Strand: 7.1.4 (and a lot of 7.1.3)

**Emphasis:** Magnets

**Anticipated Time Required** (assuming 50 minute class periods):
Episode 1 - 100 min
Episode 2 - 50 min
Episode 3 - 70 min
Episode 4 - 50-80 min depends on quality of writing desired
Episode 5 - 50 min

**Dominant CCC:** Cause and effect  
**Dominant SEP:** Collect and analyze data, construct models

**Management Strategies** to support equitable access to content:

**Shopping list:**

**Episode 1**
- Round ceramic magnets
- Bar magnets or other shapes
- Nails
- Thread
- Paper clips (small and large)
- Pieces of cardboard or other materials (used to understand that magnetic fields can penetrate through matter)
- Rulers
- Magnets of different strengths (some of those old worn out magnets you got laying around…)
- Pins
- Leaves or pieces of wax paper
- Markers
- Bowl of water

**Episode 2**
- At least 1 small compass per pair.
- Paper
- Ruler
- Bar magnets
- Pencil
- Iron filings
- Small tray or box

**Episode 3**
- Battery
- Alligator clips and wire
- 22-30 gauge enamel coated (insulated) copper wire
- Nail or bolt to wrap wire around
- Battery
- Sand paper to strip the insulation off the wire
- Paperclips or staples

**Episode 4**
- Materials list will depend on variables you choose to have students test.
### 7.1.4 Storyline Planner

**Anchor Phenomenon:** Aurora Borealis

Student Performance Expectation: Students explore magnets and electromagnets and construct models and explanations of why things are magnetic from data. Students will be able to use their models and data to construct an understanding of the cause other aurora phenomena.

<table>
<thead>
<tr>
<th>Dominant DCI</th>
<th>Dominant CCC</th>
<th>Dominant SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Science</td>
<td>Cause and effect</td>
<td>Collect and analyze data</td>
</tr>
</tbody>
</table>

#### Science Experiences

<table>
<thead>
<tr>
<th>CCC/SEP</th>
<th>What are students doing? (This should match your SEP!)</th>
<th>What specific understandings should students get from this experience? (What pieces of the performance expectation does the experience provide?)</th>
<th>New questions students have to propel us to the next science experience</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cause and effect/ making models</td>
<td>View aurora borealis video. Ask questions Engage with lab exploring magnetism. Construct first try model of how magnets work. Compare models to peers and construct a group model.</td>
<td>Magnets produce forces that act at a distance. Magnetic forces can travel through objects. Magnetic forces attract sometimes and repel other times. Compasses are little floating magnets. How to draw things that</td>
<td>First try and second try models. Lab notes</td>
</tr>
<tr>
<td></td>
<td>Cause and effect/ making models</td>
<td>Cause and effect/ making models, asking questions</td>
<td>Cause and effect/ conduct investigation collect and analyze data</td>
<td>Cause and effect, argue from evidence</td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------</td>
<td>--------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>2</td>
<td>Construct models of magnetic fields using a compass and iron filings.</td>
<td>Magnetic fields make magnetic field lines. They have different shapes depending on the magnet, but similarities too.</td>
<td>Why are things magnetic?</td>
<td>Modeling magnets, # 3 and 4</td>
</tr>
<tr>
<td>3</td>
<td>Receive direct instruction on the causes of magnetism. Explore electricity and EMF using gaussmeter. Construct electromagnets and ask questions.</td>
<td>Electricity and magnetism are related. That magnetic fields are produced when electrons are able to move or spin in one direction.</td>
<td>What affects the strength of a magnetic field? Why is the earth magnetic?</td>
<td>Model # 5</td>
</tr>
<tr>
<td>4</td>
<td>Conduct investigation on variables that affect magnetic field strength using electromagnets.</td>
<td>Number of coils, strength of electrical force, type of materials all affect the strength of magnetic field.</td>
<td>Why is the earth magnetic? What causes the aurora borealis? How is it related to magnetism</td>
<td>Lab Report or Poster Project and Presentation</td>
</tr>
<tr>
<td>5</td>
<td>Gather information from models, images, and articles on the formation of the auroras.</td>
<td>The auroras are a phenomena related to the interaction of earth's magnetic field with the sun's magnetic field and the solar wind.</td>
<td>What would happen if we didn't have a magnetosphere?</td>
<td>Exit tickets</td>
</tr>
</tbody>
</table>
### 7.1.4 Episode 1 (from sara’s plan- floating paperclip)

<table>
<thead>
<tr>
<th>Student Science Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic:</strong> Magnetism</td>
</tr>
</tbody>
</table>

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

**7.1.3**  
Construct a model using observational evidence to describe the nature of fields existing between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects) and the forces they exert.

**7.1.4**  
Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

**Lesson Performance Expectations:**

Students will develop and revise models of magnetism anchored in a particular phenomenon (floating paper clip). Students will then test their models’ ability to account for new phenomena (generators, electromagnets, or iron filings). Students will use appropriate language (made explicit by the teacher in sentence frames) for describing their models and asking questions of peers to extend their thinking. Students will share leadership responsibilities required for consensus modeling. Students will participate in whole class discussions by repeating/rephrasing, adding new ideas, asking questions, providing counter evidence or a counter argument.

<table>
<thead>
<tr>
<th><strong>Students Will. . . To Construct Meaning</strong></th>
<th><strong>Teacher Will. . . To Support Students</strong></th>
</tr>
</thead>
</table>
| Engage with a Phenomenon: Fill out an OEQ template while watching the video on the AURORA BOREALIS turn and talk to your neighbor about your observations, explanations and questions. Prepare to share those with the class if called on. | From 7.1.3  
Prepare to engage with phenomenon:  
OEQ template  
Phenomenon: Aurora Borealis  
Aurora Borealis at Magnetic Midnight.  
After quiet writing time, have students turn and talk about their observations, explanations and questions.  
Management Strategy: Randomly generate students to share.  
Write their questions on the board.  
To learn about this beautiful phenomenon we need to learn about magnets! |

H. Waite
Gather and Reason:
Sort into lab groups based on color. Perform group responsibilities based on your number.

Receive a copy of the lab packet. Start by going to stations and filling out the I learned/ I wondered template. Write down your inferences and the evidence that supports them.
For examples: I saw that magnetic attract things because I saw things moving towards the magnet.

Travel with your lab group. You will have 5 minutes at each station.

Management strategy: Numbered Heads Together
Organize students into lab groups of 4 students by using colored Number stickers or colored cards with numbers written on them. The level of science language/skills difficulty for this standard is moderate to difficult. Take that into consideration as you pass out your cards and look for good combinations based on your understanding of student needs.

Guiding Question: How do magnets work? (what is the cause of the effect)

Students will engage with the lab by completing I Learned... because... /I wondered template. This could be written into their journals or passed out as worksheet (below) along with ‘modeling magnetic fields’ worksheet.

Management Strategy: What to ASSESS!
I have thought a lot about when students should journal vs when they should complete an assignment. One thought I had was that I should grade anything that demonstrates use of the SEP, so in this case I should be grading their ability to ‘CONSTRUCT A MODEL’ or ‘COLLECT AND ANALYZE DATA’. Since I find journal grading difficult, and worksheet grading a little easier (for both time, space, and providing feedback) I have chosen to create a worksheet and address both the content (DCI) and the SEP

Goal: Students will construct a model of fields coming from within magnets and fields between magnets based on their experience with 9 stations:

see descriptions below

Materials:
Return to group tables

Communicate:

Read worksheet ‘Constructing a model of how magnets work’

Learn slogans for new words.

Read task expectations on worksheet with instructor

Quick Write on what it means to be invisible. Why are things invisible. How can we show things that are invisible?

Be prepared to share your thoughts with the class.

Complete first try of model of how magnets work.

Share models and explanations with group

Read group task instructions with teacher. Take turns deciding how group model should look and what it means

Number 1 will ask:
What are the similarities/differences in our models?
•I noticed X# have……
•I noticed only X’s has….
Number 2 will ask:

- Round ceramic magnets
- Bar magnets or other shapes
- Nails
- Thread
- Paper clips (small and large)
- Pieces of cardboard or other materials (used to understand that magnetic fields can penetrate through matter)
- Rulers
- Magnets of different strengths (some of those old worn out magnets you got laying around…)
- Pins
- Leaves or pieces of wax paper
- Markers
- Bowl of water

As students are working circulate especially to students who may need help. Ask them probing questions like “What do you see (observe)?” “What does it feel like?” “How do you explain what you see or feel?” “If you were to draw what this feels like, what might it look like?”

When students have completed their observations, they should return to their group tables.

Students are introduced to new vocabulary through a class reading of the introduction to the worksheet. Constructing a model of how magnets work-

Students construct slogans for the words, FORCE, FIELD, EXERT, ATTRACT and REPEL and share with the class. Choose a slogan for each and write it down for later review.

(This may not be necessary if you already explored vocabulary with the other 7.1.3 section, either section can work as an introduction to forces and fields)

Read: TASK EXPECTATIONS with students before they begin the ‘working independently’ section.

Direct Instruction:
Setting Students up to Succeed on assessment:
Help students to recognize that there is a lot going on here that is INVISIBLE.

Quick write

Question: Why are things invisible? How can we show things we’ve observed or inferred but that we can’t see?

Have students suggests ways that they could show things
What do we agree should be in our model?
• I think we should include…. because…..
• I agree/disagree because……
  I felt this in the lab and I think we could show it by...
Number 3 will ask:
Are we ready to draw? How should we start?
• I think we should draw….because/for example
Number 4 will ask:
Is there anything missing in our drawing?
• We need to add……
Number 1 will ask:
What’s our evidence for this model?
  ● Our evidence is……
  ● I think it’s like this because...
Number 2 will draw group model
Number 3 and 4 will write group description and explanation

Present models to the class. Choose a spokesperson to speak for the group. Post model on the board.

Participate in respectful discussion while learning from the models produced by the class.
Ask questions
Respond to questions and comments with journal reflection

<table>
<thead>
<tr>
<th>Element</th>
<th>Expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elements that are not observable</td>
<td>Does the explanation account for unobservable elements or observable phenomena?</td>
</tr>
<tr>
<td>Interactions between those unobservable elements</td>
<td>Does the explanation account for the arrangement of unseen elements or their interactions?</td>
</tr>
<tr>
<td>Interactions or behaviors of those unobservable elements that are microscopic</td>
<td>Are the unseen elements macroscopic or microscopic?</td>
</tr>
<tr>
<td>Is the model showing progression</td>
<td>From Static/macroscopic ---&gt; to Dynamic/microscopic</td>
</tr>
</tbody>
</table>

If their models are still too static and too macroscopic, then they require more evidence/instruction.

Reflection Questions:
“I like your model, do we understanding what is going on in the magnet that is making it act like this?”
“Would you change your model after listening to your peers?”
“Would you like more evidence?”
“What do you think this has to do with the Aurora Borealis?”
“How well did you participate in this process?”

Assessment of Student Learning
Assessment is based on rubric for assessing models and informing instruction. Proficient students are engaged in constructing models and explaining them individually and as a group. Proficient students will be asking questions and looking for evidence to help perfect their models. Keep notes on how students participate in small group and whole class discussions & have students complete reflections on their participation. Can be in checklist form to streamline recording!

How do magnets work?
Making Observations, constructing explanations:  Name ____________________________
<table>
<thead>
<tr>
<th>Station</th>
<th>I learned that...because i saw...</th>
<th>I wondered about...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
<td></td>
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<td>4</td>
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<td>5</td>
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<td>6</td>
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<td>7</td>
<td></td>
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</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Modeling Magnetic Fields

Read along with the instructor:
The word FIELD in science means an area where an object can EXERT a FORCE. A FORCE is a push or a PULL. We observed magnetic FORCE today. EXERT means to ACT on something with a force. Magnetic force was exerted anytime something in lab was PULLED together or PUSHED apart. When a force pulls things together we say they ATTRACT. When a force pushes things apart we say they REPEL.

As a group decide on a SLOGAN for these vocabulary words, be prepared to share them with the class.

FORCE:

EXERT:

FIELD:

ATTRACT:

REPEL:

Task: You are required to CONSTRUCT A MODEL of HOW MAGNETS WORK.

**Explanation of Science Practice:**
Constructing a model has several components. Constructing a model means that you must use the inferences you made from your observations in lab to:

- Draw (with pictures, words, and arrows)
- Describe (tell what the model represents in words)
- Explain (tell why you think this is true)

Task: SHARE your model with your group.

Here are some examples of the language you could use to share your model:

- *In my drawing you can see........ I included X,Y,Z because...... OR My drawing has.....because......
- *My evidence for this model is......
- *Something I observed today......
- *Something I observed somewhere outside of class......
- *Something I read...
- *Something I learned in another science class......

FIRST TRY
Working Independently (by yourself) - Use your observations to CONSTRUCT A MODEL-, that answers the question: How do magnets work? Be prepared to share your model with your group in ________ minutes.

How do magnets work? In lab we noticed that there is a force that comes from within a magnet that affects the way it interacts with other magnets or other objects.

1. FIELDS that come from WITHIN a magnet
2. FIELDS that exist BETWEEN magnets and other objects.

Model of fields that come from within a magnet.

Describe and explain your model
__________________________________________________________
__________________________________________________________
__________________________________________________________
__________________________________________________________

Model of fields that exist between magnets

Describe and explain your model
__________________________________________________________
__________________________________________________________
__________________________________________________________
__________________________________________________________

Group Task Instructions
Task: Construct a model as a GROUP that shows magnetic force fields coming from magnets and acting on other objects in that field.

Constructing a model as a group means coming to a CONSENSUS (agreement) on…
- what the model should look like
- how to label it,
- what it means
- why you think that it is a true representation of how magnets work.

This will be done by taking turns asking questions. Everyone will help to answer the questions in turn. Pass the sheet around as you take turns asking questions.

Number 1 will ask:
What are the similarities/differences in our models?
• I noticed X# have……
• I noticed only X’s has….

Number 2 will ask:
What do we agree should be in our model?
• I think we should include…. because…..
• I agree/disagree because…….
  I felt this in the lab and I think we could show it by...

Number 3 will ask:
Are we ready to draw? How should we start?
• I think we should draw….because/for example

Number 4 will ask:
Is there anything missing in our drawing?
• We need to add…….

Number 1 will ask:
What’s our evidence for this model?
  • Our evidence is……
  • I think it’s like this because...

Number 2 will Draw group model

Number 3 and 4 will write group description and explanation
Describe and Explain Group model here:

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

SECOND TRY: Draw group model here
<table>
<thead>
<tr>
<th>Station 1</th>
<th>Target observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• What materials are attracted to a magnet?</td>
<td></td>
</tr>
<tr>
<td>– String</td>
<td></td>
</tr>
<tr>
<td>– Paper</td>
<td></td>
</tr>
<tr>
<td>– A nut or washer</td>
<td></td>
</tr>
<tr>
<td>– A paper clip</td>
<td></td>
</tr>
<tr>
<td>– Cardboard, other substances</td>
<td></td>
</tr>
<tr>
<td>– Plastic</td>
<td></td>
</tr>
<tr>
<td>– Metal hole-puncher</td>
<td></td>
</tr>
<tr>
<td>– Pick something from your backpack that you are curious about!</td>
<td></td>
</tr>
<tr>
<td>• Some materials can be magnetized, others cannot.</td>
<td></td>
</tr>
<tr>
<td>• Some metals can be magnetized others cannot.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station 2</th>
<th>Target observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>● What happens when you put 2 magnets on one side of a pencil and one magnet on the other side?</td>
<td></td>
</tr>
<tr>
<td>● Test out different ways to put the magnets on the pencil.</td>
<td></td>
</tr>
<tr>
<td>• Magnets are polar (kid language will be different!)</td>
<td></td>
</tr>
<tr>
<td>• Sometimes magnets attract each other, sometimes they repel each other.</td>
<td></td>
</tr>
<tr>
<td>• You can make magnets attract or repel by “flipping” one of them</td>
<td></td>
</tr>
<tr>
<td>• When the magnets push away from each other, what appears to be empty space stays between them.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station 3</th>
<th>Target observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• How many paperclips can you pick up with a magnet through a piece of wood or cardboard?</td>
<td></td>
</tr>
<tr>
<td>• Variation:</td>
<td></td>
</tr>
<tr>
<td>– How many paperclips can you pick up with a magnet through a piece of cardboard?</td>
<td></td>
</tr>
<tr>
<td>– What happens when you add pieces of cardboard?</td>
<td></td>
</tr>
<tr>
<td>– How many pieces of cardboard can you use before you can no longer pick up a paperclip</td>
<td></td>
</tr>
<tr>
<td>• Magnetic fields (again, this is not in kid language!) can and do travel through materials.</td>
<td></td>
</tr>
<tr>
<td>• The magnetic field does not extend forever around the magnet, there is a limit to it’s range</td>
<td></td>
</tr>
<tr>
<td>• Paperclips closer to the magnet experience a greater pull than paper clips farther from the magnet.</td>
<td></td>
</tr>
<tr>
<td>Station 4</td>
<td>Target observations</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------</td>
</tr>
</tbody>
</table>
| • How can you make a paperclip float with magnets?  
- Try with different #s of magnets! | • If the magnet is too far away the paperclip will not float  
• You can feel resistance when you hold the paperclip in a floating position.  
• You need more than one magnet for the floating trick to work well – more magnets = easier to make magnets float. Note: Ss may or may not work out this relationship on their own, but, the teacher can help draw this out in whole class discussion. |

<table>
<thead>
<tr>
<th>Station 5</th>
<th>Target observations</th>
</tr>
</thead>
</table>
| • How many paperclips can you pick up with a nail with a magnet touching the nail? | • Nails can become temporarily magnetized by touching a magnet.  
• As Ss will see in the next station, this is different from the cardboard exercise because the cardboard allows the magnetic field to act through it without becoming magnetized, the nail on the other hand becomes magnetized. |

<table>
<thead>
<tr>
<th>Station 6</th>
<th>Target observations</th>
</tr>
</thead>
</table>
| • What happens to your ability to pick up paperclips with a nail after you rub a magnet across the nail 20-30 times? | • Nails can become temporarily magnetized by coming into contact with a magnet.  
• This temporary magnetization (word? J) will not last long, can wear off and can be dissipated on purpose by tapping the nail. (Ss may not see this on their own but you can point it out during whole class discussion) |

<table>
<thead>
<tr>
<th>Station 7</th>
<th>Target observations</th>
</tr>
</thead>
</table>
| • What happens to the paperclips on the end of a nail when you flip the magnet? | • When you initially remove the magnet, the paperclip should stay attached to the nail.  
• When you flip the magnet the paperclip should drop as a result of the reversal in polarity.  
• Note: This station is a little tricky so Ss may need help “seeing” what you want them to see here. |
<table>
<thead>
<tr>
<th>Station 8</th>
<th>What are the differences between these magnets?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target observations</td>
</tr>
<tr>
<td></td>
<td>● Magnets are made of different materials</td>
</tr>
<tr>
<td></td>
<td>● The pull comes from different places</td>
</tr>
<tr>
<td></td>
<td>● Some magnets are stronger than others.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station 9</th>
<th>Can you make a compass with a leaf if you magnetize a needle?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target observations</td>
</tr>
<tr>
<td></td>
<td>● Compasses are floating magnets</td>
</tr>
</tbody>
</table>
### 7.1.4 Episode 2

**Student Science Performance**

<table>
<thead>
<tr>
<th>Topic: Magnetism</th>
<th>Title: Shock and Awe</th>
</tr>
</thead>
</table>

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

**7.1.3** Construct a model using observational evidence to describe the nature of fields existing between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects) and the forces they exert.

**7.1.4** Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

### Lesson Performance Expectations:

Students will develop and revise models of magnetism anchored in a particular phenomenon (magnetic interactions). Students will then test their models’ ability to account for new phenomena (compasses or iron filings)

Students will use appropriate language (made explicit by the teacher in sentence frames) for describing their models and asking questions of peers to extend their thinking. Students will share leadership responsibilities required for consensus modeling. Students will participate in whole class discussions by repeating/rephrasing, adding new ideas, asking questions, providing counter evidence or a counter argument.

**CCC:** Systems and system models, cause and effect

**SEP:** Developing and using models, Constructing explanations

### Students Will... To Construct Meaning

- **Read and review your journal notes and reflections**
- **Watch interactive model of how electric fields of oppositely charged particles create field lines.**
- **We will look at**
  - positive to positive
  - Negative to negative
  - Positive to negative
- **Draw a model of each one of these interactions.**

### Teacher Will... To Support Students

- **Read/Review More Evidence: Constructing magnetic fields with a compass.**
  - Students will work in pairs within their lab group.
  - For example: youngest and oldest together or middles or let them choose.

- **Give students exposure to charge field lines with the following interactive:**

- **Show students the following combinations:**
  - Positive to positive
  - Negative to negative
  - Positive to negative
  - Students should draw models of these fields in their journals.
  - Ask students to consider how this matches their earlier models?
Use the magnet and the compass and see if you can identify any patterns as you move the compass around the magnet.

Take notes in your journal on video plotting magnetic field lines. Watch carefully. We will watch it once and then go through the highlights again.

Work with one of your table partners on Model #3. One of you will hold the pencil, while the other moves the compass. Every 5 minutes you will trade.

Students will map the magnetic field using a compass and a magnet. Model the practice for students and then give them an instruction sheet.

Materials:
- At least 1 small compass per pair.
- Paper
- Ruler
- Magnet
- Pencil
- Iron filings
- Small tray or box

Management Strategy: Voice and Pen
Students should work in pairs and alternate roles. One uses the pencil (pen), the other gives instructions (voice). Set a timer and have them alternate every 5 minutes. Proverbially speaking- Only one pencil should be used. Voice should sound like “I noticed this so I think we should…” “I was wondering what would happen if…”

Give students magnets and compasses and let them explore for a bit before showing them the instructions.

There are several videos on how to do this. You choose what works for you.

“Plotting magnetic field lines” (judgemeadowsci)
https://www.youtube.com/watch?v=DMO373nDp8M
https://www.youtube.com/watch?v=JUZC679CwKs
Wrap your magnet in plastic wrap...tightly.
Place your magnet on the tray or box you are given. Put a clean piece of paper over the magnet.
Sprinkle iron filings on the paper over the magnet and observe.

I made a model that wasn’t nearly this neat my first time with no instruction. Don’t laugh. :)

I recommend following these instructions in the video, they will help.
The tricky thing...all magnets have a different magnetic field pattern depending on the shape and how the magnet was polarized. **You will have to explore the magnets you are using before you give them to your students. Practice!**

If you want it to be easy, use labeled bar magnets polarized through the long axis.
**Note:** I noticed that I wasn’t clear about which was the North side of the magnet and which was the south side.

The compass will point toward the south side of the magnet and away from the north side. I got it wrong on my drawing because I was thinking about it like the earth, but the earth’s magnetic north pole is actually the south pole and vice versa...so can’t use that logic.

Students work together to construct a model of the magnet. If they finish early, give them another magnet to work on.

**More evidence:**
To confirm their observations show them the magnetic field using iron filings. These are messy and difficult to work with, so you may want to just do a demonstration. If you are feeling brave, give students a tray or a box and a small container (like the kind they put glitter in) of iron filings.
**Wrap the magnet in plastic wrap** so that you don’t get iron filings directly on the magnet. They don’t come off very well.

Cover the magnet with a piece of paper and sprinkle the iron filings on the paper over the magnet and
On your assignment (or in journals)
Model #4- Iron filings

Draw a model of like charges repelling and opposite charges attracting with iron filings.

Complete the Assessment ‘Reflections on constructing a model of ‘how magnets work.’

Let them experiment with the iron filings and observe how magnets interact with other magnets.
What does the field look like if we put them together with opposite poles?
What does it look like if we put them together with like poles.
Have them draw these interactions in their journals.

Assessment: Reflection on constructing a model of How magnets work.

<table>
<thead>
<tr>
<th>Element</th>
<th>Expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elements that are not observable</td>
<td>Does the explanation account for unobservable elements or observable phenomena?</td>
</tr>
<tr>
<td>Interactions between those unobservable elements</td>
<td>Does the explanation account for the arrangement of unseen elements or their interactions?</td>
</tr>
<tr>
<td>Interactions or behaviors of those unobservable elements that are microscopic</td>
<td>Are the unseen elements macroscopic or microscopic?</td>
</tr>
<tr>
<td>Is the model showing progression</td>
<td>From Static/macrosopic ---&gt; to Dynamic/microscopic</td>
</tr>
</tbody>
</table>

Journal Reflection: We use compasses to find the north and south poles on earth, what does that tell us about the
Reflect in your journal on these questions: 
*We use compasses to find the north and south poles on earth, what does that tell us about the earth?*

*How do you think this relates to the Aurora borealis we observed?*

*What questions do you have?*

*Be prepared to share with the class.*

---

**Assessment of Student Learning:** Student models will be assessed to guide instruction. Proficient students are able to recognize the differences in the mental models they had constructed and the mapping of the magnetic fields they have observed. Their models and explanations should show a comparison to current thinking from past thinking and the role of evidence in changing their understanding.

---

Model #3  Modeling magnetic fields using a compass. Watch the video carefully and follow instructions as they are given to you. Video if you want to watch at home
Model # 4 - Iron filings - Iron filings hurt eyes! Do not blow them around or rub them into your eyes!!!!!! Be extremely careful!
Wrap your magnet in plastic wrap. Put in small box. Sprinkle with iron filings.

Draw a model of your magnet with iron filings.

Draw a model of your magnet with another magnet with opposite poles facing. Make sure to wrap other magnet in plastic wrap!!!!!!

Draw model of your magnet with another magnet with like poles facing. Make sure to wrap other magnet in plastic wrap!!!!

Trying Again: Reflection on constructing a model of How magnets work
Name ____________________________.

H. Waite
<table>
<thead>
<tr>
<th>First model</th>
<th>Last Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looked like this</td>
<td>Looks like this</td>
</tr>
<tr>
<td>I explained it like this</td>
<td>I explain it like this...</td>
</tr>
<tr>
<td>Because I didn’t understand</td>
<td>Because I now understand</td>
</tr>
</tbody>
</table>
## 7.1.4 Episode 3

### Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Magnetism</th>
<th>Title: Shock and Awe</th>
</tr>
</thead>
</table>

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

**7.1.3** Construct a model using observational evidence to describe the nature of fields existing between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects) and the forces they exert.

**7.1.4** Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

**CCC:** Systems and system models  
**SEP:** Constructing models, analyzing and interpreting data

#### Lesson Performance Expectations:

Students continue to gather information to construct a model and an explanation that includes the macro and micro aspects of electromagnetic forces and explains the behavior of these magnets with model that includes field lines and electron flow. Explanation should also include evidence from past experiences that support the model and explanation.

**CCC:** Systems and System models, Cause and Effect  
**SEP:** Develop a model, carry out an investigation.

### Students Will... To Construct Meaning

- Read and review from last episode
- Think/Pair/share Prepare an OEQ template and watch video on how magnets are made.  
  Prepare to share your observations, explanations, questions
- Take notes on when materials become magnetized

### Teacher Will... To Support Students

- Read and Review- Return past models to them
- Students continue to work with their lab groups
- **Prepare:** Students prepare to watch the video by preparing an OEQ template. Generate student names to share observations, explanations, questions.
- How it’s made- magnets  
  [https://www.youtube.com/watch?v=noGGcyPHtdI](https://www.youtube.com/watch?v=noGGcyPHtdI)
- **Direct Instruction:** Magnets are made of metals whose atoms have been lined up to make the magnet polar with opposite charges on either end. Then they are shocked with electricity to make magnetic properties stronger. Before people manufactured magnets they were found in nature, it is believed they were rocks that had become magnetized when they were hit with LIGHTNING. In lab we saw that we could rub a magnet on a nail and make it magnetic temporarily. That was because the electrons in the metal could be lined up and start moving in one
direction and this ‘current’ or flow of electrons through the metal makes the metal magnetic. This is why somethings are attracted to a magnet and some things are not. Some materials have atoms with electrons that can be arranged so that they lines up and others don’t. When a piece of iron or cobalt comes near a magnet, the structure of electrons is affected by the magnetic field and turns that object, while they are together, into another magnet and they become attracted just like two magnets would be.


When a bar of metal is made into a ‘Permanent magnet’ the atoms are ‘pinned’ into a position where their electrons are fixed in the correct position for magnetism to occur. Anything that disrupts that position will make a magnet lose its magnetism. For example, heating a magnet will cause it to lose its magnetism or hitting a magnet repeatedly (or crashing it into another magnet) will weaken the magnetic field over time or make it lose its magnetic force entirely.

Shows magnetic field penetrating bar of iron and inducing a magnetic field in the iron bar.

Teacher Note: magnetic properties are found in elements whose atoms have one unpaired electron. The spin of this unpaired electron creates opportunity for electric force to induce a magnetic field which is perpendicular to the
Prepare to share your answers with the class.

Given supplies and instructions build an electromagnet. With your table partner

Ask questions about electromagnets.

Prepare to share your answers with the class.

Given supplies and instructions build an electromagnet. With your table partner

Ask questions about electromagnets.

Prepare to share your answers with the class.

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Ask questions about electromagnets.

Prepare to share your answers with the class.

Given supplies and instructions build an electromagnet. With your table partner

Ask questions about electromagnets.
describe ‘how magnets work’

- draw a model and an explanation that includes the newest information you have about How Magnets Work.

Show your model to a peer for a peer edit, have them fill out the rubric and help you figure out how to make your model better. Show them your old model.

When you feel like your rough draft is EXCELLENT, then fill out the final ASSESSMENT. TRY AGAIN MODEL #5.

**Inquiry:** After students have had time to experiment with the simple electromagnet Have students write questions and post them in Parking Lot.

**Assessment:** Students should complete model #5 of How Magnets Work

Give students the compasses and have them construct a model of the magnetic field produced by their electromagnet.

Model should show that magnetic fields are produced as negative charges (electrons) move through the wire. The magnetic field is perpendicular to the direction of electron flow.
**Review questions**

**magnetic field (red)**

![Magnetic Field Lines Around a Helix](http://www.geocities.ws/rjwarren_stm/Physics_Notes/Helix.gif)


**Prepare to write: Constructing a vocabulary list.**

Students write in their journals. What words do you need to use in order to correctly explain a model of “How magnets work.”?

Students construct rough draft of final model and explanation using required vocabulary.

Students should use the rubric for self evaluation and for peer editing BEFORE using the template for the assignment below.

**Sentence Stems** could be given to help students:

- This model shows…..
- Arrows are used to show…..
- Evidence for this model includes…..
- What is not shown in the model is……..

**Give students grading rubric and have them peer edit models according to the rubric. If students need to add to their model then they should.**

<table>
<thead>
<tr>
<th>Element</th>
<th>Expectation</th>
</tr>
</thead>
</table>

H. Waite
Elements that are not observable | Your explanation **talks** about parts of the model that are hard to observe or draw. Required vocabulary used.
---|---
Evidence included in explanation. | Your explanation describes evidence and observations that helped you make the model.
Interactions between those unobservable elements | Your model shows
- where the parts of the system that are causing this effect are located
- how they are arranged
- how they are moving
Interactions or behaviors of those unobservable elements that are microscopic | Are the invisible parts of this system shown in some way including large field lines or small electrons.
Is the model showing progression | Is this model more clear and accurate than your last model?

Questions: What makes an electromagnet stronger?
Why is the earth magnetic?

---

**Assessment of Student Learning**

*Proficient students can construct a model of magnetism that includes the flow of electrons leading toward a dynamic/microscopic view of magnetic forces.*

Try Again- Model#5 - How magnets work.

Name __________________________________________

Construct a **rough draft of your model and an explanation in your journal** and self evaluate (check your own work) using the **rubric**.

When you feel like the models and explanation are complete, have a peer check your work using the rubric. Then use this template (form) to write your final assignment.
Draw your model. Include electrons and show the direction of the magnetic field that is produced compared to the direction of the flow of electricity in this system.

Describe your model in words and explain the reasons why your model changed from your last model.

___________________________________________________________________________________
___________________________________________________________________________________
___________________________________________________________________________________
___________________________________________________________________________________
___________________________________________________________________________________
___________________________________________________________________________________

Name of student__________________ Name of peer editor _____________

Task- Self Evaluation- Go through the entire rubric and make sure your model and explanation are complete.

<table>
<thead>
<tr>
<th>Expectation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your explanation talks about parts of the model that are</td>
<td></td>
</tr>
</tbody>
</table>
hard to observe or draw.

Required Vocabulary is used correctly in explanation.

Your Explanation includes evidence that support the explanation.
I think ….because...

Your model shows
- where the parts of the system that are causing this effect are located
- how they are arranged
- how they are moving
- how this system interacts with other objects?

Are the invisible parts of this system shown in some way including large field lines or small electrons.

Is this model more clear and accurate than your last model?

Task- Peer Editing
Quietly read through the rubric and write comments. When you are clear about how might help them improve, give them helpful suggestions and comments. Like: I really like how you did…, I feel like this part would be more clear if...

<table>
<thead>
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</tr>
</thead>
<tbody>
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<td></td>
</tr>
<tr>
<td>Required vocabulary used correctly.</td>
<td></td>
</tr>
<tr>
<td>Their Explanation includes evidence that support the explanation.</td>
<td></td>
</tr>
<tr>
<td>I think ….because...</td>
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<td></td>
</tr>
<tr>
<td>- how this system interacts with other objects?</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Are the invisible parts of this system shown in some way including large field lines or small electrons.</td>
<td></td>
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<tr>
<td>Is this model more clear and accurate than their last model?</td>
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</table>
### Student Science Performance

<table>
<thead>
<tr>
<th>Topic: Magnets</th>
<th>Title shock and awe</th>
</tr>
</thead>
</table>

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

**7.1.3** Construct a model using observational evidence to describe the nature of fields existing between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects) and the forces they exert.

**7.1.4** Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

- **CCC:** Cause and effect
- **SEP:** Carry out an investigation, collect and analyze data

#### Lesson Performance Expectations:

<table>
<thead>
<tr>
<th>Students Will. . . To Construct Meaning</th>
<th>Teacher Will. . . To Support Students</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Quick write on video of car parts being picked up with an electromagnet.</em></td>
<td><strong>Show</strong> students ELECTROMAGNET used to pick up junk in junk yards. How do you think they make a magnet strong enough to pick up a car?</td>
</tr>
</tbody>
</table>

[https://www.youtube.com/watch?v=6yhNOXQkMpY](https://www.youtube.com/watch?v=6yhNOXQkMpY)

*Questions:* How is this working? How come it is so strong?

**Lab Report:** See supplementals on how to design an experiment through writing. Protocol. Assign them lab roles for the experiment on variables that affect the strength of an electromagnet. Pass out cards with roles and an identifier (number, name, shape, character)

- **Roles**
  - **Leader** - In charge of selecting group and keeping group on task and completes the assignment, time keeper for experiment.
  - **Manager** - In charge of materials for the lab including set up and clean up.
  - **Writer** - In charge of anything that is written down data and leading group to complete lab reports.
  - **Expert** - In charge of reading instructions, leading discussion on experiment design and execution.

Students should consider variables that might affect the...
Conduct experiment.
Write about experiment.
Talk about your experiment.

strength of the electromagnet, here are a few they might consider. You can decide what materials you have and where you want them to go.

Independent Variables might be:
- Number of turns on the coil or length of the wire.
- Size of the current by increasing battery size or number
- Different cores steel, copper, aluminum, etc. You can use nails, bolts, pipe, tubing, and more.
- Leads used

Dependent Variables Might be:
- Number or size of paperclips picked up
- Time for the electromagnet to attract the paper clips
- Readings on gaussmeter

Students conduct experiments and prepare to write or present data to the class.

http://miniscience.com/kits/Magnet_Motor_kit/index.html

Making an electric motor
https://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_p051.shtml

Another one.

Assessment: Lab report graded with rubric

Or another assessment idea may be a mini lab report and then have students create posters and present to the class.

Assessment of Student Learning

Proficient students show an understanding of the relationship between electric force and magnetism through their writing on a lab report or poster presentation. They should also show an understanding of how to collect and analyze data through their discussion. Graded according to rubric.
### Overarching Performance Expectations (Standard) from State Standards or NGSS:

**7.1.3** Construct a model using observational evidence to describe the nature of fields existing between objects that exert forces on each other even though the objects are not in contact. Emphasize the cause and effect relationship between properties of objects (such as magnets or electrically-charged objects) and the forces they exert.

**7.1.4** Collect and analyze data to determine the factors that affect the strength of electric and magnetic forces. Examples could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

**CCC:** Systems and system models, cause and effect  
**SEP:** Constructing explanations, analyzing and interpreting data, obtaining information, developing and using models.

### Lesson Performance Expectations:

**Students Will... To Construct Meaning**

<table>
<thead>
<tr>
<th>How does the Aurora Borealis form?</th>
<th>Teacher Will... To Support Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>What does that have to do with magnets?</td>
<td>View Aurora Borealis</td>
</tr>
</tbody>
</table>

Use understanding of models and magnets and charges to construct an understanding of the Aurora Borealis (northern lights) from articles, images and models.

“You may not always understand the words, but maybe someone in your group has the evidence or the definition that will help you! Highlight or circle words that don’t make sense. Do the best you can to understand the text with the pictures and models to help you. Read carefully and apply what you have learned about magnets and magnetic fields and charged particles to help you understand. This is how we use past learning to learn new things! It works!”
Construct a model of how the Aurora forms. Each team member will be given a separate colored pen and be asked to contribute to the model.

Participate in gallery stroll and compare the models of other students. Write on their models positive comments or productive questions.

“I like how you showed this”
“I’m not clear what you mean by this.”

construct an understanding of the aurora borealis and earth’s magnetic field from the following pieces of evidence.

Each member of your group will be given a piece of evidence and asked to analyze it and prepare to explain it to your group

Assessment:
Draw a model of how the Auroras of earth form. Each person needs to contribute to the model by using a different color pen. They should contribute to the model in that area in which they became expert.
Example: The student that read about earth’s magnetic field, should draw earth’s magnetic field.

Students will present their models to the class for a graffiti stroll.

When the students have constructed an explanation show them a few of these videos. They are amazing.

The sun is magnetic
https://www.nasa.gov/feature/goddard/2016/understanding-the-magnetic-sun
https://www.youtube.com/watch?v=URN-XyZD2vQ

Earth’s magnetic shield
https://www.youtube.com/watch?v=ReSi_kPTN1c

Why solar storms are so dangerous
https://www.youtube.com/watch?v=GrnGi-q6iWc

Solar Explosion Nasa
http://sci.esa.int/cluster/54022-cluster-helps-to-model-earths-mysterious-magnetosphere/

Cool animation of solar wind pushing on earth’s magnetic field

Exit Ticket: Explain how the aurora borealis formed.
Exit ticket: Why is the earth magnetic?

Journal Reflection: Evidence from the fossil record and
iron intrusion from rock suggests that life started sometime between the time period in which earth’s magnetic field gained strength and the time that rocks started showing evidence that the atmosphere contained oxygen around 3.5 billion years ago. Was the development of earth’s magnetic field necessary for life to develop on earth? What is the cause of earth’s magnetic field and why does it seem to fluctuate over time? What creates a strong magnetic field versus a weak magnetic field. These questions could take you to 7.2.4 modeling earth, or they could take you to 7.3 and needs of living things.

Assessment of Student Learning
*Short description of the evidence the teacher is willing to accept that a student is proficient with the performance expectations. This may be a rubric, narrative or other set of descriptors that are useful for distinguishing proficient from non-proficient performances.*

Exit Ticket - What causes Auroras? Name ________________________________
Explain the role of Earth’s magnetic field, the sun’s magnetic field and charged particles in the Aurora Borealis.

Vocabulary:

Model:

Explanation:

Exit Ticket- What causes Auroras? Name ____________________

Explain the role of Earth’s magnetic field, the sun’s magnetic field and charged particles in the Aurora Borealis.

Vocabulary:

Model:

Explanation:

Exit Ticket- Why is the EArth Magnetic? Name ____________________
Vocabulary:

Model:

Explanation:

Exit Ticket - Why is the Earth Magnetic? Name ___________________________

Vocabulary:

Model:

Explanation:
### 7.1.4 - Lesson Developed by Dr. Sarah Braden

<table>
<thead>
<tr>
<th>Grade: MS</th>
<th>Title: Modeling magnetism: the floating paper clip</th>
<th>Topic: Magnetism</th>
</tr>
</thead>
</table>

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

**Lesson Performance Expectations:**
- Ss will develop and revise models of magnetism anchored in a particular phenomenon (floating paper clip). Ss will then test their models’ ability to account for new phenomena (generators, electromagnets, or iron filings).
- Ss will use appropriate language (made explicit by the teacher in sentence frames) for describing their models and asking questions of peers to extend their thinking. Ss will share leadership responsibilities required for consensus modeling. Ss will participate in whole class discussions by repeating/rephrasing, adding new ideas, asking questions, providing counter evidence or a counter argument.

**Students Will . . . To Construct Meaning**

**Engage with a Phenomenon: Floating paper clip.**

**Gather:** Observations (drawings & notes) about how magnets interact with different objects under various conditions.

**Reason:** Hypothesize/model HOW the magnets produce the observable properties students collected/noticed at the stations by focusing on the floating paperclip phenomenon. The model must be consistent with the observable evidence.

**Communicate:** Using verbal contributions to both peer group and whole class discussions, students will describe and explain their drawings/models of magnetism & ask questions to clarify their understanding of their peers’ models.

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

- Prep lesson with valued/appropriate language of participation made explicit to students at multiple points throughout the lesson.
- Manage students’ participation in groups using colored cards & explicit instructions for leadership roles & the process of forming consensus models.
- Provide an accessible phenomenon for Ss to work with.
- Circulate while students are working independently and in groups to provide feedback and ask strategic questions to push students’ thinking. Also help individual Ss prepare to share their models – particularly EL students.
- Provide built in wait time by allowing sufficient time for independent work before group work.
- Use strategic talk moves to promote broader participation in whole class discussions and shift classroom culture away from valuing only one correct answer.
- Draw students’ attention to evidence, counter evidence, and additional scenarios strategically to push their thinking about their models (independent, small group, and whole class settings).

If T wants students to model at the micro-level, will need to ask students specifically to think about and draw what is happening inside the magnet and the paperclip to allow this phenomenon to occur.
Assessment of Student Learning

Proficiency will be determined based on whether or not students' models show the desired level of specificity at the macro or micro levels, whether the models are static or dynamic, whether they account for observable evidence (experientially provided in class), and whether or not students' models demonstrate increased sophistication/change over time. A simple 0/1 scoring could be set up for each of these dimensions if grades must be applied.

Materials Required:
- Station labels & instructions
- Magnets, nails, pencils, string, paper clips, tape.
- Paper for students to draw
- Chart paper for students to depict consensus models
- White board or chart paper to record ideas during whole class discussions.
- T may want a clipboard w/ a chart to keep track of notes on students’ thinking AND notes on Ss participation according to instructions for how to collaborate.

Management Strategies:

<table>
<thead>
<tr>
<th>Teacher Does</th>
<th>Students Do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present the phenomenon &amp; Q: How does a magnet make a paperclip float in air? think-Pair-Share T refrains from commenting too much on Ss ideas at this point. Make record of Ss initial ideas on the board.</td>
<td>Ss watch demo &amp; do Think-Pair-Share</td>
</tr>
<tr>
<td>Messing about: T circulates while students visit stations, and listens to student thinking and/or is available to answer procedural Qs. Can ask probing Qs as relevant.</td>
<td>Messing about: Ss visit different stations constructed by the teacher to make observations about how magnets interact with each other and other materials. Ss keep track of ideas with notes and pictures.</td>
</tr>
<tr>
<td>Initial Modeling – Independent work time Circulate and ask probing Qs, help Ss who aren’t sure how to get started, visit EL students (&amp; others) to make sure they are ready to share their models with their classmates.</td>
<td>Initial Modeling – Independent work time Ss generate drawings and initial answers to the anchor question. Ss plan how they will share their drawings with their peers.</td>
</tr>
<tr>
<td>Initial Modeling – Sharing models T circulates to collect info on student thinking – what’s in the models, and to ensure Ss follow the participation framework and that no one student is dominating the conversation or “playing teacher/expert”.</td>
<td>Initial Modeling – Sharing models Ss share their models in a small group using the participation &amp; explanation structure provided by the teacher.</td>
</tr>
<tr>
<td>Consensus Modeling T circulates to monitor Ss participation according to the framework AND to ask probing Qs about Ss thinking – to push Ss thinking.</td>
<td>Consensus Modeling Ss work together using the suggested participation framework to create a consensus model for the anchoring phenomenon.</td>
</tr>
<tr>
<td>Sharing consensus models à building towards class consensus</td>
<td>Sharing consensus models</td>
</tr>
<tr>
<td>------------------------------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>T facilitates science talk about the models. (See notes in PPT)</td>
<td>Ss listen, present, and ask Qs following the participation framework.</td>
</tr>
</tbody>
</table>

Ss revise their models based on whole class discussion (2\textsuperscript{nd} round of small group consensus modeling). Repeat process as above, assign different roles to students.

Ss test their models on a new phenomenon (e.g., electromagnets, generators, and/or behavior of iron filings (if not used in initial stations & depending on T goals))

May have independent and/or small group work here. Activities can/should involve standard 7.1.4.

Ss revise models.

Ss use models to explain or make predictions of a novel scenario.
Solar activity associated with Space Weather can be divided into four main components: solar flares, coronal mass ejections, high-speed solar wind, and solar energetic particles.

- Solar flares impact Earth only when they occur on the side of the sun facing Earth. Because flares are made of photons, they travel out directly from the flare site, so if we can see the flare, we can be impacted by it.
- Coronal mass ejections, also called CMEs, are large clouds of plasma and magnetic field that erupt from the sun. These clouds can erupt in any direction, and then continue on in that direction, plowing right through the solar wind. Only when the cloud is aimed at Earth will the CME hit Earth and therefore cause impacts.
- High-speed solar wind streams come from areas on the sun known as coronal holes. These holes can form anywhere on the sun and usually, only when they are closer to the solar equator, do the winds they produce impact Earth.
- Solar energetic particles are high-energy charged particles, primarily thought to be released by shocks formed at the front of coronal mass ejections and solar flares. When a CME cloud plows through the solar wind, high velocity solar energetic particles can be produced and because they are charged, they must follow the magnetic field lines that pervade the space between the Sun and the Earth. Therefore, only the charged particles that follow magnetic field lines that intersect the Earth will result in impacts.
A coronal mass ejection on Feb. 27, 2000 taken by SOHO LASCO C2 and C3. A CME blasts into space a billion tons of particles traveling millions of miles an hour. **Credit:** SOHO ESA & NASA

The outer solar atmosphere, the corona, is structured by strong magnetic fields. Where these fields are closed, often above sunspot groups, the confined solar atmosphere can suddenly and violently release bubbles of gas and magnetic fields called coronal mass ejections. A large CME can contain a billion tons of matter that can be accelerated to several million miles per hour in a spectacular explosion. Solar material streams out through the interplanetary medium, impacting any planet or spacecraft in its path. CMEs are sometimes associated with flares but can occur independently.

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*Editor: Holly Zell*
A solar eruptive prominence as seen in extreme UV light on March 30, 2010 with Earth superimposed for a sense of scale. Credit: NASA/SDO

A solar prominence (also known as a filament when viewed against the solar disk) is a large, bright feature extending outward from the Sun's surface. Prominences are anchored to the Sun's surface in the photosphere, and extend outwards into the Sun's hot outer atmosphere, called the corona. A prominence forms over timescales of about a day, and stable prominences may persist in the corona for several months, looping hundreds of thousands of miles into space. Scientists are still researching how and why prominences are formed.

The red-glowing looped material is plasma, a hot gas comprised of electrically charged hydrogen and helium. The prominence plasma flows along a tangled and twisted structure of magnetic fields generated by the sun's internal dynamo. An erupting prominence occurs when such a structure becomes unstable and bursts outward, releasing the plasma.

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The Sun unleashed a powerful flare on 4 November 2003. The Extreme ultraviolet Imager in the 195A emission line aboard the SOHO spacecraft captured the event. Credit: ESA & NASA/SOHO

A solar flare is an intense burst of radiation coming from the release of magnetic energy associated with sunspots. Flares are our solar system’s largest explosive events. They are seen as bright areas on the sun and they can last from minutes to hours. We typically see a solar flare by the photons (or light) it releases, at most every wavelength of the spectrum. The primary ways we monitor flares are in x-rays and optical light. Flares are also sites where particles (electrons, protons, and heavier particles) are accelerated.

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The sun is a magnetic variable star that fluctuates on timescales ranging from a fraction of a second to billions of years.

Solar flares, coronal mass ejections, high-speed solar wind, and solar energetic particles are all forms of solar activity. All solar activity is driven by the solar magnetic field.

Credit: NASA

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Aurora and Manicouagan Crater

An astronaut aboard the International Space Station adjusted the camera for night imaging and captured the green veils and curtains of an aurora that spanned thousands of kilometers over Quebec, Canada.

Snow and ice in this winter image, acquired on Feb. 3, 2012, reflect enough light from stars, the moon, and the aurora to reveal details of the landscape. On the lower right, we see a circle of ice on the frozen reservoir that now occupies Manicouagan impact crater (70 kilometers in diameter). City lights reveal small settlements, such as Labrador City (an iron-ore mining town) and the Royal Canadian Air Force base at Goose Bay on the Labrador Sea.

The aurora borealis (northern lights) is the light that glows when charged particles from the magnetosphere (the magnetic space around Earth) are accelerated by storms from the sun. The
particles collide with atoms in the atmosphere; the green and red colors, for instance, are caused by the release of photons by oxygen atoms.

The fainter arc of light that parallels the horizon is known as airglow. This is another manifestation of the interaction of the Earth’s atmosphere with radiation from the sun.

The atmosphere shields life on Earth from the sun’s harmful radiation. It also causes small asteroids to burn up or catastrophically explode before hitting the ground. Larger asteroids can occasionally penetrate the atmosphere and collide with our rocky planet—with dramatic effects.

Geologists know that a large asteroid slammed into Earth roughly 214 million years ago, creating a crater about 100 kilometers (60 miles) across on the landmass that is now part of Canada. The impact caused a shock wave to radiate across Earth’s surface, followed closely by high-velocity winds. Near the impact point, wind speeds would have exceeded 1000 kilometers (600 miles) per hour. The shock wave and air blast would have severely damaged and killed plants and animals out to distances of approximately 560 kilometers (350 miles)—as far as Goose Bay. After erosion by glaciers and other processes over millions of years, the Manicouagan crater is now about 60 kilometers (37 miles) wide.

Annotated image: NASA’s Earth Observatory

Image Credit: NASA

Caption: D. Kring, Lunar and Planetary Institute, Universities Space Research Association; Michael Trenchard, Barrios Technology, Jacobs Contract at NASA-JSC; and M. Justin Wilkinson, Texas State University, Jacobs Contract at NASA-JSC

Last Updated: Aug. 8, 2016
Editor: Sarah Loff
Storms From the Sun
March 8, 2012

Artist illustration of events on the sun changing the conditions in Near-Earth space.

Image Credit:
NASA

Space weather starts at the sun. It begins with an eruption such as a huge burst of light and radiation called a solar flare or a gigantic cloud of solar material called a coronal mass ejection (CME). But the effects of those eruptions happen at Earth, or at least near-Earth space.

Scientists monitor several kinds of space "weather" events -- geomagnetic storms, solar radiation storms, and radio blackouts – all caused by these huge explosions on the sun.

**Solar Radiation Storms**

A solar radiation storm, which is also sometimes called a solar energetic particle (SEP) event, is much what it sounds like: an intense inflow of radiation from the sun. Both CME's and solar flares can carry such radiation, made up of protons and other charged particles. The radiation is blocked by the magnetosphere and atmosphere, so cannot reach humans on Earth. Such a storm could, however, harm humans traveling from Earth to the moon or Mars, though it has little to no effect on airplane passengers or astronauts within Earth's magnetosphere. Solar radiation storms can also disturb the regions through which high frequency radio communications travel. Therefore, during a solar radiation storm, airplanes traveling routes near the poles – which cannot use GPS, but rely exclusively on radio communications – may be re-routed

**Geomagnetic Storms** Auroras occur primarily near Earth's poles. They are the most common and the only visual result of space weather.
How the Sun Caused an Aurora This Week

An aurora dances in the atmosphere on August 20, 2014, as the International Space Station flew over North America. This image was captured by astronaut Reid Wiseman from his vantage point on the ISS. In the upper foreground is a portion of the ISS’ robotic arm.

**Credits: NASA/ISS**

On the evening of Aug. 20, 2014, the International Space Station was flying past North America when it flew over the dazzling, green blue lights of an aurora. On board, astronaut Reid Wiseman captured this image of the aurora, seen from above.
This model shows where the aurora was visible at 7:30 p.m. EDT on Aug. 19, 2014, as the International Space Station flew over it. The model is an Ovation Prime model and it is available from the Community Coordinated Modeling Center at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

This auroral display was due to a giant cloud of gas from the sun – a coronal mass ejection or CME – that collided with Earth's magnetic fields on Aug. 19, 2014, at 1:57 a.m. EDT. This event set off, as it often does, what's called a geomagnetic storm. This is a kind of space weather event where the magnetic fields surrounding Earth compress and release. This oscillation is much like a spring moving back and forth, but unlike a spring, moving magnetic fields cause an unstable environment, setting charged particles moving and initiating electric currents. The geomagnetic storm passed within 24 hours or so but, while it was ongoing, the solar particles and magnetic fields caused the release of particles already trapped near Earth. These, in turn, triggered reactions in the upper atmosphere in which oxygen and nitrogen molecules released photons of light.

The result: an aurora, and a special sight for the astronauts on board the space station.

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(Editor: Holly Zell_

H. Waite
A magnetosphere is that area of space, around a planet, that is controlled by the planet's magnetic field. The shape of the Earth's magnetosphere is the direct result of being blasted by solar wind. The solar wind compresses its sunward side to a distance of only 6 to 10 times the radius of the Earth. A supersonic shock wave is created sun-ward of Earth called the Bow Shock. Most of the solar wind particles are heated and slowed at the bow shock and detour around the Earth in the

**Magnetosheath.** The solar wind drags out the night-side magnetosphere to possibly 1000 times Earth's radius; its exact length is not known. This extension of the magnetosphere is known as the

**Magnetotail.** The outer boundary of Earth's confined geomagnetic field is called the

**Magnetopause.** The Earth's magnetosphere is a highly dynamic structure that responds dramatically to solar variations. Also residing within the magnetosphere are areas of trapped charged particles; These particles travel from the radiation belt to the poles of earth causing the aurora borealis. These particles only appear in a circle around the north pole. Particles don’t go to the north pole directly, they go around it. Credit: NASA/Goddard/Aaron Kaase

_Last Updated: July 30, 2015_

*Editor: Holly Zell*
Many technologies of the 21st century are vulnerable to solar storms.

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Schematic illustration of the invisible magnetic field lines generated by the Earth, represented as a dipole magnet field. In actuality, our magnetic shield is squeezed in closer to Earth on the Sun-facing side and extremely elongated on the night-side due to the solar wind.

Earth’s polarity is not a constant. Unlike a classic bar magnet, the matter governing Earth’s magnetic field moves around. Geophysicists are pretty sure that the reason Earth has a magnetic field is because its solid iron core is surrounded by a fluid ocean of hot, liquid metal. The flow of liquid iron in Earth’s core creates electric currents, which in turn creates the magnetic field. Credit/Copyright: Peter Reid, The University of Edinburgh

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Earth’s magnetosphere and the sun’s magnetosphere create a pathway for charged particles like positively charged protons and negatively charged electrons and other forms of radiation to travel to the earth. The same way iron filings line up between two magnets. These particles are produced by explosions on the sun. These explosions cause a wave of particles to fly at the earth so fast, it only takes a few minutes for them to get to earth. This wave of particles is called the solar wind.

Earth’s magnetosphere protects us from MOST of these charged particles and the solar wind blows around us. Some particles get trapped in earth’s magnetic field lines and move towards the north and south poles causing the Aurora Borealis (northern lights) or Aurora Australis (southern lights). These lights show where some radiation leaks through earth’s magnetosphere to earth’s atmosphere.

This energy causes the elements of earth’s atmosphere like oxygen and nitrogen to glow! Different elements glow with different colors. Oxygen glows green and yellow, while Nitrogen glows red and blue.
The stripes that we see when we look at the Aurora are caused by charged particles following earth's' magnetic field lines, the same way that iron filings make lines around a magnet.

Even Saturn has auroras from the sun’s solar wind! Does this mean saturn is also magnetic?