Powerful Practices Series

The POWER of Investigating

Guiding Authentic Assessments

Julie V. McGough and Lisa M. Nyberg

NSTA press
National Science Teachers Association

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Arlington, Virginia

“We keep moving forward, opening new doors, and doing new things, because we’re curious and curiosity keeps leading us down new paths.”

—Walt Disney

Dedicated to our parents, who nurtured curiosity by encouraging questions and inspiring our quest to explore the world!

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Connecting Questions and Investigations

Developing Investigations

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Engaging Students and Teachers in Investigations

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Color Coding

Throughout *The Power of Investigating*, the text, illustrations, and graphics are color-coded to indicate the components of the instructional model.

Questions are printed in **red**.

Investigations are printed in **blue**.

Assessments are printed in **purple**.

Combining thoughtful **questions** with engaging **investigations** produces amazing **assessments**—just as combining **red** and **blue** colors produces **purple**.

We've also provided links and Quick Response (QR) Codes to the NSTA Extras page where you can view videos related to content throughout the book. Visit *www.nsta.org/investigating* to view all supplementary content.

The Authors

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Ms. McGough has taught for more than 20 years, working with students from preschool through fifth grade. She currently teaches at Valley Oak Elementary, in Fresno, California. She has also worked as an adjunct faculty member and a master teacher preparing new teacher candidates for California State University, Fresno. Her teaching has been recognized with the Crystal Award in her district, and she is a California state finalist for the Presidential Award for Excellence in Science and Mathematics Teaching.

Ms. McGough's academic background includes a BS in education and an MEd in gifted education. She is currently pursuing a PhD in science education. Ms. McGough works as a leader in professional development and serves on the curriculum design team for her school district. She served on the NSTA Preschool and Elementary committee and has published in the NSTA journal *Science and Children*.

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Dr. Nyberg has taught for more than 30 years as an educator of students ranging from preschool to graduate school. Dr. Nyberg currently works as an elementary science and technology teacher educator at California State University, Fresno. Her teaching has been recognized through a number of awards and features, including the Presidential Award for Excellence in Science and Mathematics Teaching, the National Science Foundation Award for Excellence in the Teaching of Mathematics and Science, the Disney Channel Salutes the American Teacher, and the *PBS ScienceLine* (Public Broadcasting System) and *Learning Science Through Inquiry* television series. Businesses have also acknowledged her work, awarding her the OMSI/Techtronix Award for Excellence in Teaching and the American Electronics Association Award for Science Teacher of the Year.

Dr. Nyberg's academic background includes a BA in biology, a BS in education, an MS in education, and a PhD in curriculum and instruction. She has served as a board member for NSTA's Preschool and Elementary Division and its Preservice Teacher Preparation Division. In addition, she has served on a number of advisory boards, including those of PBS and the Children's Television Workshop for the television show *Sesame Street*.

Dr. Nyberg has worked as a leader in professional development. She has written and edited books, articles, and grants in the areas of science education and communication, including an award-winning book, *How To Talk So Kids Can Learn* (Scribner 1995), which focuses on communication strategies that teachers and parents may use to optimize learning.

The *Powerful Practices* Series

The Power of Investigating is the second book in the NSTA Press *Powerful Practices* series. The first book, *The Power of Questioning,* was selected by educators and publishers of the Association of American Publishers as a REVERE award finalist. The REVERE Awards identify and honor high-quality resources that educate learners of all ages.

PART 3
How Do I Integrate Investigations?

Sustaining Purposeful Investigations

How Do I Connect Investigations Within a Unit of Study?

Related investigations help students connect concepts and develop deep understanding. For example, an investigation of worms connects to previous learning experiences about other animals and leads to investigations of plant life. Students research the differences between amphibians and reptiles based on a spontaneous investigation of animals a child brought to the classroom. Working with worms prompts the question, "Are worms amphibians?" Students make connections and use prior knowledge to analyze and determine similarities and differences between amphibians and worms. They connect that worms are prey for many animals and play an important role in growing plants, which leads to investigations about food chains and food webs.

Students connect ideas and build on previous learning experiences as they actively practice asking questions and defining problems. In this way, learning transforms from a two-dimensional experience (words and pictures on a page) to a three-dimensional experience (active and engaged interaction with content). Three-dimensional learning experiences increase the complexity and accessibility of the content for *all* learners (for example, visual, auditory, and kinesthetic learners).

How Do Investigations Support Depth of Knowledge?

Webb's (2005) Depth of Knowledge (DOK) framework helps determine the level of cognitive demand or rigor (McGough and Nyberg 2015, p. 22). Connecting investigations within a thematic unit of study (see Figure 3.1) and in conjunction with project-based learning helps teachers and students transition from learning about skills and concepts (DOK Level 2) to strategic thinking and reasoning (DOK Level 3) and extended thinking (DOK Level 4). The complexity increases, leading to multidimensional thinking and learning! For example, building owl boxes to help the farmers in a local community communicates student reflection and understanding of the interdependent relationships in an ecosystem and allows them to contribute beyond the classroom.

Figure 3.1. Depth of Knowledge (DOK) Framework Applied to Interdependent Relationships in Ecosystems

DOK Level 1: Recall and reproduction

- Requires recall of information such as fact, definition, term, or simple procedure, including following a simple process or procedure.
- Typically requires one step. Example: Recall the fact(s).
- Question: What are the parts of an owl? Name the parts of an owl.

DOK Level 2: Skills and concepts

- Includes mental processing beyond recalling or reproducing a response.
- Requires more than one step. Example: Make observations and infer an explanation.
- Question: What do owls eat? Dissect owl pellets. Observe the bones from the pellet to determine what the owl ate.

DOK Level 3: Strategic thinking and reasoning

- Includes cognitive demands that are complex and abstract with more-demanding reasoning.
- Requires multiple steps.
- Question: How could we design an owl box to help the farmers in our community? Design and build a model owl box to determine the accurate measurements for a specific type of owl.

DOK Level 4: Extended thinking

- Requires high cognitive demand using higher-order thinking processes such as analysis, synthesis, and reflection; involves very complex ideas across multiple content areas.
- Possible question: How can we communicate what we have learned, and what can we do to positively affect our local environment? Make brochures to present information and inform, and build owl boxes to donate to farms.

How Does the Powerful Practices Model Integrate the Science and Engineering Practices?

A Framework for K–12 Science Education (NRC 2012) states, "[W]e use the term 'practices,' ... to stress that engaging in scientific inquiry requires coordination both of knowledge and skill simultaneously" (p. 41). The Powerful Practices model dynamically integrates questions, investigations, and assessments with all eight science and engineering practices to offer three-dimensional learning experiences for all students.

The practices support English-language learners by encouraging communication through modeling, developing explanations, and engaging in argumentation. "From the very start of their science education, students should be asked to engage in the communication of science, especially regarding the investigations they are conducting and the observations they are making" (NRC 2012, p. 77).

The practices integrate purposeful reading and writing to engage students in thoughtful argumentation by supporting reasoning with evidence from text and collected observations and data from investigations. Life itself is full of wonder! When we observe, we can ask questions such as, "How does it work?" "Why does it look the way it does?" "How does it connect to other things?" and "Why is it important?" Then we ask, "How can we find out?" and "How can we support our explanation with evidence?"

The science and engineering practices help students develop connections through meaningful experiences, deepening their understanding of the world and how it works. Investigations provide interesting and relevant learning opportunities to help students make sense of complex concepts and engage them in further study. Figure 3.2 shows how the science and engineering practices could be implemented in a study of birds of prey.

Figure 3.2. Science and Engineering Practices for a Study of Birds of Prey

1. **Asking questions (for science) and defining problems (for engineering)**
   How will we know what size to make the owl box? What kinds of owls live in the orchard where we will place the owl box?

2. **Developing and using models**
   How should we design the inside of the owl box?
3. **Planning and carrying out investigations**
   How will we dissect the owl pellet?
4. **Analyzing and interpreting data**
   How will we know what kinds of animals the owl ate? Using information from the data table, how do we know where the raptor's habitat is according to the food source?

5. **Using mathematics and computational thinking**
   Use pattern blocks to model a raptor's wingspan. Measure the blocks with a yardstick and compare students' "wingspans" to that of a bird of prey.

6. **Constructing explanations (for science) and designing solutions (for engineering)**
   We know the owls ate two rodents because we found two rat skulls.
7. **Engaging in argument from evidence**
   I think this feather belongs to a Harris's Hawk because of the markings on the tip of the feather.

8. **Obtaining, evaluating, and communicating information**
   Teach others about our experience through writing, building models, and presenting information.

How Do Investigations Support Learning Through Thematic Units?

Thematic units shape big ideas by providing multiple experiences to develop a depth of understanding rather than covering disconnected topics. "Organizing information into a conceptual framework allows for greater 'transfer'; that is, it allows the student to apply what was learned in new situations and to learn related information more quickly" (NRC 2000, p. 13). Integrating a variety of teaching strategies across multiple subject areas offers opportunities for active engagement and critical thinking.

The Unit Planning Guide in this book (pp. 17–19) designs learning experiences around the *NGSS* disciplinary core idea LS2.A: Interdependent Relationships in Ecosystems. A thematic unit based on a river ecosystem offers opportunities to study many kinds of animals, their needs, and how they use their body parts to seek, find, catch, and eat food. The river ecosystem as a thematic unit transforms S.T.E.M. into S.T.R.E.A.M.S. by integrating reading, art, and social studies with science, technology, engineering, and mathematics. Students engage in the scientific and engineering practices as they make connections across disciplines, developing understanding of important concepts.

An integrated thematic unit designs learning experiences to transform a simple topic such as fish into a complex study of how salmon grow, develop, live, and interact with their habitat. Authentic investigations build in-depth knowledge, leading to connections and further questions. Students engage in science and engineering practices as they ask questions, investigate the life cycle of salmon, and produce authentic assessments such as models of predators (a bear and an eagle). Providing art lessons or including a local artist who works with animals or landscapes can support learning about animal patterns (for example, camouflage) and texture. Social studies lessons support student connections to local geography and social interactions (for example, agriculture and farming in the river valley). Integrated thematic investigations transform learning experiences from two-dimensional to three-dimensional.

This student is reflecting on the thematic journey…

- watching salmon eggs hatching
- making alevin models
- creating adult salmon art
- designing a waterfall entry
- building a bear predator model
- constructing an eagle predator model
- releasing salmon into the river

How can you build integrated investigations?

Scan the QR Code or visit *www.nsta.org/investigating/video7.*

How Do Investigations Support Learning Through Project-Based Learning?

"It is the process of students' learning and the depth of their cognitive engagement—rather than the resulting product—that distinguishes projects from busywork" (Larmer and Mergendoller 2012, p. 2). Project-based learning (PBL) includes significant content about something students need to know, a driving question, and inquiry and innovation to create a product to present to others (Table 3.1).

Project-based learning that is focused on the *NGSS* disciplinary core idea LS2.A: Interdependent Relationships in Ecosystems provides significant content for students designing a project to restore plant life at the river after a damaging drought (Figure 3.3). A driving question for this project might be, "How does the river habitat affect the animals that live there?" Students need to know this information as they interact with the environment around them. They observe life cycles (for example, of insects, frogs, plants, and salmon), compare and contrast animal classifications (such as amphibians and reptiles), and learn about predator–prey relationships. Students engage in critical thinking, collaboration, and problem solving as they make decisions using student voice and choice to develop 21st-century competencies. The project involves revision and reflection to think about their learning and changes they may need to make before presenting the project outside the classroom.

Table 3.1. Eight Essentials for PBL

1. Significant content
2. A need to know
3. A driving question
4. Student choice and voice
5. 21st-century skills
6. Inquiry and innovation
7. Feedback and revision
8. Publicly presented product

Source: Larmer and Mergendoller 2012.

Figure 3.3. Students Planting New Trees Along a Riverbank as Part of a Project to Restore Plant Life at the River After a Damaging Drought

The relevance of the focus and content provides meaningful engagement as students recognize the effect of a drought on the river and plan ways to restore the riverbank with new plants.

Building Integrated Investigations

When investigations are integrated thoughtfully, a dynamic learning environment is created and is visible in the classroom. The diagram in Figure 3.4 shows the flow of creating, constructing, and connecting that produces integrated investigations. Figures 3.5 and 3.6 show evidence of how investigations lead to authentic assessments. In Figure 3.5, the teacher constructed a plan using informational text and images on the wall to focus instruction on the life cycle and needs of salmon, including engineered models of salmon eggs, alevin, and an adult salmon. Figure 3.6 shows

Figure 3.4. Visualization of the Create, Construct, Connect Concept

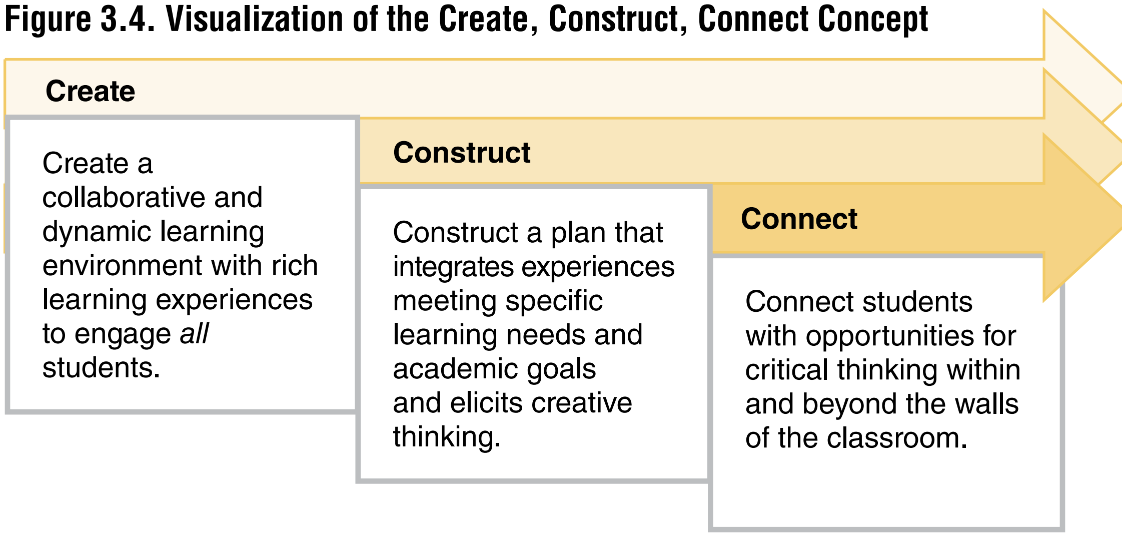


Figure 3.5. Dynamic Classroom Learning Environment

how students think critically as they connect what they have learned in the classroom when they release the young salmon into a nearby river. Figures 3.7 (p. 74) and 3.8 (p. 75) show examples of creating, constructing, and connecting at work in three-dimensional integrated learning.

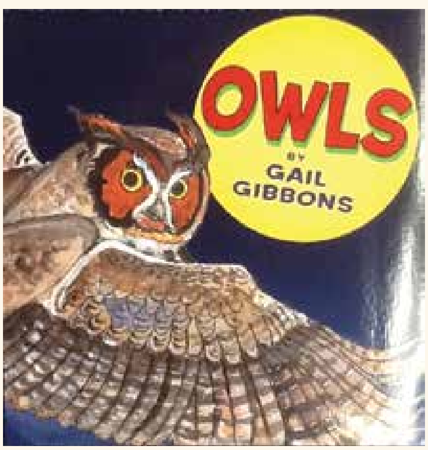
Figure 3.6. Example of Connected Learning

One student, Tomoya, observed fish in an aquarium and labeled a fish drawing (top left), and read books about fish (top right). When learning about the salmon life cycle and the complexity of the river ecosystem, Tomoya's knowledge deepened. He made connections to other animals and developed an understanding of interdependent relationships of predators and prey. A class field trip to release the salmon in the river offered Tomoya and other children an opportunity to reflect on their responsibility of caring for the environment (bottom left and right).

Figure 3.7. Three-Dimensional Integration: Studying Owls

Create Interest

Student interest may lead to a unit of study about different birds of prey. Students may ask, “How are birds of prey similar and different?” Inviting a guest speaker who works with the local wildlife rescue or accessing live web cams can offer students experiences with real owls and raptors. Dissecting owl pellets gives students a hands-on experience.



Construct Experiences

Reading engaging books such as *Owls* by Gail Gibbons may support a topical study of owls. Students may ask, “How do owls move?” and “Why are owls nocturnal?” Additional books and videos support investigations to study the physical characteristics of owls (for example, the beak, talons, ears, and wings) and compare and contrast owls with other birds of prey.

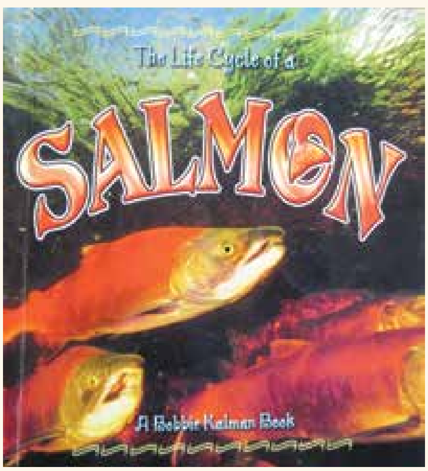
Connect Learning

A study of interdependent relationships in ecosystems offers the opportunity to ask, “How do plants and animals interact in an ecosystem?” and “How do owls impact our local farming community?” Building model owl boxes connects math and engineering. Students may collaborate, plan, and build real owl boxes to donate to farmers in the local community.

Figure 3.8. Three-Dimensional Integration: Studying Salmon

Create Interest

Student interest may lead to a unit of study about the life cycle of salmon. Students may ask, "How do salmon grow and develop?" and "Why do they live in the river and the ocean?" Observing salmon eggs in the classroom helps students see the life cycle up close.



Construct Experiences

Reading engaging books such as *The Life Cycle of a Salmon* by Bobbie Kalman and Rebecca Sjonger may support a topical study of fish or salmon. Students may ask, "What are the parts of a fish?" and "Why do some fish live in a river and others in the ocean?" Additional books and videos support investigations to study salmon or fish in general.

Connect Learning

A study of interdependent relationships in ecosystems offers the opportunity to ask, "What can we do to help the salmon survive in a river in our area?" Releasing salmon raised in the classroom into the local river connects students to the environment. Engage students in educating the community about river pollution. Students may organize a cleanup day at the river.

How Does Investigating Create Opportunities That Lead to Deeper Questioning and Authentic Assessments?

Integrating literacy through questioning and investigating enables students and teachers to construct understanding that leads to authentic assessment opportunities. The language of academic discourse and metacognitive strategies is modeled in authentic learning experiences and class discussions. Through consistent modeling and interaction, students learn the skills of questioning and metacognition and learn to apply these skills to small-group and independent learning situations.

Sometimes big questions arise after multiple exchanges with familiar content. Empower students in the process of learning by integrating multiple intelligences! Students need to question, investigate, and show understanding. Howard Gardner states,

> "Everything can be taught in more than one way. Anything that is understood can be shown in more than one way. Assessment should not be something that is done to you. It should be something that you are the most active agent. The child is at the center of learning." (Edutopia 2016)

Questions cultivate student investigations. Student engagement cultivates more questions! Investigations enhance reading, writing, technology, and learning. As students reflect on the learning process, they generate new questions and opportunities for authentic assessment. What does assessment in the Powerful Practices model "sound" like?


I heard the frog make a sound and saw his throat get bigger as the sound changed. How does sound work?
How does sound help animals communicate?
What can I make or do to show what I learn about sound?

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The POWER of Investigating

Guiding Authentic Assessments

"How does a teacher build and maintain a learning environment that will help students investigate meaningful questions?"
—from Part 1 of *The Power of Investigating*

The Power of Investigating invites you to capture the potential for learning with children—who are natural investigators. But this pedagogical picture book does more than just *describe* how to build investigations—it also *shows* you, so you can easily implement the investigations right away in your own K–5 classroom. Authors Julie McGough and Lisa Nyberg provide the following features:

- Vivid photographs and videos that let you see and hear teachers and students engage in investigations that integrate STEM practices and literacy skills. The seven featured videos show you how teaching can be fun and produce amazing, authentic assessments.
- The theory and strategy to help students investigate meaningful questions and communicate their findings. You will explore ways to plan and manage investigations and use resources that bring learning to life.
- Models of five types of investigations that will help students develop literacy skills.
- Ways to maximize instructional time by integrating the *Next Generation Science Standards,* the *Common Core State Standards*, state standards, and STEM education practices.

As the second book in NSTA's *Powerful Practices* series, *The Power of Investigating* builds on the questioning strategies modeled in *The Power of Questioning*. The authors are veteran educators who know how busy and demanding today's K–5 classroom is. A powerful tool in a small package, the book provides fresh, lively strategies you and your students will learn from and enjoy.

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GRADES K–5

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