized around an inquiry-based cycle that includes: Engage, Explore, Explain, Elaborate, and Evaluate.

Engage: Helps students focus on the learning task, generates interest, and connects to students’ everyday understandings.

Explore: Students discover key principles and concepts of STEM through direct experience with the materials and they develop new skills.

Explain: Students and their instructor develop a common language to discuss their learning experience and to communicate their new understandings.

Elaborate or Extend: Students are involved in experiences that challenge persistent misconceptions or that deepens their understanding.

Evaluate: Students receive feedback periodically on their conceptual understanding and their ability to apply the concepts to new situations.

A curriculum can cycle through each of these phases several times over the course of the unit. Included in this handbook is a more detailed article about the 5E learning cycle by Lori Bowen in Appendix A.

At each phase of inquiry, different types of questions are applicable that you can use in conversation at your small groups and on Edmodo. In the Engage and Explore phases, for example, the questions are gauged at developing skills in observation, while in the later phases – Explain and Elaborate – questions with higher order thinking skills are used. At all times allow students to construct their own meaning first. Rarely will you be providing answers to them.

Productive Questioning

Productive questions are those that have the following result:

• These types of questions stimulate productive activity: “Let’s go find out!”

• Productive questions stimulate thought rather than invoking a simple “yes,” “no,” or one word answer.

• A productive question is an invitation to a closer look, to a new experiment, or another design.

This questioning promotes science and engineering as a way of working and conducting scientific inquiry. It also focuses on answers that are

derived from first hand experiences with the materials in the design studio, and the practical application of these materials. And finally, this questioning encourages awareness that there are many different answers that may be “correct.” There is more than one path to engineering a solution.

Below are some kinds of questions you might ask as a facilitator in the small groups and on Edmodo:

**Engage Phase:** Attention-focusing questions -
- What do you notice?
- What does it do?
- What do you see, feel, or hear?

**Explore Phase:** Measuring and counting questions -
- How many, How long, How often?
- What is stronger, heavier, or longer?

**Explanation Phase:** Comparison and action questions –
- How are these alike or different?
- How is that groups’ design like yours?
- What happens if…?

**Elaboration Phase:** Problem-posing questions –
- Pose a problem where students have to apply their new knowledge: How would make a house to keep penguin eggs warm?

Wait to ask “why” questions until youth have considerable experience with the materials. You want them to reflect on the relationships they have discovered or recognized through their work with the curriculum. Eventually we want students to be asking these questions to each other.

**Guidelines for Productive Questions**

1. Observe the effect of your questions on the students – are you able to get them to talk or write about their thinking?

2. Use the simplest form of productive question in the engage and explore phases to help students notice details they might have missed.

3. Use measuring and counting questions to move students from purely qualitative observations to more quantitative observations.

4. Use comparison questions to help youth to begin ordering their observations and data.

5. Use action questions to encourage experimentation and to investigate relationships.

6. Use problem posing questions when students are able to set up hypotheses for themselves and to test situations.

When asking questions to stimulate reasoning, make sure to say: “What do you think about…?” or “Why do you think…?” **Wait until students have the experience necessary so that they can reason from evidence.**
When youth ask “why” questions consider whether they have the experience and content to understand the answer. Don’t be afraid to say that you don’t know, or that no one knows.

Finally: as students talk to you, take all their questions seriously.

Learning about energy transfer and insulation

**Challenging Misconceptions**

As you talk with girls and boys, you will notice they hold some misconceptions about science that are particularly persistent. Ask questions that will encourage students to re-examine their observations or data to correct their own misconceptions. We advocate directing students’ attention to their first-hand experience with the materials in the curriculum before relying on their experience outside the after school program.

To be able to identify misconceptions, you should be familiar with the key scientific and engineering concepts in the Engineering Teaching Kit (ETK). Attending a training session in the ETK is mandatory.

Below are just a few of the common misconceptions that you might hear from students (or read in their posts to Edmodo or on their storyboard). The misconceptions listed below are focused on the Save the Penguins and Save the Seabirds ETK curriculum. Please refer to Appendix B for a complete list of misconceptions for all our ETKs.

As we introduce more units, we will expand and add to our list of misconceptions in the appendix of this handbook.

**Misconception: Heat is a substance. Heat is not energy.**
- **Basic concept:** We want students to understand that heat is the result of three kinds of thermal energy transfer (radiation, conduction, and convection) and is not a substance.
- **Focus student attention:** Heat does not add weight or mass to something so it’s not a substance. Would a melted penguin (warm) weight more than a frozen one (cold)? No.

**Misconception: Heat and cold are different.**
- **Basic concept:** Cold is the absence of thermal energy, or a
lower energy state. Have students think about hot and cold as opposite ends of the spectrum from more to less energy. There is no such thing as cold, really. It just means there’s less thermal energy.

• **Focus student attention:** Get students to talk about what temperature is “hot” and at what temperature is “cold.” If you ask enough students they will see that the terms hot and cold are somewhat arbitrary. They should begin to associate measuring temperature as measuring an energy state. Only heat transfers. Energy transfers. Cold is not energy—it is when something is missing energy.

**Misconception:** A force only comes from one direction at a time. If something isn’t moving, then no forces are acting on it. The more force on an object, the more it moves.

• **Basic concept:** Forces always come in pairs. If the forces are equal, there is no movement. If the forces are unequal, movement occurs in the direction of the weaker force. Forces are everywhere. The gravitational force affects everything in the universe.

• **Focus student attention:** Return to the magnetic motor demonstration and review all the different forces that are acting on the string lifting the weights in the cup. Gravity pulls down on the cup and the motor pulls up on it. Challenge students to find more ways to get their motor to exert more force so the cup moves.

**Misconception:** Friction is due to the irregularity of the surface. Friction always hinders motion and it’s something we always want to eliminate friction.

• **Basic concept:** Friction is the force between two objects when they are moving next to each other and touching.

• **Focus student attention:** Go back to the pull back race cars with different wheel surfaces and examine each car’s ability to move. Have the student explain how friction functions with each car. Have students imagine walking on a slippery surface that has very little friction. Friction is necessary for walking!

**More misconceptions can be found in Appendix B of this handbook, which apply to all our ETKs in Studio STEM.** Be aware of common misconceptions so that you can recognize them in conversations and on Edmodo with your team. Again, don’t leap in to correct students, but instead gently urge them to review their reasoning using the data they collected.

**Social Networking with Edmodo**

Studio STEM uses Edmodo, a social networking site, as another location to share their emerging understandings about science and engineering, as well as a place to share their insights about their designs. All the different locations in Studio STEM are linked together.
through Edmodo and students can comment and share ideas with students from other school systems.

![Image](image.jpg)

Integrating technology is a key element of Studio STEM

Each student has a personal account on Edmodo (http://edmodo.com). As a facilitator, you will also set up your own personal account and you will be invited to the Studio STEM group on Edmodo in an email from the Studio STEM Project Coordinator.

We ask that you periodically log on and check the Studio STEM site for Edmodo and facilitate a conversation with your team members. You can also converse with students at your site or students at another Studio STEM location. Use what you know about productive questioning, but also share with them web sites from the Internet that they might find helpful as they continue to build upon their knowledge and skills.

Here are some examples of questions, probes, and information sharing that facilitators have used with students on the Edmodo site:


- **Students were extra careful and ran extra tests to make sure they have the "right" items! Anyone have advice on designs for this group??**

- **Did somebody build a red house for penguins? I wonder why it's red?**

- **I thought foil was a conductor. How does it keep heat insulated?**

Below is the kind of conversation by girls and boys that we like to see on Edmodo. The students are exchanging ideas and discussing their design with one another:

**C:** My team (the cookie monsters) totally redid our house. It was a total mess. What we are doing is, we are making it dome shaped. Our first idea was to make it square and kinda make it like a lid. So we would just lift the top up, put our penguin inside, and then we would just put the roof back on top.

**B:** awsome if we stil had money i would of taken that into consideration.

**C:** what materials are you using

**J:** How do you plan to make the dome shape?
C: Um... we don't really know yet but so far we have used a wood stick, some paper, and I think that’s about it so far.

When these kinds of conversations happen, as a facilitator, you can jump in and ask about the science behind their design decisions. For example, you could ask C: How is the dome shape related to keeping your penguin cold?

You and the students can also upload photos and video collected during the design, redesign, and testing process. Be sure to connect these photos with some productive questioning. Ask them to describe what is happening in the photos/videos and add captions if the students have not done this.

Edmodo has an additional feature to engage students in reflection on their learning. In addition to posting comments or questions, you can add a poll or a quiz for students to answer (see below).

Students’ tendency is to use Edmodo for socializing only. We ask that you direct students’ attention to encourage reflection on their design choices and their new knowledge.

Notice how this poll above revealed that some students have very persistent misconceptions about the role of the aluminum foil in their design. This poll offers an opportunity for you to ask more productive questions.

Below is another example of a poll that was constructed on Edmodo. It revealed that students understood the concept of absorption of radiation.

You can construct polls using what you know about common misconceptions that students might have about science (see Appendix B for ideas).

Site Leaders and the Technology Supervisor at each site moderate all conversations on Edmodo. However, alert the Site Leader and Studio STEM Project Coordinator if you see any use of technology that is questionable.

Sticky Situations in Team Work

For the most part, you will find the work with youth exciting, enjoyable, and rewarding. In our pilot study, however, we noticed the potential for a few sticky situations. In each case,
please contact your Site Leader who will work with the students to resolve the situation.

Sometimes groups include team members whose personalities clash. If tension and conflict is ongoing for more than a few minutes, have the site leader speak to the students. Your work as facilitator does not include disciplining the students.

Sometimes a team member is rambunctious, doesn’t listen to directions, or doesn’t follow guidelines for safety. Again, have the Site Leader handle this situation with disciplining the student if gentle reminders aren’t effective.

Another sticky situation is what we termed “the crush.” Youth might try to flirt with you, rather than focusing on the work at hand. Sometimes the flirting can take the form of teasing – which can get out of control. Again, contact your site leader to remedy the situation.

Finally, if an accident occurs where you or the student are injured, contact your site leader immediately. The Site Leader has a first aid kit and will determine whether emergency assistance is needed.

Other Duties as Facilitator

Our funding for Studio STEM comes from the National Science Foundation. Receiving this funding means that we must conduct research and gather data to determine the effectiveness of our program. You will be asked to sign a consent form that indicates your willingness to be part of our research.

There are several other tasks related to our research that will help us gather data on students' participation and the effectiveness of the program. You might be asked to participate in the following:

- Setting up cameras, or filming students as they talk about their designs and understanding.
- Collecting data cards from each student at the end of each session.
- Completing your own survey online at the end of each session.
- Interview with our evaluators at the end of each unit.

Important: please communicate changes in your schedule with the Studio STEM Project Coordinator. The middle school youth come to expect you each week, but also, the Project Coordinator will need to find a replacement for you if your schedule changes and you are unable to continue as a volunteer.
Appendix A: The 5E Model of Instruction

By Lori Bowen
The 5E Model of Instruction

**Engage**

The first phase is to engage the student in the learning task. The student mentally focuses on an object, problem, situation or event. The activities of this phase should make connections to past and future activities. The connections depend on the learning task and may be conceptual, procedural, or behavioral. Learning Targets should be shared and discussed with the students to ensure they will have a clear path to the intended learning.

Asking a question, defining a problem, showing a discrepant event, and acting out a problematic situation, and using appropriate humor are all ways to engage the students and focus them on the instructional activities. The role of the teacher is to present a situation and identify the instructional task. The teacher also clearly sets the rules and the procedures for the activity.

<table>
<thead>
<tr>
<th>The activities…</th>
<th>The student…</th>
<th>The teacher…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiate the learning task</td>
<td>Asks questions such as: Why did this happen?</td>
<td>Raises questions and problems</td>
</tr>
<tr>
<td>Generate interest</td>
<td>What do I already know about this?</td>
<td>Elicits responses that uncover students’ current knowledge about the concept</td>
</tr>
<tr>
<td>Access prior knowledge</td>
<td>What can I find out about this?</td>
<td>Generates interest</td>
</tr>
<tr>
<td>Connect to past knowledge</td>
<td>How can this problem be solved?</td>
<td>Generates curiosity</td>
</tr>
<tr>
<td>Set parameters of the focus</td>
<td>Shows interest in the lesson</td>
<td></td>
</tr>
<tr>
<td>Frame the idea</td>
<td>Responds to questions demonstrating their own entry point of understanding</td>
<td></td>
</tr>
</tbody>
</table>
**Explore**

Once the activities have engaged students, they need time to explore their ideas. Exploration activities are designed so that all students have common, concrete experiences upon which they continue building concepts, processes and skills. This phase should be concrete and meaningful to students. The aim of exploration activities is to establish experiences that teachers and students can use later to formally introduce and discuss content-specific concepts, processes, or skills. During the activity, the students have time in which they can explore objects, events, or situations. As a result of their mental and physical involvement in the activities, the students establish relationships, observe patterns, identify variables, and question events.

The teacher’s role in the exploration phase is first and foremost to select activities that lead to substantive concept building. The teacher’s role, then, is that of facilitator or coach. The teacher initiates the activity and allows the students time and opportunity to investigate. If called upon, the teacher may coach or guide students as they begin constructing new explanations. The teacher will monitor students as they work and raise questions to lead students in their learning.

<table>
<thead>
<tr>
<th>The activities...</th>
<th>The student...</th>
<th>The teacher...</th>
</tr>
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<tbody>
<tr>
<td>● Provide students with common base of experiences</td>
<td>● Thinks creatively within the limits of the activity</td>
<td>● Elicits responses that uncover the students’ current knowledge about the concept</td>
</tr>
<tr>
<td>● Experience key concepts</td>
<td>● Tries alternatives to solve a problem</td>
<td>● Raises questions or problems</td>
</tr>
<tr>
<td>● Discover new skills</td>
<td>● Shares ideas</td>
<td>● Acts as a facilitator</td>
</tr>
<tr>
<td>● Probe, inquire, and question experiences</td>
<td>● Discusses with others</td>
<td>● Observes and listens to students as they interact</td>
</tr>
<tr>
<td>● Examine thinking</td>
<td>● Suspends judgments</td>
<td>● Asks good inquiry-oriented questions</td>
</tr>
<tr>
<td>● Establish relationships and understanding of concepts</td>
<td>● Conducts activities, predicts, and forms hypotheses</td>
<td>● Generates interest</td>
</tr>
<tr>
<td></td>
<td>● Makes generalizations</td>
<td>● Generates curiosity</td>
</tr>
<tr>
<td></td>
<td>● Becomes a good listener</td>
<td></td>
</tr>
</tbody>
</table>
**Explain**

Explanation means, “The act or process in which concepts, process, or skills become plain, comprehensible, and clear.” The process of explanation provides the students and teacher with a common use of terms relative to the learning experience. In this phase, the teacher directs student attention to specific aspects of the engagement and exploration experiences. First, the teacher asks the students to give *their* explanations. Second, the teacher introduces explanations in a *direct* and *formal* manner. Explanations are ways of ordering and giving a common language for the exploratory experiences. The teacher should base the initial part of this phase on the students’ explanations and clearly connect the explanations to experiences in the engagement and exploration phases of the instructional model. The key to this phase is to present concepts, processes, or skills briefly, simply, clearly and directly, and then continue on to the next phase.

<table>
<thead>
<tr>
<th>The activities…</th>
<th>The student…</th>
<th>The teacher…</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Focus students’ attention on a particular aspect of their engagement or exploration experiences</td>
<td>• Explains possible solutions or answers to other students</td>
<td>• Formally provides definitions, explanations, and new vocabulary</td>
</tr>
<tr>
<td>• Provide opportunities to demonstrate conceptual understanding</td>
<td>• Listens critically to other students’ explanations</td>
<td>• Uses students’ previous experiences as the basis for explaining concepts</td>
</tr>
<tr>
<td>• Introduce a concept, process, or skill</td>
<td>• Questions other students’ explanations</td>
<td>• Encourages students to explain their observations and finding in their own words</td>
</tr>
<tr>
<td>• Connect prior knowledge and background information to new discoveries</td>
<td>• Listens to and tries to comprehend explanations offered by the teacher</td>
<td>• Provides definitions, new words and explanations</td>
</tr>
<tr>
<td>• Communicate new understandings</td>
<td>• Refers to previous activities</td>
<td>• Listens and builds upon discussion with students</td>
</tr>
<tr>
<td>• Connect informal language to formal language</td>
<td>• Uses recorded observations in explanations</td>
<td>• Asks for clarifications and justification</td>
</tr>
</tbody>
</table>

Adapted from *Achieving Scientific Literacy* by Rodger W. Bybee
Once the students have an explanation of their learning tasks, it is important to involve them in further experiences that apply, extend, or elaborate on the concepts, processes, or skills. Some students may still have misconceptions or they may only understand a concept in terms of the exploratory experience. Elaboration activities provide further time and experience that contribute to learning. The teacher should provide opportunities for students to practice their learning in new contexts.

<table>
<thead>
<tr>
<th>The activities…</th>
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</tr>
</thead>
<tbody>
<tr>
<td>● Challenge and extend students’ conceptual understanding and skills</td>
<td>● Applies new labels, definitions, explanations, and skills in new or similar situations</td>
<td>● Expects students to use vocabulary, definitions, and explanations provided previously in new context</td>
</tr>
<tr>
<td>● Develop deeper and broader understanding, more information, and skills</td>
<td>● Uses previous information to ask new questions, propose solutions, make decisions, design experiments</td>
<td>● Encourages students to apply the concepts and skills to new situations</td>
</tr>
<tr>
<td>● Apply learning to a new or similar situation</td>
<td>● Provides reasonable conclusions and solutions from evidence</td>
<td>● Reminds and refers students of alternative explanations</td>
</tr>
<tr>
<td>● Extend and explain concept being explored</td>
<td>● Records observations, explanations, and solutions</td>
<td>● Uses previously learned information as a vehicle to enhance additional learning</td>
</tr>
<tr>
<td>● Communicate new understanding with formal language</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Evaluate

At some point it is important that students receive feedback on the adequacy of their explanations. Formative evaluation should occur from the beginning of the teaching sequence. The teacher can complete a summative evaluation following the elaboration phase. Teachers must assess learning targets through the use of formative and summative assessments in order to determine whether students have met the standards proficiently and to determine each individual student’s level of understanding. Students should use the skills they have acquired and evaluate their own understanding as well.

<table>
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<th>The activities…</th>
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</tr>
</thead>
<tbody>
<tr>
<td>• Assess understanding (self-, peer- and teacher evaluation)</td>
<td>• Demonstrates an understanding or knowledge of concepts or skills</td>
<td>• Observes and assesses students as they apply concepts and skills to new situations</td>
</tr>
<tr>
<td>• Demonstrate understanding of new concept by observation or open response</td>
<td>• Evaluates his/her own progress</td>
<td>• Looks for evidence that students have changed their thinking</td>
</tr>
<tr>
<td>• Apply within problem situation</td>
<td>• Answers open response questions</td>
<td>• Asks open-ended questions such as: Why do you think…? What evidence do you have…? What do you know about the problem…? How would you answer the question…?</td>
</tr>
<tr>
<td>• Show evidence of accomplishment</td>
<td>• Provides reasonable responses and explanations</td>
<td>• Encourages students to assess their own learning</td>
</tr>
</tbody>
</table>
Appendix B: Common Misconceptions about Science Concepts in Studio STEM: Heat & Energy Transfer, Forces & Motion, and Electricity.

**Important:** Don’t correct students by giving them the “right” answer. Instead, try to have students re-examine the results of their hands-on activities so they can correct their own misconceptions. Direct them to their first-hand experience with the materials in the curriculum.

<table>
<thead>
<tr>
<th>Misconception</th>
<th>Basic Concept</th>
<th>Focus Student Attention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Save the Penguins</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat is a substance.</td>
<td>We want students to understand that heat is the result of three kinds of thermal energy transfer (radiation, conduction, and convection) and is not a substance.</td>
<td>Heat does not add weight or mass to something so it’s not a substance. Would a melted penguin (warm) weigh more than a frozen one (cold)? No.</td>
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<td>Cold is like heat, but the opposite.</td>
<td>Cold is the absence of thermal energy, or a lower energy state. Have students think about hot and cold as opposite ends of the spectrum from more to less energy. There is no such thing as cold, really. It just means there’s less thermal energy.</td>
<td>Get students to talk about what temperature is “hot” and at what temperature is “cold.” If you ask enough students they will see that the terms hot and cold are somewhat arbitrary. They should begin to associate measuring temperature as measuring an energy state. Only heat transfers. Energy transfers. Cold is not energy—it is when something is missing energy.</td>
</tr>
<tr>
<td>Blue and dark colors are “cool” and provide shade so this color should go on the outside of the penguin house.</td>
<td>Thermal radiation is a form of energy transfer that is different from thermal convection. Radiant transfer of energy can happen even when the air is cold. When thermal radiation strikes a surface, the wavelengths of the energy spectra are absorbed or reflected. Darker surfaces absorb more of the radiant energy while light colors reflect the energy.</td>
<td>Guide their attention back to their experiments with the thermometers and materials. Go back to test a light color and a dark color. Have students compare that data. Ask the student to think about what happens when they walk barefoot on dark asphalt on a hot day, or when they wear a black t-shirt on a hot day.</td>
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<tr>
<td>Aluminum provides insulation for the penguin houses.</td>
<td>Aluminum reflects thermal radiation, but has virtually no insulating properties. Thermal insulation will restrict energy transfer. As a metal, aluminum transfers energy very quickly through conduction.</td>
<td>Direct students’ attention to the soda pop cans experiment they conducted. Remind them of the data they collected. Ask them to name kinds of insulation they use in their everyday lives.</td>
</tr>
<tr>
<td>Cotton balls and other</td>
<td>Thermal insulation restricts the</td>
<td>Have the student measure the</td>
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<tr>
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<td>Basic Concept</td>
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<tr>
<td>Insulating materials generate heat.</td>
<td>Transfer of energy and therefore restricts thermal conduction or thermal convection. Insulators prevent heat from transferring well, rather than heating things up.</td>
<td>Temperature under a cotton ball or yellow piece of felt and OVER the cotton ball or felt (without a heat lamp). There should be very little difference in the two temperatures.</td>
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<tr>
<td>Materials have to touch to heat up - (students only acknowledge conduction and don’t take into account convection or radiation).</td>
<td>Thermal convection and thermal radiation are two very important means for energy transfer.</td>
<td>Have the students hold their hand next to the lamp in the hot box to illustrate radiation. A microwave is another example of radiant energy. An example of convection is an air-popper for popcorn or a hairdryer.</td>
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<tr>
<td>Cold is transferred from one object to another.</td>
<td>Heat always moves from the hotter object to the cooler object.</td>
<td>Have the students examine their penguin ice cube and observe the melting. Where is the heat traveling in this example? Have the students map the movement of heat.</td>
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**Save the Seabirds and Save the Snails**

<p>| Force is a very difficult concept for children. Common misconceptions include: | Forces always come in pairs. If the forces are equal, there is no movement. If the forces are unequal, movement occurs in the direction of the weaker force. Forces are everywhere. The gravitational force affects everything in the universe. | Return to the magnetic motor demonstration and review all the different forces that are acting on the string lifting the weights in the cup. Gravity pulls down on the cup and the motor pulls up on it. Challenge students to find more ways to get their motor to exert more force so the cup moves. |
| • A force only comes from one direction at a time.                            |                                                                                                                                               |                                                                                                                                                        |
| • If something isn’t moving, then no forces are acting on it.                |                                                                                                                                               |                                                                                                                                                        |
| • The more force on an object, the more it moves.                             |                                                                                                                                               |                                                                                                                                                        |
| Friction is due to the irregularity of the surface. Friction always hinders motion and it’s something we always want to eliminate friction. | Friction is the force between two objects when they are moving next to each other and touching.                                              | Go back to the pull back race cars with different wheel surfaces and examine each car’s ability to move. Have the student explain how friction functions with each car. Have students imagine walking on a slippery surface that has very little friction. Friction is necessary for walking! |
| If an object is at rest, it has no energy.                                    | Objects at rest have potential energy when in a gravitational field. They can always fall.                                                    | Place the race car at the top of a ramp and discuss what kinds of energy it has. Or place the |</p>
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<tr>
<td>More voltage equals more energy.</td>
<td>Voltage and current are important in determining the amount of energy that is present.</td>
<td>Compare a high voltage solar cell with a lower voltage one. Hook each up to the same motor. The lower voltage one might produce more energy if it produces more current because energy = voltage x current.</td>
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<tr>
<td>If something is moving, a force must be acting on it to keep it moving in the direction to keep it moving.</td>
<td>The Law of Inertia states that things keep moving all by themselves, naturally, with no forces pushing them unless a force stops them. A thrown ball does not have a force pushing it anymore. Inertia is what keeps it moving. Inertia is a property of all matter.</td>
<td>What pushes the moon? Nothing. Something pushed it once, and it keeps on going. What pushes the Earth? Nothing. Something pushed it once and it keeps on moving. If a car is turned off, does it stop immediately? No. It keeps on moving due to inertia until a force like friction or air resistance slows it down.</td>
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<tr>
<td>The bigger the gears (the more teeth), the faster it moves.</td>
<td>The smaller gear with fewer teeth makes one rotation faster.</td>
<td>Return to the gear demonstration and have students count the number of rotations of the small gear for every rotation of the large gear. Attach each gear to the motor and observe how much energy it produces.</td>
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<tr>
<td>Gravity begins to act when an object begins to fall and it ceases to act when the object lands on the ground.</td>
<td>Gravity exists between the object and the Earth all the time.</td>
<td>What would happen if gravity did not work all the time on earth? Talk about what happens on a space walk with astronauts and how they have to work carefully with their tools. How is that different from us working with tools on earth?</td>
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<tr>
<td>Magnetism is a kind of gravity.</td>
<td>Magnetic force and gravity are two different types of forces. Magnetic force is the force of attraction between magnets and magnetic materials or the unlike poles of two magnets, or the force of repulsion between two like poles of magnets. Gravity is the force of attraction between two masses.</td>
<td>For gravity to be measurable one object must have a very great mass (like the earth). But magnetism is related to electricity. When astronauts work in zero gravity, they use electricity and magnetism to help them do their work and to keep track of their tools.</td>
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<tr>
<td>Electric current flows from the negative to the positive terminal.</td>
<td>The conventional current flows from the positive to the negative terminal, although in actual fact, current in a wire in a circuit is due to the flow of electrons from the negative to the positive terminal.</td>
<td>For electrons to move, there needs to be a closed circuit – a complete “loop.” Electricity is the motion of electrons in a conductor (the wire). You need a source of electrons (like a battery) to light a bulb. Think of the electrons moving from the source (the positive terminal) to the light and then returning to the negative terminal to complete the circuit.</td>
</tr>
<tr>
<td>When electric current increases, voltage increases; there is no voltage when there is no current flowing.</td>
<td>Voltage is a precondition for current to flow, not a property of current. Voltage is present even when no current is flowing.</td>
<td>You can generate thousands of volts through static electricity by walking on a carpet, but you might not have any current for it to travel or to do any real damage. Have students go back to the voltage meter and look at the relationship between Amps and Volts using the two electromagnetic motors.</td>
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Appendix C: Scripted Questions for Facilitating Conversation.

Productive Questions:
• Stimulate productive activity: “Let’s find out!”
• Are in an invitation to look closer, a new experiment, or a new design.
• Foster an environment where children begin asking their own questions.

Types of Productive Questions:
• Attention focusing questions:
  o What do you notice?
  o What does it do?
  o How does this feel?

• Measuring and counting questions:
  o How many…how long…how often?
  o Have them record their observations on their storyboards.

• Comparison questions:
  o How are these alike or different?
  o How is your design similar or different from others?

• Action questions:
  o What happens if…? (Requiring them to test it out, rather than just purely speculate.)

• Problem posing questions:
  o How would you make a house for a penguin egg (keeping it warm)?
  o How would you make this gear turn faster (slower)?
  o How can we increase the number of Amps (volts, etc.)?

In the early phases (Engage, Explore Phases) ask simple questions that have students focused on the materials, activities, and recording their observations.

In the later phases (Explain, Evaluate, Extend or Elaborate) ask more complex questions that help students reflect on the relationships between their observations and what they have discovered or recognized.