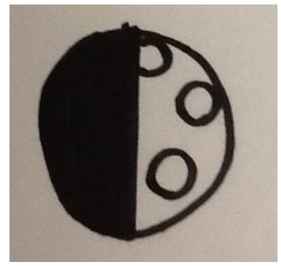
1. Patterns.

Patterns help to make sense of nature. Patterns can be observed in repeating shapes, structures, and events. Where do you see patterns?

The phases of the Moon follow a predictable pattern.



Why the Moon symbol is used for Patterns- With direction, very young students can observe and identify the pattern in the phases of the Moon. As students get older their understanding gets more sophisticated as they can model the movements of the Earth, Sun, and Moon and use mathematical representations to explain orbits.

Critical questions for patterns-

Is there a pattern?
What is the evidence for this pattern?
Do similarities and differences reveal a pattern?
Is this pattern real or imagined? (People sometimes see patterns where there isn't one)
What predictions can I make based on this pattern? Can I test them?
Is there a cause for this pattern?
Engineering- How widely can this pattern be applied? What are its limits? Can I use this pattern to design a solution?
What other crosscutting concepts can be applied to this pattern?
How does this pattern compare to other patterns I have learned about?
Based on what I've learned, what other symbol could be used to represent patters?

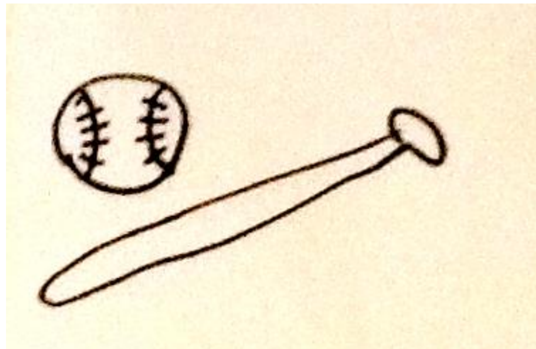
Questions that connect to the Science and Engineering Practices-

Asking Questions- What questions can I ask about this pattern?
Defining Problems- How can I change this pattern? How can I use this pattern?
Models- How can I model this pattern? Can I make a model to explain this pattern?
Investigations- How can we design and carry out an investigation to confirm that this pattern is real?
Data- Is there a pattern to this data? How can I organize and display my data to show this pattern?
Using Math- How can we use math to represent this pattern?
Computational thinking- How can we use a computer to find or visualize patterns in the data?
Explanations- How can I explain this pattern? How can this pattern support my explanation?
Solutions- Does this pattern tell me if the solution works?
Argument- What is the evidence for this pattern? Can I use this pattern as evidence to support my argument?
Information- What is already known about this pattern? How can I best communicate about this pattern?

2. Cause and Effect

When we do science we try to find out the reasons why things happen. What causes have you identified? What effects do they produce? What is your evidence?

The force of the bat causes a change in the motion of the ball.



Why the Ball and Bat is the symbol for Cause and Effect- Young students can clearly understand the relationship between the force of the bat and the movement of the ball. As students get older their understanding will become more sophisticated and involve applying Newton's laws to understand the many forces on both the bat and ball.

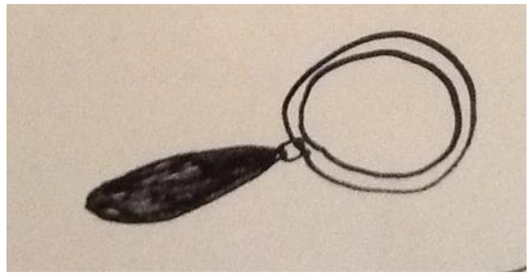
<u>Critical Questions for Cause and Effect</u>
What evidence is there for a cause and effect relationship?
How can this cause and effect relationship be tested?
What are other possible causes? Are there many causes?
Is the cause and effect relationship real or imagined?
How is this cause and effect relationship similar to and different than others I have learned about?
Engineering- How can I use this cause and effect relationship?
What other crosscutting concepts apply to this cause and effect relationship?
Based on what I've learned, what other symbol could be used to represent Cause and Effect?

<u>Questions that connect to the Science and Engineering Practices-</u>
Asking Questions- What is the cause of this effect?
Defining Problems- What is the desired effect?
Models- What model will explain this cause and effect relationship?
Investigations- How can we design an investigation to see if this is the cause of this effect?
Data- Does our data support this cause and effect relationship?
Using Math- How can we measure the relationship between the cause and effect? How can we model it with math?
Computational Thinking- How can we make a computer model of this cause and effect relationship?
Explanations- What explains how the cause leads to the effect? What does this cause and effect relationship help to explain?
Solutions- Will this cause the desired effect?
Argument- What is the evidence that the cause leads to the effect?
Information- What is already known about this cause and effect relationship? How can I best communicate about this cause and effect relationship?

3. Scale, Proportion, and Quantity

Scale, proportion, and quantity help us understand how nature is different when we study the very large and very small. What have you learned about how things change at different scales

A hand lens reveals that rocks are made of many different minerals.



Why is the hand lens the symbol for Scale? Looking at nature through a hand lens is often a student's first introduction to the idea that the world is different when seen at different scales. Students will learn that lenses have played a big role in advancing science's understanding of both the very large and very small.

Critical questions for Scale, Proportion, and Quantity-

How would the phenomenon we are studying look at the micro or nano scale?
How does this interaction affect the global scale?
How does this system look at a smaller and larger scales? What is new and what is the same?
Engineering- Can we make this bigger or smaller? How will it change if we do?
Engineering- What is involved in making this process take place at an industrial scale?
How does this scale relate to you? How much bigger or smaller is it than what you are used to experiencing?
How can we study nature at this scale?
How can we accurately measure this at this scale?
How are the other crosscutting concepts affected at this scale? How are they affected if we change scale?
Based on what I've learned, what other symbol could be used to represent Scale, Proportion, and Quantity?

Questions that connect to the Science and Engineering Practices-

Asking Questions- How does this change at different scales?
Defining Problems- Can I make this bigger or smaller?
Models- How can I make a model that helps me understand nature at this scale?
Investigations- How can we investigate nature at this scale? What tools will we need?
Data- What does the data tell us about how nature works at this scale? What does the data tell us about how the system changes at different scales?
Using Math- How can we use math to describe and measure this scale? How does math help us understand what happens if this gets bigger or smaller? (or increases or decreases)
Computational Thinking- How can we use computers to see how this changes as it gets bigger or smaller?
Explanations- How can I explain how nature works at this scale? Can I explain how what happens at this scale affects nature at other scales?
Solutions- Does a change in size work? How can we make it work?
Argument- What is the evidence that we have for our description of nature at this scale?
Information- What is already known about nature at this scale? How can I best communicate about this scale?

4. Systems and Systems Models

In systems the whole is greater than the sum of its parts. Nature is complex and confusing. Thinking about systems and making systems models can help you make sense of it. What systems can you identify and study? What are their parts? How do they work together? What are the inputs and outputs of the system? What processes go on in this system? How do they connect to other systems?

Living things are complex systems made of many smaller interrelated systems, having inputs and outputs, and interacting with systems in their environment

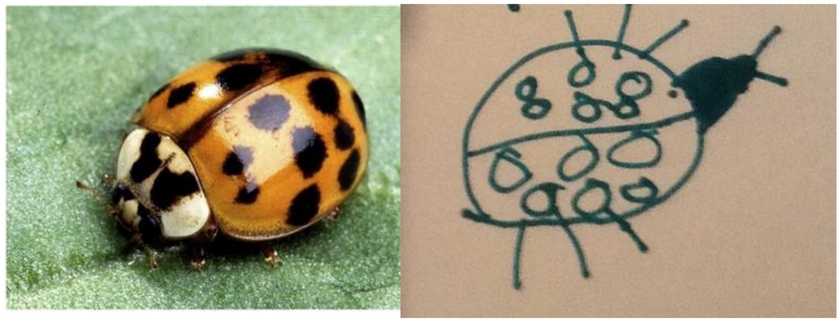


photo by Scott Bauer USDA

Why is the beetle the symbol for systems? The idea of systems is an abstract concept and is one of the hardest crosscutting concepts for young students. Living things are the most complex systems that science studies and at the same time accessible to young students. They can understand that living things are complex and are made of many parts. Living things have various inputs and outputs and interact with their environment and other living things. Much of student's study of life science will be to understand the many systems involving living things. The beetle is easy and fast to draw and is cute.

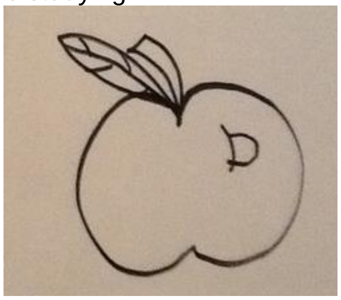
Critical questions for systems and systems models-
What are the limits of this system?
What other systems affect this system? How?
What parts and sub-systems make up this system? How do they work together?
What are the inputs and outputs of this system?
What interactions and processes involve this system?
What are the advantages to thinking about this as a system?
In what ways is this system like others I have learned about? How is it different?
Engineering- How can we improve the function of the system?
What is accurate and inaccurate about our model of this system?
How can our systems model be made more accurate?
What other crosscutting concepts apply to this system?
Based on what I've learned, what other symbol could be used to represent Systems and Systems Models?

Questions that connect to the Science and Engineering Practices-
Asking Questions- How does this system work?
Defining Problems- How can I design a system to solve a problem?
Models- How can I model this system? Can we model how this system functions?
Investigations- How can we change variables to test this system?
Data- What kind of data can help us understand this system? What does the data tell us about the system?
Using Math- How can we use math to model how this system works?
Computational Thinking- How can we use computer models to understand this system?
Explanations- How can I explain the function of this system?
Solutions- Will this system solve the problem? Has the system been improved?
Argument- What evidence do we have to support our model of this system?
Information- What is already known about this system? How can I best communicate what I know about this system?

5. Energy and Matter

Energy and Matter change forms but are not created or destroyed. Energy flows and matter cycles through natural systems. How do energy and matter work in systems that you are studying?

Food gives us both energy to live and grow and the matter that builds our bodies.



Why is the apple the symbol for Energy and Matter? Energy and matter are very abstract concepts for younger students to understand. However students can understand that their bodies need food to give them energy to play and for their bodies to grow. The idea of food is central to how energy and matter interact in living systems. Older students will start to learn that the energy in their food began in the Sun and was converted through food chains and that the matter is continuously recycled in the environment. The apple is easy and fast to draw and represents a healthy food choice. A candle was considered for the symbol, but the connection between energy and matter is less obvious to young students.

Critical questions for Energy and Matter-
How are energy and matter related in this system?
Where does the energy for this system come from? Where does it go?
What does energy do in the system? How is it changed?
What is the role of matter in this system? How does it change? How does it enter and exit the system?
Is the role of energy and matter in this system similar to other systems I have learned about? How is it different?
Engineering(energy)- How can we improve the energy efficiency of this system?
Engineering(matter)- If we change the materials, does that improve the system?
How do the energy and matter in this system relate to other crosscutting concepts?
Based on what I've learned, what other symbol could be used to represent Energy and Matter?

Questions that connect to the Science and Engineering Practices-
Asking Questions- How does energy work in this system? How does matter function?
Defining Problems- How can I make this more energy efficient? How can I use energy to improve the system? How can the materials be improved?
Models- How can we model the flow of energy ? How can we model the cycling of matter?
Investigations- Can we design and carry out an investigation to determine how energy or matter affects this system?
Data- What does the data tell us about the effect of energy on this system? What does the data tell us about the matter in this system?
Using Math- How can we use math to quantify the energy and matter in this system?
Computational Thinking- How can computers be used to track matter or energy in this system?
Explanations- How can I explain how energy affects this system? How can I explain how matter changes in this system?
Solutions- Does the change in materials improve the system? Is energy being used to improve the system?
Argument- What is the evidence for how energy and matter affect this system?
Information- What is already known about energy and matter in this system? How can I best communicate about energy and matter in this system?

6. Structure and Function

How things are shaped and put together determines what they do. Where do you see a relationship between structure and function?

The keystone is a critical structure in an arch that gives it its function of strength Students can use the keystone symbol to show a relationship between structure and function

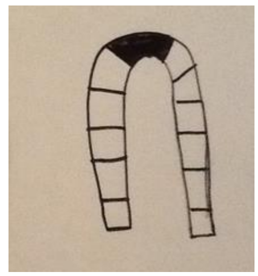


photo by Katie Elaine Armstrong

Why is the keystone and arch the symbol for structure and function? The arch is one of the earliest discoveries of engineering and is simple and easy to understand. Young children can build an arch and understand the importance of the keystone in holding it together. The arch as a symbol helps to connect the crosscutting concepts with engineering. The arch is easy to draw for young students and easy to see what it is when drawn

Critical questions for Structure and Function-

How does the function depend on the structure?
How does the structure support the function?
Are there other structures that can serve the same function?
How does this relationship between structure and function compare to others that I have learned about?
Engineering- How can the structure be improved?
How does the structure limit the function?
How do other crosscutting concepts relate to this structure?
Based on what I've learned, what other symbol could be used to represent Structure and Function?

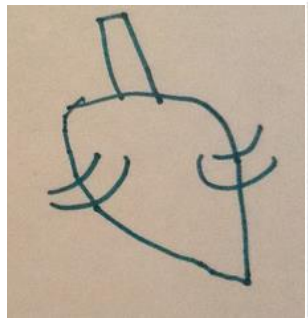
Questions that connect to the Science and Engineering Practices-

Asking Questions- How does the function depend on the structure?
How does the structure support the function?
Defining Problems- How can we design a structure to perform this function? How can we improve the structure?
Models- How can we model how this structure works?
Investigations- What variables about this structure can we change to find out how the function is affected?
Data- What does the data tell us about how changes to this structure affect its function?
Using Math- How can we use math to measure and describe the function?
Computational Thinking- How can computers be used to study how the structure affects the function?
Explanations- How can I explain how the structure is related to the function?
Solutions- Does the structure serve the function? Did the change in structure improve the function?
Argument- What is the evidence for the structure supports the function?
Information- What is already known about the relationship between structure and function in this system?
How can I best communicate about this relationship between structure and function?

7. Stability and Change

In nature, some things stay the same and some things change. Changes can be fast or slow. What reasons can you find for things changing or remaining stable? How are change and stability connected?

The constant spinning of a top is what keeps it in a stable upright position. Students can use the top symbol as they explore the relationship between stability and change



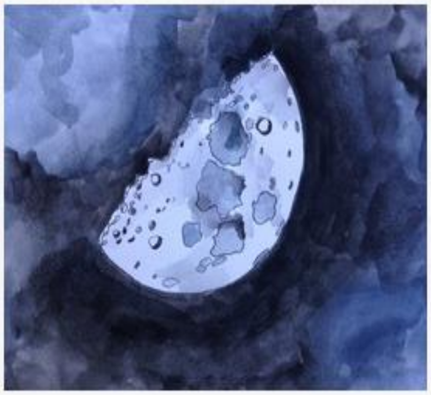
Why is the top the symbol for stability and change? The top represents a dynamic system that is fascinating and fun for young students to investigate. It is clear that the top's stability is affected by several factors and that within the stability of the spinning top there is constant change (precession). Students can investigate the spinning top and discover what makes it more and less stable. As students get older they can investigate the challenging physics behind rotational movement and apply it to the study of engineering and space systems.

Critical questions for Stability and Change?

What causes change in this system?
What causes stability in this system?
Are there feedbacks that make this system more or less stable?
Engineering- How can we make the system more stable? How can we make it change?
What is the time scale for this system to remain stable or change?
If the system is stable, what would cause it to change?
If the system is changing, what would make it become stable?
Is the stability static or dynamic?
How does stability and change in this system compare with other systems I have learned about?
What other crosscutting concepts relate to stability and change in this system?
Based on what I've learned, what other symbol could be used to represent Stability and Change?

Questions that connect to the Science and Engineering Practices-

Asking Questions- What causes change in this system? What causes stability in this system?
Defining Problems- How can we make this system more stable? How can we make it change?
Models- How can we model how this system changes?
Investigations- Can we design an investigation to study what leads to stability and change in this system?
Data- What does the data tell us about what affects the stability of this system?
Using Math- How can we use math to measure the rate of change in this system? Can math describe the balance that keeps it stable?
Computational Thinking- How can computers be used to analyze stability and change in this system?
Explanations- How can I explain why this system changes or remains stable?
Solutions- Have me made the system more stable? Does the system respond to change the way we want it to?
Argument- What is the evidence for the stability and change in this system?
Information- What is already known about stability and change in this system? How can I best communicate what I've learned about stability and change in this system?



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