Middle School

NGSS

The Private Eye® for the Next Generation

Looking / Thinking by Analogy

Middle School

The Private Eye® aligned with the Next Generation Science Standards

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Science and Engineering Practices & The Private Eye Process

NGSS “Science and Engineering Practices” are native to The Private Eye process!

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1. Asking Questions:
The four core Private Eye questions lead students into all eight Science and Engineering Practices in the NGSS. As students investigate any phenomena, as they to try to make sense of and understand the phenomena, natural or manmade, they typically begin by asking the 1st of four TPE Questions — “What else does this remind me of? What else does it look like? What else?” With this simple question they connect the phenomenon to their own experience as they forge comparisons they will mine for insight. There’s no wrong answer; all students can participate. The answers to this the initial question are analogies — in the compressed form of metaphors and similes. Analogies do many things, starting with: they capture characteristics. Students further explore these characteristics using the 2nd Private Eye Question: “Why did it remind me of *that*?”

2. Developing and Using Modeling:
NGSS says “Models include diagrams, physical replicas, mathematical representations, analogies and computer simulations.” A closer look reveals that most models ARE analogies! Student analogies generate models as well as hypotheses. When students ask the 3rd and 4th Private Eye Questions: “Why is it like that, I wonder?” they use their analogy lists as clues to why something is the way it is by asking the next Private Eye question: “If it reminds me of ________, I wonder if it might work or function like that in some way?” Or “Could I design something like that? **Could I design a model like that** to help give insight into my current puzzler or problem?”

3. Planning and Carrying Out an Investigation:
The Private Eye Questions lead students directly into planning and carrying out an investigation — into hypothesizing or “making sense of” why some object / material / event / reaction is the way it is (“Why is it like that, I wonder?”). Students generate and use analogies as clues to help answer that question — or for design solutions (“If it reminds me of ________, I wonder if it might work or function like that in some way?” Or “Could I design something like that?”) Students explain their thinking, then design tests for their hypotheses, run tests, construct explanations, argue from evidence, and pursue further research, and communicate tentative results.

During Private Eye investigations students design, run and repeat tests of their analogy-based hypotheses, record and share results, add research…

4. Analyzing and interpreting data (from their testing)

5. Using Mathematics and Computational Thinking: As students run and refine tests, they’ll estimate, measure, compute, chart, and graph results.

6. Constructing Explanations (for science) Students explain overlapping characteristics of an analogy and how the analogy can give insights and clues for why something is the way it is; they explain why they designed the tests they did, etc. **For engineering, students design solutions.** Student analogies prompt design solutions. “If ‘x’ reminds me of ‘y’ could I design something like that?” Biomimicry, for example, is based on analogies.

7. Engaging in Argument from Evidence: Students offer evidence of overlapping characteristics in their analogy; they offer evidence from test results to support or refute hypothesis, etc.

8. Obtaining, Evaluating and Communicating Information: Students use their own analogies as high quality springboards for obtaining, evaluating and communicating insight and information about phenomena.

> The NGSS claim-evidence approach is a key instructional shift and The Private Eye helps teachers make that shift:
> no longer are students mere fact collectors, they are critical thinkers who can apply their conceptual understanding to new situations. This raises the expectations for teachers to have lessons fit together coherently, build on each other, and help students build proficiency on a targeted set of performance expectations. This cannot be done through isolated science activities, reading about science or through student choice centers. In order for students to be proficient at the performance expectations based in the Core Disciplinary Ideas, teachers need to create high quality units that makes connections to the subject area, but also to the Common Core State Standards in Mathematics and English Language Arts to truly leverage student thinking and learning. The Private Eye provides the framework for those high quality units.

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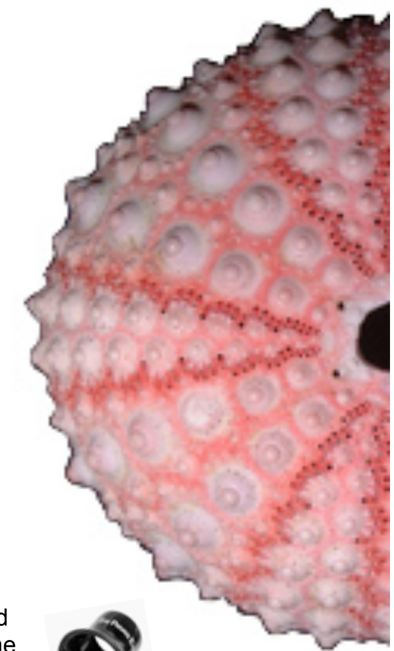
Crosscutting Concepts & The Private Eye Process

(Five are native to The Private Eye)

The crosscutting concepts are themes or ideas that cut across all the scientific disciplines and engineering. They are ideas that … prove fruitful in explanation, in theory, in observation, and in design. —Science for All Americans, AAAS 1989 as quoted in: "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" , National Academy of Sciences, 2012



1. Patterns:

The Private Eye increases pattern awareness and pattern recognition. The 5x loupe gives students a wallop of wonder and surprise; linked to the first Private Eye Question "What else does this remind me of?" — patterns appear and a hunt for similarities begins. Answers not only make pattern personal (and thus more memorable), they become clues to: "Why does this pattern exist?" What causes this pattern? (Clues are in the form of compressed analogies: i.e., metaphors / similes.) With a new found curiosity about patterns and with built-in clues to why a given pattern exists in nature, students generate hypotheses about patterns.

2. Scale, Proportion and Quantity:

All The Private Eye steps and activities engage students in *experiencing* and using the concept of "Scale, Proportion and Quantity." Students view objects and phenomena with one's unaided eye, see smaller and smaller parts using a 5x loupe, then move to a 10x view (two loupes are nested). With this incremental change students comfortably loupe-leap to the microscopic. They use microscopes and/or SEMS to view the objects at even smaller scales. This helps students of all ages smoothly build the concept that: "Natural objects exist from the very small to the immensely large." *

3. Structure and Function [also called "Form and Function"]

The Private Eye method is based on the structure/function relationship underlying all of nature. The relationship between structure and function is so tight in nature that where there are similarities in form (structure) between two different things or systems, there may be similarities in function. Students loupe-view (or microscope view) their object — and the small structures in the object — asking "What else does it remind me of? What else? What else?" Their answers create an analogy list — a list which explores characteristics and properties of a phenomena through the lens of comparison and provides clues to why something is the way it is.

Students use the second Private Eye Question, "Why did it remind me of that?" to explain the characteristics and properties embedded in the analogies. Now they have a way to answer: "Why is it like that? Why is this thing shaped or formed or structured the way it is?" by asking: "If it reminds me of _____, could it function or work like that in some way for the survival of the object or phenomenon?"

4. System and System Models:

Systems follow the same principles of Structure and Function relationships that the rest of the universe follows: Using The Private Eye students learn that form and function are so interdependent in nature that where there are similarities of form between two different things *or systems*, there may be similarities in function. Thus, to understand a new, unfamiliar system, students using The Private Eye ask "What else — what other systems — does this remind me of?", because "the two may function or work in similar ways". "Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering."*

5. Cause and Effect: Mechanism and explanation.

By heightening pattern-awareness, analogical thinking, and an understanding of Structure and Function relationships, students using The Private Eye more readily and successfully investigate cause and effect in phenomena: faced with a puzzling event, the quickest way to figure out the mechanism behind that event is to use The Private Eye strategy: "What else does this relationship / mechanism remind me of? What else? Because… if it reminds me of an event for which I already know the mechanism and cause, maybe the same kind of mechanism — or a similar mechanism — is causing this puzzling event." "A major activity of science is investi-gating and explaining causal relationships and the mechanisms by which they are mediated… [which are then] used to predict and explain events in new contexts."*

6. Energy and Matter: Flows, cycles, and conservation. "Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations."*

7. Stability and Change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

* "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" by the National Academy of Sciences

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3-D Learning with The Private Eye

Disciplinary Core Idea: PS1 Matter and Its Interactions

(Corresponding Topic: *Structure and Properties of Matter*)

Performance Expectation and the 3-Dimensions

MS-PS1-1: Develop models to describe the atomic composition of simple molecules and extended structures. [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [*Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of all individual atoms in a complex molecule or extended structure is not required.*]

DISCIPLINARY CORE IDEAS:
PS1.A: Structure and Properties of Matter

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PRACTICE: Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.

The Private Eye Alignment and Process

The NGSS has placed an emphasis on modeling that was previously not present in the majority of state science standards. Since the release of the NGSS, many teachers have been asking what modeling is and what it looks like in the classroom. Put simply, modeling is analogy! Models can take many shapes and forms, such as drawings, concept maps, graphs, and computer models, all of which are analogies that help us understand how the world works. For example, the drawings students create while Loupe-Looking can be annotated to develop greater complexity in the concept they are modeling. Furthermore, louped drawings can be used as a jumping off point for exploration of the Crosscutting Concepts of Patterns and Scale, Proportion, and Quantity.

Students can first use patterns to discover the beautifully regular macroscopic shapes of extended structures (e.g. pencil shavings and various crystals). Next, they can infer from their drawings that extended structures that have regular patterns macroscopically likely have regular patterns on a molecular level. Students use their minds eye and the concept of scale to extend their drawings down to the level of molecules, ions, and atoms. Analogies and TPE Questions can be used to draw out those observations and inferences.

The Private Eye Process

1. **Loupe-Look:** Start by eliciting student knowledge about pure substances. What do we know about them? How can scientists study them? Provide samples of pure substances for students to loupe such as minerals, metal/graphite shavings, and/or crystals. As students observe them under 5X and 10X magnification, ask them "What else does this remind you of?" Analogies related to patterns and structure will follow.

Lesson Examples

Geology – Crystals, Minerals, Rocks (p. 162) – Gather an array of different rocks, minerals, and crystals. Discuss why some have more regular shapes (crystals) while others have variable patterns and mosaics. Ask, "Why is it like that?" to elicit ideas about composition and purity. Models can be drawn to sort out ideas of regular repeating matrices in crystals versus mixtures of solid materials in sedimentary rocks. After Loupe exploration, small rocks and crystals fit under a 50X microscope for noticing finer detail and patterns within patterns.

Crystal Hunting (p. 162) – A major advantage of using crystals for this performance expectation is that you can compare crystals with repeating molecular subunits (e.g. snowflakes/freezer frost) with crystals composed of extended structures (e.g. ionic salts, quartz, or carbon matrices such as graphite or coal). Having different crystal types allows students to develop different molecular models based on their macroscopic observations,

CROSSCUTTING CONCEPTS:

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

Scale, Proportion and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

2. **Write:** To develop a model that includes scale, students will need to delve deeply into the question "Why is it like that" and "If it looks like _____, I wonder if it might be put together in a similar way?" This will help students target which distinguishing features to include in their drawings and annotations as they develop their model.

3. **Draw:** As students sketch out the patterns that they observe under the loupe, have them create annotations, magnification boxes, and/or other visual tools to illustrate what they can see macroscopically as well as hypothesize what they think is going on at the molecular level. Text and reference materials on their substance of study can support the latter. Use their macroscopic drawings to link their observations with research on the Core Idea of extended structures being composed of repeating subunits or large molecules.

4. **Theorize:** Pull together student drawings, annotations, and components of scale to revise their models. Adding to and revising models is a key component of sense making around a phenomenon. Help your students revise their models by facilitating a class gallery walk or group presentations. What do you notice about your classmate's models? Can you find something to add to yours? Have students share their analogies to advance their use of language and to construct meaning. Root the discussion in TPE Question 4: "If it reminds me of _____ I wonder if it might be put together in a similar way?"

deepening their understanding of different types of substances and their interactions. Students can compare the analogies used for ice with the analogies used to describe quartz or graphite. How are they similar? How are they different? Encourage students to critique each other's models and analogies, focusing on evidence from research that supports their louped observational evidence. Borax and Epsom salts both make excellent crystals, try different water temperatures for different sized crystals for additional inquiry.

Microcosm to Macrocosm (p.162) – This lesson is a perfect fit for highlighting the Crosscutting Concept of Scale, Proportion, and Quantity. Have students Loupe-Look a snowflake or freezer frost (it helps to put them on a glass slide already cold from the freezer or wooly fabric). Have students draw the crystals at increasing magnification (5X, 10X, 100X) to notice repeating structures. As they write and then draw, have students probe deeper into those structures in order to theorize what the molecular scale might look like. Providing information about hydrogen bonding may be beneficial at this point, but limit the explanation to the concept that some molecules are attracted to each other (i.e. intermolecular forces exist between molecules, governing geometric patterns of interaction).

3-D Learning with The Private Eye

Disciplinary Core Idea – PS3 Energy

(Corresponding Topic: *Energy*)

Performance Expectation and the 3-Dimensions

MS-PS3-3: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

DISCIPLINARY CORE IDEAS:

PS3.A Definitions of Energy

- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B Conservation of Energy and Energy Transfer

- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

ETS1.A: Defining and Delimiting an Engineering Problem

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.

ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.

The Private Eye Alignment and Process

The NGSS puts near equal weight on engineering design and scientific inquiry. This provides a wonderful opportunity for creativity, systems thinking, and hands-on engaging lessons! In this performance expectation, students meander through the entire engineering design cycle with the aid of their loupes to magnify their minds and their designs. The engineering design process is often non-linear. Once students have defined their problem, with criteria and constraints, they will go back and forth between prototyping, testing, more prototyping, sharing ideas and data, until reaching their final iteration. This iterative design process is key for instilling in students the idea that there is no perfect product, but simply ones that come closer to meeting criteria and fitting within constraints. Use the 3rd TPE question to get at this idea. "Why is it like that," will help students to evaluate their designs critically, always wondering if their design could be improved.

The Private Eye Process

1. **Loupe-Look:** Due to the visually interesting nature of insulating versus conducting materials, it is recommended to use the insulation option for this performance expectation when used with TPE. Provide a variety of insulating materials to students then use the questions "What else does it remind me of?" and "What else does it look like?," to draw out student observations as they loupe look the materials. Encourage them to use 10X to get at the finer details and small spaces.

2. **Write:** Have students group like materials and write analogies for each grouping. What do the different foams have in common? Fiberglass insulation?

3. **Draw:** First have students draw each material under magnification (5X and/or 10X). Now that they have had some observational experience, students will be ready to define their design problem, including both the criteria (goals) they are trying to meet and the

Lesson Examples

The Inventor: Problem Solving (p. 166) – Provide students with a variety of insulation materials, synthetic and biological (try **Dusty Miller (pp. 54-55)**. For the synthetic insulation materials, go to your local hardware store and get samples of various insulation materials. Styrofoam, pipe insulation, foams, bubble wraps, and fiberglass building insulation are all good options and provide interest under magnification. For safety, make sure to keep fiberglass insulation in a plastic baggie when louping and provide students protective gloves and plastic draping if they choose to use it for their designs. Insulating fabrics such as fleece and wool are also options. Once students have investigated the materials you provided, encourage them to explore their own homes, gardens, and stores for insulation materials to use in their designs.

You, the Inventor, the Designer, the Biomimetics Scientist (pp. 167-168) – Have students study and observe the ways that various animals stay warm. From Fly Fishing shops you can get swatches of different kinds of animal furs to loupe. Students then use this information to select synthetic and/or natural materials in their designs. Wool, fur, hair, feathers, blubber, and so many more adaptations have evolved to keep animals warm. Downy feathers and wool are easily obtained, have students observe their properties under loupe. Have students construct their own materials by modifying existing natural and synthetic ones.

PRACTICE: Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. **CROSSCUTTING CONCEPTS:** **Energy and Matter** • The transfer of energy can be tracked as energy flows through a designed or natural system. **Structure and Function** • Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.	constraints (limits) they are working within. Once defined, they can start playing with the materials and drawing out their design ideas. Encourage them to loupe look throughout this playful prototyping phase in order to include relevant material details into their drawings. 4. **Theorize:** As students design and build their prototypes, have them test the performance of their designs frequently. This can be done easily by measuring the temperature of the insulated liquid over a brief time period (the less it changes the better the insulation). Facilitate class discussions of their designs by using the 3rd and 4th TPE questions, “Why is it like that (why did it perform like that)?” and “If my design’s _____ (shape, materials, properties, etc.) reminds me of this other design, I wonder if its insulation could be improved by modifying it in a similar way?” This last question especially will help students improve their designs through the sharing of ideas and data. Additionally, it will compel students to understand how their designs work in relation to energy transfer and probe them to do further research and observation. Have students loupe-look each other’s designs to facilitate this critique and idea-sharing phase. With the sharing of designs paired with research, students will feel confident as they build their final design and test its performance.	

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3-D Learning with The Private Eye

Disciplinary Core Idea -
LS1 From Molecules to Organisms: Structures and Processes

(Corresponding Topic: *Growth, Development, and Reproduction of Organisms*)

Performance Expectation and the 3-Dimensions

MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]

DISCIPLINARY CORE IDEA: LS1.B – Growth and Development of Organisms

- Animals engage in characteristic behaviors that increase the odds of reproduction.
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.

PRACTICE: Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).

- Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

The Private Eye Alignment and Process

Engaging in Argument from Evidence is a powerful cross-disciplinary practice where students use evidence (collected and/or provided) to make claims supported by reasoning. Coaching students to use the claim-evidence-reasoning framework facilitated by The Private Eye Process is a great way to get students writing *and* talking about their ideas grounded in evidence. Using the Crosscutting Concepts to frame discussions of TPE questions will deepen student understanding. In this performance expectation, Structure and Function describes how a trait might work to aid reproduction. Cause and Effect is used to discuss how those structures might increase the probability of successful reproduction. The analogies students create with TPE questions first help them discover the Structure and Function link, then they use those discoveries to discuss and make claims about probability for reproductive advantage (Cause and Effect).

The Private Eye Process

1. **Loupe-Look:** Start your lesson with a specific phenomenon, such as flowering plant reproduction. Give students specimens of plant reproductive parts or live animals (such as pill bugs or fruit flies in a jar) to observe behaviors. Drawing attention to 1. Plant parts or 2. Animal behaviors, use the questions "What does it (the plant part or animal behavior) remind me of?" and "What else does it look like?" to help students look critically at their subjects with the aide of their loupes. The finer details of plant parts and minute behaviors are brought to life by the loupe. Use analogies to bring forth ideas about how structures might indicate functions.

2. **Write:** Have students choose an analogy or simile they would like to pursue further (e.g. the waltz of the fruit fly or the sticky tape stigma). This analogy is the

Lesson Examples

Seed Pods Pop (p. 145) – Collect/buy a selection of seed pods to investigate. Start your lesson with a discussion on seed dispersal and why it is important for reproductive success. Next, elicit student background knowledge on the various types of seed dispersal (e.g. wind, water, propulsion, animal, etc.). As students Loupe-Look ask them "What do you notice about the seed pods?" "What else does it remind me of? If it reminds me of a _______ (e.g. wing, trampoline, Velcro) I wonder if it might function like that in some way to disperse seeds?"

Cricket Jar and Waltzing Walking Sticks (p. 151) – First have students brainstorm ways that they know that insects/grasshoppers behave, and then ask them if any of those behaviors might be linked to reproduction. Have students perform close observation of movements and anatomy, can any of these parts/behaviors be related to reproduction? Help them distinguish between foraging and reproductive behaviors. Once they have described a behavior they can ask, "What does it remind me of? Why is it like that?" to delve deeper into the purpose and importance of that behavior.

Animal Weight Lifters and Farmers (p. 151) – An ant farm is ideal for observing the behaviors of the queen and workers as they build up a colony by laying eggs and doing all the tasks necessary to care for their young.

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CROSSCUTTING CONCEPTS:

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.

Cause and Effect

- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

basis of their claim, which states that structure or behavior X leads to some (i.e. low, medium, high) degree of increased reproductive success. After initial observations then writing analogies, students choose one feature to make a claim about.

3. **Draw:** Drawing is a key tool for eliciting quality evidence from student observations. Give students time to explore their structure/behavior in finer detail and encourage them to view each structure/behavior from multiple angles and magnifications (5X, 10X, 20X or greater on a microscope if possible). Encourage them to examine shape, texture, negative space, color, etc.

4. **Theorize:** Use the questions "Why did it remind me of that?" and "Why is it like that?" to help students come to the third part of their argument, reasoning. Reasoning is used to connect the evidence students gathered to the claim they made. For example, the glue like texture of the flower's stigma increases the likelihood that pollen will stick to then fertilize it. This supports the claim that the stigma is beneficial to the reproductive success of flowers. With more evidence, that claim can be strengthened. Customize the 4th TPE question to support students in formulating their reasoning, "If it functions like _____, I wonder if it might function like that in some way to improve the odds of reproduction?"

Caterpillar Thriller (p. 151) – Every step of a caterpillar's life cycle has evolved to increase its odds of survival and potential to reproduce. How does the caterpillar behave throughout its life cycle to achieve this goal? "What do those behaviors remind you of?" "What else? What else?"

Flower Power! (p. 146) and Beautiful Weeds (p. 147) – Flowers and, in particular, the flowers of weeds have an incredibly diverse array of structures that successfully increase the odds of pollination, fertilization, and/or seed dispersal. Use these organisms to peer into the secret world of plant sexual reproduction. Given that the entire flower's sole purpose is reproduction, students will easily identify multiple different sources of evidence to support their claims.

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3-D Learning with The Private Eye

Disciplinary Core Idea -

LS1 From Molecules to Organisms: Structures and Processes

(Corresponding Topic: *Growth, Development, and Reproduction of Organisms*)

Performance Expectation and the 3-Dimensions

MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [*Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.*]

DISCIPLINARY CORE IDEA:
LS1.B – Growth and Development of Organisms

Genetic factors as well as local conditions affect the growth of the adult plant.

PRACTICE: Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

The Private Eye Alignment and Process

The Private Eye Process of looking and thinking by analogy turns student observation into scientific explanation. Constructing explanations is key to fostering understanding that the natural world behaves in ways governed by the same basic mechanisms past, present, and future. If students gather evidence about a phenomenon, they are not just investigating that specific instance; rather they are gathering evidence that contributes towards a broader body of knowledge about cause and effect relationships. If all plants are related, for example, then it could be said that all plants will suffer from drought in a similar way.

Because of genetic traits, some species are more tolerant of drought, but without a certain amount of water, plant cells will always shrink and eventually die. This performance expectation is about the understanding of and differentiation between the influence of environmental and genetic factors on growth of organisms. By comparing the effects of environmental factors within a species with the differences between related species, conclusions about both environment and genetics can be made. When students investigate the growth of organisms under loupe magnification, differences in growth rates and patterns are amplified for high engagement student observation. With the addition of analogy, detailed explanations come forth with ease.

The Private Eye Process

1. **Loupe-Look:** This performance expectation calls for two distinct lines of inquiry, on the effects of environmental and genetic factors. Prepare your lessons by having two contrasting experiences, one where students loupe a single plant or animal species as it grows over time in a variable environmental condition (such as varying levels of water, pH, fertilizer, food, etc.). Additionally, students investigate two different (but related) species/breeds/varieties of

Lesson Examples

Dusty Miller and Cousins (p.147) and Dusty Miller (pp. 54-55) – Dusty Miller and its relatives in the Artemesia family are beautiful under the loupe and have a variety of interesting, genetically based, traits that promote their growth. That incredible forest of fuzz, "Why is it like that?" Might it help the plant grow? How? Compare it in the classroom or plant it in your school garden, observe it over the course of a month, which varieties grow fastest? Does fertilizer help?

Adopt a Seed (p.144) – It's exciting to watch a seed grow! See if the conditions you put it in will help it thrive, or prevent it from growing, possibly even change its form. Link this performance expectation with the ESS topic of Human impact and do an acid rain or drought study. How might pollution or climate change affect seed germination and plant growth? Do some plants grow faster than others? Are some more resilient to environmental change?

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CROSSCUTTING CONCEPTS:

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.

Cause and Effect

- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

plant or animal to observe the impact of genetic differences on growth. For example, red and white potatoes have very different (and beautiful under loupe!) growth patterns as they sprout.

2. **Write:** During each investigation, students focus on either genetic or environmental factors as they write their analogies. For example, the white potato's lumpy sprout totems pale in comparison to the red potato's myriad of sprout buds and branches. The differences in growth patterns are clearly genetic as you compare different varieties of plant or animal. Next, as students write about their environmental factor investigation, they can express their observations with detailed analogies. The radish grown in acidic water is stunted and small, dirt brown with sickly spots, while the ones grown in neutral water are vibrant, green as grass! The acidic radishes grow like a tortoise and the neutral ones like a hare.
3. **Draw:** As students draw their various organisms have them pay special attention to areas of growth. From where do the potatoes grow? Everywhere or just at the buds? How do the leaves grow? Where will the flower appear? What color is it? Does it look healthy? If not, how will you represent that in your drawing.
4. **Theorize:** In this final stage, students will put together their theories in the form of a scientific explanation. Students make claims about the effects of genetic and environmental factors and support them with evidence and reasoning. As they write their claim ask, "If it reminds me of _______ , I wonder if that factor (i.e. the environmental or genetic factor) might cause it to grow in a similar way?" Encourage students to use their written analogies and drawings as sources of evidence. To connect their evidence to their claim through reasoning, students answer the question, "Why is it like that?"

Slugs, Snails, and Puppy Dogs' Tails (pp. 157-159) – Helix is a great animal to keep in your classroom for long-term observation. Change Helix's environment and see how its weight is affected. If you can breed them or obtain them when they are small students will be able to see them develop into adult snails and test out their theories on what Helix likes best to eat, how much moisture it prefers, and what temperature it thrives best in. For genetic comparisons, obtain another variety of snail or slug and compare their growth rates in the same conditions. Do they behave differently as adults? What about the patterns in their skin and shells? Do those change as they get older?

Caterpillar Thriller and Mosquito Divers (p. 151) – Metamorphosis is one of the most stunning developmental processes in the animal kingdom! Observe multiple individuals of the same species (mosquito larvae or caterpillars) under different environmental conditions to see how things like food can affect their pupae, timing of eclosion (exiting of the pupa), or other observable behaviors. Then compare the pupae and other parts of the life cycle across insect species, how are they the same? How are they different? Close inspect1ion of eggs, larvae, pupae, and adults will yield a myriad of surprising observations when louped. Flies are hairy? Adults just emerged, are they a different color? How do you know when they are ready to mate?

Beautiful Weeds (p. 147) and A Plot of Grass (p. 148 – You don't need a field trip to observe nature up close**,** use any walkable nature space, or even your school field, to study how various factors might affect the propagation and growth of grass and weeds. Why is the grass thick here and thin there? Why do some weeds grow tall in the sun and others prefer the shade? As students observe the features of various plants have them get up close and personal to observe traits hidden to the naked eye. Theorize how those traits help them grow and how the environment makes growth harder or easier as they strive to reach maturity.

3-D Learning with The Private Eye

Disciplinary Core Idea -

LS2 Ecosystems: Interactions, Energy, and Dynamics

(Corresponding Topic: *Interdependent Relationships in Ecosystems*)

Performance Expectation and the 3-Dimensions

MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.]

DISCIPLINARY CORE IDEA: LS2.1 Interdependent Relationships in Ecosystems

- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

PRACTICE: Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.

The Private Eye Alignment and Process

The focus of this performance expectation the interaction of species in *different* ecosystems. Providing students the opportunity to gather evidence from diverse habitats allows them to construct explanations that apply across earth's ecosystems. With this approach, a deep understanding of how nature keeps in balance will emerge, preparing the way for student understanding of how human impact can upset that balance. Paired with this standard, The Private Eye is a perfect way to investigate the often hidden interactions happening in places that students least expect! What could be happening in just a few milliliters of pond water? A scoop of soil? The branch of a tree? In ecological communities, some of the most pivotal roles are performed by the tiniest members! Rather than telling students the role of each critter they observe, ask them "What else does this remind you of," to draw out clues that will lead them to the role each organism plays. With enough evidence, students will construct robust explanations of the patterns of interaction happening across ecosystems. They will explain, for example, that all ecosystems need decomposers, have competition (cross-reference evolution: the struggle for survival), and rely on producers.

The Private Eye Process

1. **Loupe-Look:** Start your lesson with louped observation of an ecosystem of your choice (remember, some ecosystems can fit in the palm of your hand!). Asking students "What does each organism remind you of? What else? What else?" will help students focus their observations on both the anatomical features and behaviors of their subjects. With the aid of analogy, students will turn the unfamiliar worlds of antennae and mouthparts into familiar images of catcher's mitts and garbage disposals.

Lesson Examples

"One-Inch Ponds and The Private Eye"
(Pond Lesson Handout) – This activity is a perfect way to observe a fully interactive ecosystem in the classroom! With visually interesting subjects like daphnia, seed shrimp, and elodea, students will easily write analogies that illustrate the many interactions happening in such a small space. Another advantage of the one-inch pond is its potential for variety.

Have students investigate different ecosystems simply by filling different ponds from different sources. How does a pond model whose source is a healthy natural pond compare to a pond model made from polluted waters? With a pond model created intentionally with organisms ordered from a biological supply company?

Alternately, students could start this investigation with a one-inch pond then go on a field trip or school site visit to observe interactions outdoors. How do aquatic ecosystems differ from terrestrial ones?

Aquatic organisms are particularly interesting under a loupe, making the one-inch pond both engaging and ripe for analogy!

CROSSCUTTING CONCEPTS:

Patterns

- Patterns can be used to identify cause and effect relationships.

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.

2. **Write:** Ask students "Why did it remind me of that? and "Why is it like that?" to help them turn their

   observations into an ecosystem roadmap. For example, watching seed shrimp sweep up detritus with their broom like mouthparts will cue students towards their role, they are the pond janitors! Encourage students to write at least 10 analogies per organism under observation.

3. **Draw:** Allowing students to visually process their observations with detailed drawings helps them notice the many ways in which organisms interact with their environment. Encourage students to draw multiple organisms on the same page and connect them with arrows annotated with proposed relationships. For example, if students observe two different insects eating the same plant, then they have now elucidated 3 relationships (two herbivorous and one competitive). At this point students may or may not have the academic language assigned to these roles, encourage students to use lay and academic terms to annotate their drawings. They can revise their explanations later with more research. The "Need to know," will drive academic language acquisition!

4. **Theorize:** Help students synthesize their observations of different ecosystems into a single explanation by asking the 4th TPE question "If this ecosystem has ______ relationships, I wonder if this other ecosystem has similar relationships?" Finding patterns in one ecosystem that can be generalized to all ecosystems will illuminate student understanding of the interconnectedness of the natural world.

Bug Safari and Impromptu Aquariums (p. 156) - Similar to the above approach for 1-Inch Ponds, have students make terrariums or larger aquariums. Make both to compare and contrast!

A Yard of Yard , A Plot of Grass, Backyard Safari, Beach Louping, and Log as Cradle (p.148 and 151) – Having students observe a discreet areas of different habitats, even just a square yard, allows a student to focus their observations and keep a reasonable scope for their ecosystem maps. Whether grass, shrub, nurse log, or beach, pick a natural location and set students loose with their loupes. Students will quickly be motivated to find each and every organism that keeps that habitat in balance. Don't forget to have them look for traces of organisms as well. A stray feather or footprint indicates the presence of yet another trophic level to include in their explanation. By investigating the trace under loupe, they may be able to guess at the species that left it.

		A Cup of Soil (p. 148) – Soil is habitat rich with interactions and dynamic changes. Which organisms supply the raw material for soil? Which organisms break those materials down? Can we find evidence of these processes by loupe looking? What are the roles of insects? Earthworms? Are there any predators lurking? Again, looking for traces of organism (even animal feces is a clue) will help students to elucidate the various relationships buried in earth and time. **George Washington Carver's Garden and Collections (p. 148)** – Have students read about George Washington Carver to inspire their inner naturalist and inventor! Explore a garden or forest; through careful observation a la Carver, students will begin to see organisms in a new light. Furthermore, extend this activity to include engineering. How can we use the roles organisms play to solve problems? Design a worm bin or school garden to put students' ecological knowledge to use. **The Winding of Worms (p. 149) -** Worms play a great many roles in the functioning of ecosystems. Observe them under loupe to discover the many ways that they promote the growth of plants. Pair this anatomical study with the observation of worms in their natural habitat to elicit even more theories on terrestrial interaction!

3-D Learning with The Private Eye

Disciplinary Core Idea - LS3 Heredity: Inheritance and Variation of Traits

(Corresponding Topic: *Growth, Development, and Reproduction of Organisms)*

Performance Expectation and the 3-Dimensions

MS-LS3-2: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. [Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]

DISCIPLINARY CORE IDEAS:
LS1.B – Growth and Development of Organisms

- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring.

LS3.A – Inheritance of Traits

- Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.

LS3.B: Variation of Traits

- In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.

PRACTICE: Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop a model to predict and/or describe phenomena.

The Private Eye Alignment and Process

Students come to our classrooms with a wealth of personal and cultural knowledge. Reproduction is one area in particular where students have wide (but varied) knowledge banks, yet it remains an area riddled with misconceptions. For one, students often assume that most or all organisms reproduce sexually, that is how humans reproduce after all! In this instance, Loupe Looking can be used to observe the very many ways in which asexually reproducing organisms are exactly (or nearly) the same. Conversely, students often come to class with the conception that humans and other sexually reproducing organisms are vastly different from other individuals of the same species. While it is true that we are all unique, we are much more similar than we are different! One must look closely to see that even though our skin, our fingernails, and our eyes may be different colors, they all have similar shapes and compositions. Peering even deeper, however, we can see that indeed our uniqueness does come through, in the form of iris starbursts, the loops and whorls of our fingerprints.

Students often gravitate towards obvious outward appearances when observing organismal traits (skin color, height, hair color, etc.), while many of the much more important traits remain hidden. Loupes help students peer deeper into subtly different traits. Furthermore, the analogies that students make to characterize traits can be used to frame the contrasting models they make for asexual and sexual reproduction, dispelling those common misconceptions.

The Private Eye Process

1. **Loupe-Look:** Provide students with an organism that was produced asexually (cloned fruits such as oranges and bananas make great subjects). Students can use themselves as an example of an organism produced sexually. For asexual

Lesson Examples

Animal Coverings: The Fabulous Body Suit (pp.160-161) – Skin, fur, hair, scales, and feathers reveal secret details when viewed under the loupe. Provide students with a variety of animal coverings (keep in mind most of these organisms are produced sexually). Start out with how we are the same, remember, the commonalities among us are much greater than our differences. Probe further, however, and students will start to recognize the subtle variations in coat pattern, scale alignment, skin moisture, feather length, etc.

Most students know that humans have unique fingerprints, but what are the "fingerprints" of other animals? Coat patterns and the overall shape and spacing of fingerprints are genetically inherited, but keep in mind that some variation is not a result of genetic variation, but rather variation derived from random events during development (point of discussion: do identical twins have the same or different fingerprints? In fact they have very similar, but unique fingerprints, therefore making fingerprints both a genetic and environmentally based trait). Other variations, such as skin moisture, color, and hair texture/form also have a genetic basis. The iris of the eye is also a wonderful subject to loupe, have students look at each other's eyes to peer into one of the most variable of human traits!

Genetics, Environment, and Evolution: Variation within a species (p.165) – The concept of variation, and the degrees of variation produced from sexual versus asexual reproduction, is often difficult for students to grasp. With close observation of both types of organisms, students will see that all species have variation. However, it is the degree of variation that sets the two types of organism apart. Have students observe a variety of species and ask them to categorize them by sexual and asexual

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CROSSCUTTING CONCEPT: **Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural systems.	reproduction, ask the question "What do you notice is the same?" "What else?" "What else?" For their human observations, have them first observe their commonalities under loupe (e.g. skin texture). Next, have them look deeper, "What can we see under the loupe that makes us unique?" "What else is different?" **2. Write:** For each organism, have students write lists of analogies for the features they observe. "What is similar? What is different?" This will form the basis of their model for asexual versus sexual reproduction. **3. Draw:** Student models will require evidence; drawings are a great way to support the claims their models make. As students draw the differences they observe, have them pay particular attention to detail. Precision is required when drawing a fingerprint. Remind students that we use fingerprints during crime scene analysis, it is important to get those details right! **4. Theorize:** The fourth TPE step is of particular importance to this performance expectation. Students are expected to develop a model of both types of reproduction that accounts for the inheritance, variation, and development of traits. This calls for a robust model well supported by evidence. "Why is it like that? Why do all ________ (i.e. an asexually species) look nearly identical?" and "Why is it like that? Why do _____(e.g. humans, dogs) have unique characteristics?" "If _____ looks the same/different, I wonder if it might have a genetic basis for being the same/different?" Have students research the differences between body cells and sex cells to pair with the observational and analogic aspects of their model. With all three components, their models will show a deeper level of understanding than if approached from the standpoint of cellular division alone.	reproduction. Carefully observation, documentation, and theorizing will allow students to notice more and more ways in which some organisms vary greatly, while others have a striking lack of variation. This discussion can be made relevant with reference to our food supply. If all of our bananas are clones, what would happen if a disease strikes? Is there a benefit to maintaining genetic diversity in our food supply? **The Simple Touch (pp. 136-137) and Your Hand (pp. 84-87) -** Students may naturally gravitate towards fingerprints when observing their skin under loupe. Have students examine their fingerprints, make ink fingerprints, or even better create a cross-curricular art project! Fingerprints have three basic shapes: whorls, loops, and arches. These shapes have a genetic basis so students can go home and take their parent's fingerprints too; do theirs look similar to both parents? Just one parent? This can be a great starter to the discussion around meiosis, dominance, and polygenic (multiple gene) traits. Sometimes we look more like one parent than the other, "Why is it like that?"  Furthermore, fingerprints can be used as an analogy to the "fingerprint" of our genetic code. The term fingerprint has been assigned in popular culture to the unique features organisms possess. The idea that we are all unique is made real with fingerprint analysis! For inspiration on an artistic extension, check out fingerprint art galleries on the TPE website at http://www.the-private-eye.com/html/galleries/fp1html/gal1.html and http://www.the-private-eye.com/html/galleries/fp2html/gal2.html

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3-D Learning with The Private Eye	**Disciplinary Core Idea – LS4 Biological Evolution: Unity and Diversity** (Corresponding Topic: *Natural Selection and Adaptations*)	
Performance Expectation and the 3-Dimensions	**The Private Eye Alignment and Process**	**Lesson Examples**
MS-LS4-2: Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.] **DISCIPLINARY CORE IDEA: LS4.A Evidence of Common Ancestry and Diversity** Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent **PRACTICE: Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events. • Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena. **CROSSCUTTING CONCEPTS:** **Patterns** • Patterns can be used to identify cause and effect relationships. • Graphs, charts, and images can be used to identify patterns in data. **Structure and Function** • Complex and microscopic structures and systems can	Constructing explanations based on evidence is the cornerstone of the intersection between the NGSS and CCSS Math and ELA practices. With this performance expectation, students can naturally engage in The Private Eye process of looking and thinking by analogy to identify similarities between closely related species and then notice differences between more distantly related organisms. The analogies students create provide an organizational scaffold for students to structure their observations within a framework of evolutionary relationships based on anatomical evidence. With this analogy-driven organization of adaptations, students can ask, "Why is it like that?" to probe further into evolutionary past. **The Private Eye Process** 1. **Loupe-Look:** Use the questions "What else does it remind me of?" and "What else does it look like?," to draw out student observations of common traits in a collection of species. 2. **Write:** Students free-write analogies as they observe the species for which they found similarities. "The armored beetles, the scaly wings of the butterfly and moth, the kaleidoscopic eyes of the insects". 3. **Draw:** Using the groupings of organisms created during their brainstorm writing phase, students draw their traits under 5x and 10x magnification. Adaptations come to life! Details observed under the loupe draw out observations of additional similarities and differences. After 5X and 10X, it's natural for students to want to leap to 20X and higher views. 4. **Theorize:** Use the questions "Why did it remind me of that?" and "Why is it like that?" to draw out student ideas on adaptation and evolutionary relationships. Students construct an explanation for relationships by drawing a family tree or cladogram then translating it into a written explanation based on evidence from their drawings and louped observations. Pairing	**World in a Box™ (p. 68-69) –** Use your collection of specimens to help students discover evolutionary relationships. Have students find similarities between organisms and draft a cladogram. Facilitate a class discussion comparing the characteristics students used to place each species on the tree of life. What analogies did they use? How did those drive their decision-making? **Adopt a Seed (p. 144) –** Acquire a variety of fast growing plant seeds (radish, turnip, lettuce, carrot, etc.) Have students loupe the seeds and use analogy to identify similar and different characteristics. Plant the seeds and use additional observations over time to revise student explanations on evolutionary relationships. This highlights the practice of "revising your thinking" based on additional evidence, a scientific habit of mind. **Seed Pods Pop (p. 145)** – Collect/buy a selection of seed pods and discover the different ways plants have adapted to disperse their seeds. Do closely related organisms have similar strategies for seed dispersal? What do you notice about the seed pods? If it reminds me of a ________ (e.g. parachute, boat, hook) I wonder if it might function like that in some way? **Skeleton Leaves (p. 146)** – Can the patterns of veins on leaves be used to infer evolutionary relationships? **Wild and Wooly (p. 150), Files and Fly Cousins (p. 151), Fish Scales (p. 151) –** Use groups of related species (e.g. fish, flies, insects) as subjects for The Private Eye process. What do the organisms have in common? What does it remind me of? Why is it like that? Construct a family tree/cladogram driven by analogy.

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be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.	written explanations with class discussion will help students further develop their claims and critique the sufficiency of their classmate's collection of observational evidence. Use the question "Why is it like that?" to naturally steer the discussion towards the concept of common ancestry and adaptation in response to the environment. Support students' use of language when constructing explanations for relationships by using the 4th TPE Question to make inferences about evolutionary relationships: "If one organism's________ — i.e., some of its structures, forms, features — reminds me of this other organism (a modern species or a fossil)… I wonder if they could be related?"	**Evolution Time- Line Game (p. 164) –** Which traits evolved first? Can we tell based on our louped drawings, observational evidence, and analogies?

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3-D Learning with The Private Eye

Disciplinary Core Idea -

ESS2: Earth's Systems

(Corresponding Topic: *Interdependent Relationships in Ecosystems)*

Performance Expectation and the 3-Dimensions

MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [*Assessment Boundary: Assessment does not include the identification and naming of minerals.*]

DISCIPLINARY CORE IDEA: ESS2.A Earth's Materials and Systems

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.

PRACTICE: Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop a model to predict and/or describe phenomena.

CROSSCUTTING CONCEPTS:

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

The Private Eye Alignment and Process

As with all performance expectations, the clarification statement provides excellent guidance on the scope of the learning students will demonstrate. In this standard, emphasis is placed on a number of different processes (crystallization, weathering, etc.) to intentionally guide students towards the conclusion that earth's processes are connected through time by the energy contained in the earth's core and the heat of the sun transforming and transferring matter. By approaching the cycling of earth's materials as one system of interconnected processes, students develop a more complete, nuanced model than if they had learned each process independently.

The Private Eye supports this interconnected approach to sense making through modeling with sequential observation and analogy. For example, students might first observe limestone, a fascinating and abundant sedimentary rock, with embedded shells and other organic matter. Next, they could observe marble, a metamorphic rock formed from limestone due to huge amounts of heat emanating from the earth's interior and pressure from tectonic plates. What do the two rocks have in common? How are they different? What else do they remind you of? By observing various materials before and after a process has changed them (e.g. limestone to marble, rough rock to smooth rock, solutions to crystals, crystals to sand)

The Private Eye Process

1. **Loupe-Look:** Magnify your mind as you explore before and after geologic snapshots of earth's materials to understand the processes that change them. Students will discover how natural processes change the composition, structure, and textures of matter as they compare materials changed by those processes. Provide students with a range of materials paired by process. For example, to show weathering students might compare the texture of

Lesson Examples

Geology – Crystals, Minerals, Rocks (p.162) – What is a rock? Help students understand what a rock is made of and how it forms by observing the minerals (mostly made of crystals) that compose rocks. Some rocks, such as the sedimentary rock leopard jasper, have beautiful crystals visibly embedded in them that spring to life under the loupe. Other rocks have grains too fine to

see. Compare the structures of different types of rock; can observations of those differences give us clues about the forces that formed them? Have students make borax crystals and observe naturally formed crystals (amethyst is particularly beautiful under the loupe!) to explore the process of crystallization.

In a Grain of Sand (p. 155) and Sand (p.162) – Ask friends and students to bring back sand from their beach adventures. What is in sand? How did it get there? How did the rocks it came from form? What else is in sand but rock? Quartz, a crystal, is a large component of

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Scale, Proportion and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Energy and Matter

- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.

rough and smooth rock, or whole quartz crystals and sand containing quartz grains. Students can even observe some processes in real time, crystallization happens over night! Have students take home their crystals as they grow atom-by-atom into regular three-dimensional structures, millions of layers in an hour!

2. **Write:** As they compare each process-paired material set, ask the question, "What else does it remind me of?" to elicit observed similarities and differences. As students find similarities, they can extend those ideas to understand what's going on the molecular level. For example, sandstone and Quartzite (a metamorphic rock of sandstone) are similar in color, but not in texture. Might this observation give a clue as to how quartzite is formed?

3. **Draw:** As students draw the various shapes and textures of their materials, additional details and analogies will come forth. "Why did it remind me of that?" Close observational on the macro scale gives insight into the changes occurring on the molecular scale.

4. **Theorize:** Ask students, "Why is like that?" and pair the discussion with emphasis on the crosscutting concept of energy and matter. "What source of energy could transform grainy sandstone into solid metamorphic rock (quartzite)? Why do atoms arrange themselves into regular shapes as they cool? What fuels the process of weathering? If it reminds me of ________, I wonder if it might be formed in a similar way?" As students make conclusions, have them record and organize their theories and observations in their model. Rich models with detailed drawings, arrows showing the flow of energy and matter, and annotations explaining each process will emerge as students discuss their ideas.

sand, can they spot quartz? Volcanic rocks? If they find bits of shell and other traces of organisms, that can lead to discussion of sedimentary rocks, and how they form from sand and other sediments to lock away the secrets of organisms long past.

Deep Time: Rock as Clock. How old is that dragonfly? How old are we? How old is the Earth? – Pair this performance expectation with MS-ESS1-4: "Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6 billion year old history." How long does it take to form a metamorphic rock? How long for quartz to weather into sand? For sand to turn back to rock? Linking different performance expectations deepens student understanding and saves valuable class time. Geologic time is notoriously difficult for students to grasp, use analogies to help students grasp the scale of geologic space and time.

Characteristics or Properties Using Analogies (p. 142) – Encourage students to refine their observations with analogies. The patterns in marble, are they like water rippling or fractures in ice? More details will help students better understand the formation

We live on a crystal planet in a crystal world. The rocks which form the earth, the moon, and meteroites… are made up of minerals and virtually all of these minerals are made up of crystals.

From Crystal & Gem, Symes and Harding (Eyewitness Books, Knopf, NY, 1991)

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Disciplinary Core Idea - ESS3: Earth and Human Activity

(Corresponding Topic: *Human Impacts)*

Performance Expectation and the 3-Dimensions

MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

Disciplinary Core Idea: ESS3.C Human Impacts on Earth Systems

- Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

PRACTICE: Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).

- Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

CROSSCUTTING CONCEPT: Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

The Private Eye Alignment and Process

Using the crosscutting concept of cause and effect is an excellent touchstone for students to draw on as they construct their arguments for this performance expectation. With the root cause of an increasing human population, what evidence can students cite to argue that this change impacts earth's systems in consequential ways?

Because human population has a direct effect on total resource consumption, it is a good idea to start your lesson with a brainstorm on ways that humans consume resources. Encourage your students to think about resources that they don't necessarily see in their everyday life, or which are hidden inside the things they use all the time. What resources are used to make a cell phone? To power the lights in the room? Where do those resources end up after they have been used? This is a good opportunity to bring up the topic of renewable versus nonrenewable resources and other conservation topics such as recycling and composting. Another effect of population increase is an increase in waste production. Have students inspect the school trash cans to catalog a list of common waste materials for further investigation.

The Private Eye Process

1. **Loupe-Look:** Whether you are investigating products for consumption or waste material, students should investigate a variety of objects for this lesson, optimally collections of objects that have differing compositions and structures. For example, cell phones are one of the fastest growing electronic products in the world. What materials are used to make them? What is in a circuit board? What else does it remind me of? Conversely, have students investigate different forms of waste. What does the garbage in a trash can remind me of? How is that different from what we put in a compost bin?
2. **Write:** As students write analogies describing the

Lesson Examples

Old and New (p. 147) - Contrast the appearance of fresh buds and leaves with that of dead plant material. What does biodegradation look like? What are the benefits of using renewable plant materials for everyday products on Earth's systems? What can we observe about synthetic materials that might indicate their inability to biodegrade?

A Yard of Yard (p. 148) - Start with a yard and go further! Host a school-focused loupe-guided litter patrol. Many people might notice large pieces of trash and litter but is there evidence of microplastic hidden in the soil or on the sidewalks? Have students pick up collections of school yard debris and take it back to the classroom to classify based on environmental impact.

Write the Biography of a Plant (p. 148) and Write the Biography of ______ . Inspire students to look inside the life story of the objects they investigate. Where do these everyday objects come from? Is their source renewable or nonrenewable? Where is it destined to go? Has it impacted climate change? Did its harvest or will its disposal displace natural ecosystems? The biography of a plant might include the making of paper and being recycled, but where was the tree grown and what were its impacts? By observing small structural details of the objects in our lives, it gives us clues about the origin and future of those objects. Have students present their biographies to the class. As students discuss the various histories and futures of their materials, have them rank them on a scale of most to least impactful on earth's systems. A rousing debate may ensue! Encourage students to provide evidence from their drawings and analogies as they argue whether their object has a low or high impact on the environment. For complex objects like circuit boards you might have students work in research teams, to investigate all the various materials and processes that go into making and disposing of those products.

Fantastic Voyage (p. 142) - Take a change of scale journey through an old computer or taken apart a cell phone. Have students draw an exploded view of the

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	structures and functions of their various materials, have them create categories that will help them contextualize the impact of those materials on earth's systems. For example, you might have students classify wastes as biodegradable or non-biodegradable. Resource materials as renewable or nonrenewable. Encourage students to share their category choices and justify their thinking based on their louped observations and analogies. Have students do additional internet research to form clear definitions of these categories as well as to research global consumption/production of the materials they are investigating. Quantitative data is made real when students observe the qualities of the objects they investigate first hand! 3. **Draw:** Using their categories as a pictorial framework, have students loupe draw collections of materials and objects with like classifications. For example, you may have given students a banana peel, styrofoam, a dead leaf, tissue paper, and a piece of nylon rope as examples of common waste materials. As students review their analogies and draw, they might ask "why did it remind me of that?" biodegradable materials have natural fibers and irregular structures, while synthetic materials are more regular in appearance. 4. **Theorize:** "Why is it like that?" By analyzing fine detail in different materials, students will begin wonder where these materials came from. A mine? A factory? A farm? The school yard? Thinking about the sources of products brings rich context to the objects in our everyday lives. "If these objects are in the same category, I wonder if they might have been made in a similar way?" Have students return to their research on the sources and destinations of the objects they have investigated. What metals are used in a circuit board? Where do they come from? What is plastic made from? What types of objects can be made from plant materials? What makes something compostable? What would happen to this material if it ended up in the ocean? By answering these questions and linking their observations and research back to human population, students will have a much deeper understanding of the impact humans have on earth's systems.	materials and patterns they observe under the loupe. There are many different materials and processes involved in making these devices and they are more in demand than ever before. As students take a voyage through the complex world of high-tech products, they will discover the far reach these devices have on global supply chains and disposal sites. Once students have isolated the various parts and materials, asking, "What else does it remind me of" will help them identify the materials and components. Pair these observations with research to annotate their exploded view drawings. Students should work collaboratively to create a holistic map of the device, where it came from, and where it might end up.

