Instructional Sequence Matters

Grades 6–8

Structuring Lessons With the NGSS in Mind

Patrick Brown

NSTA press
National Science Teachers Association

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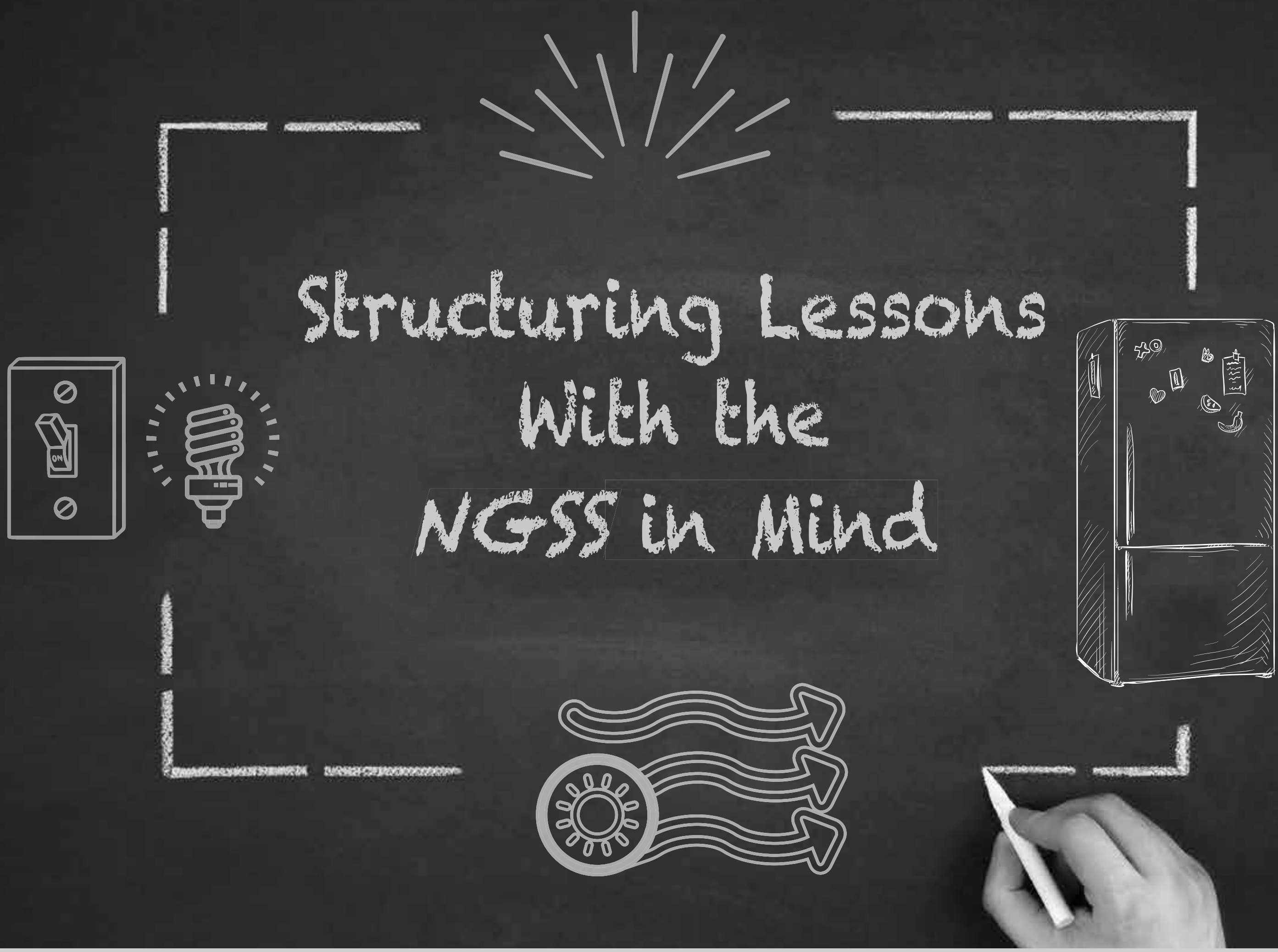

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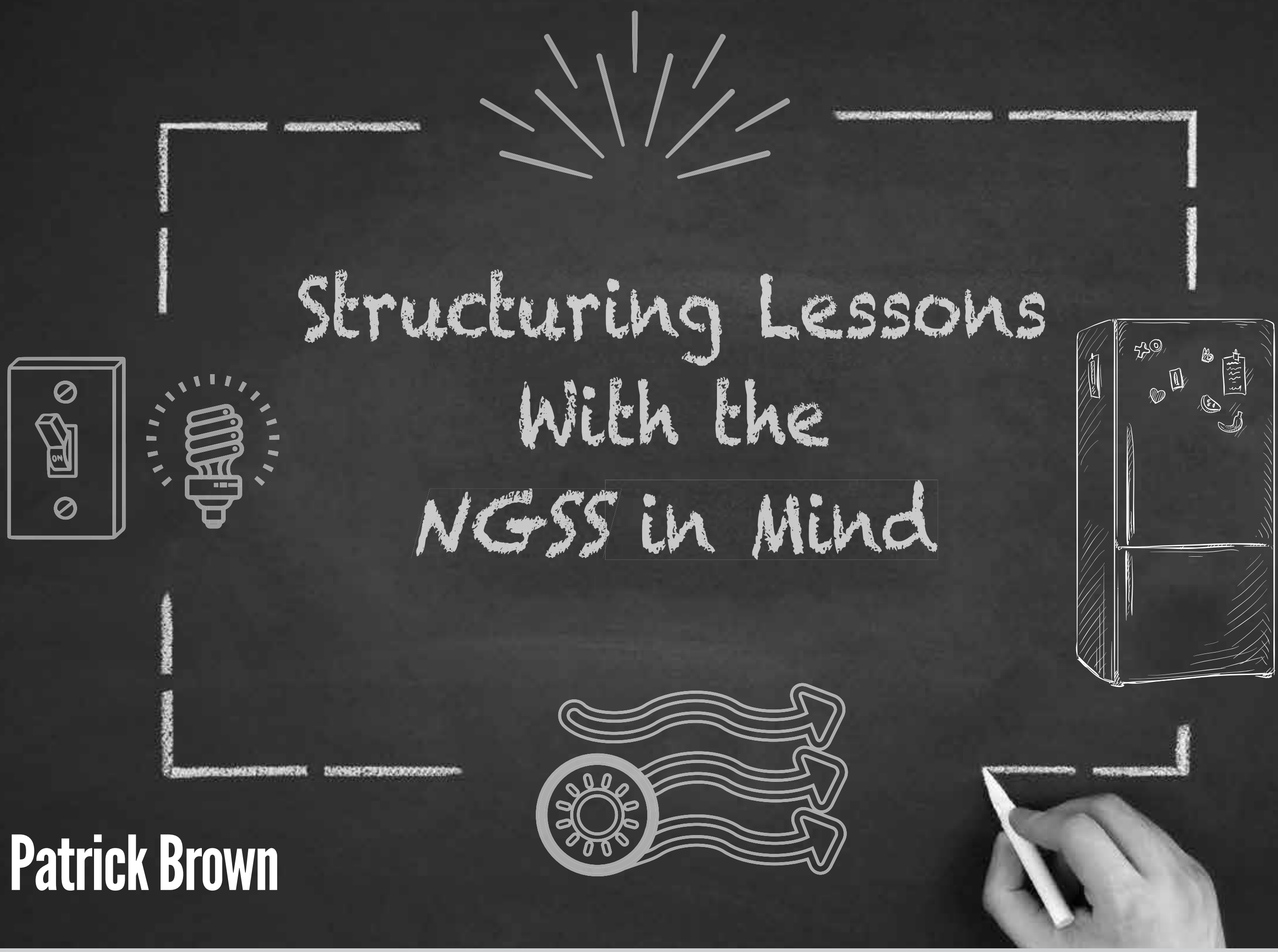

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National Science Teachers Association

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This book is dedicated to my parents, Gene and Elon Brown, whose belief in my abilities as a student and writer many years ago started me on this journey.

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Foreword

Rodger W. Bybee

From time to time, one identifies a new leader, someone the community has not recognized—yet. Then one goes to an NSTA conference and hears a presentation, joins a webinar, or reads an original book and realizes the leadership that is evident. This happened as I read *Instructional Sequence Matters: Structuring Lessons With the* NGSS *In Mind, Grades 6–8*.

Patrick Brown provides a wonderful book for science teachers. Not only is *Instructional Sequence Matters* a delightful read, it also is practical and helpful. What more could science teachers ask for?

After beginning chapters on students' development and learning, modern sequences of instruction (including the 5E instructional model), and the synthesis of science concepts and practices, Dr. Brown describes various instructional strategies, such as demonstrations, readings, investigations, videos, and lectures, all components of integrated instructional sequences. The bulk of the book illustrates what it means to effectively teach science concepts such as heat and temperature, magnetism, and electric circuits.

Through the narrative and examples, Dr. Brown encourages teachers to change their mind-set about their instructional sequence. Using terms from the 5E Instructional Model (Bybee 2015), Dr. Brown demonstrates what it means to think about and apply *explore-before-explain* as a mind-set for teaching. Why did Patrick Brown embrace this mind-set? In his career, Dr. Brown observed and subsequently conducted research on preservice science teachers who had difficulty embracing the 5E Instructional Model because it was very different from their experiences and subsequent images of teachers and teaching and their successes as science students.

The rationale for using *explore-before-explain* as a mind-set also recognizes the importance of students constructing claims based on evidence before teachers provide explanations of science phenomena.

Finally, the examples help the reader address the dimensions of science and engineering practices, crosscutting concepts, and disciplinary core ideas as presented in the *Next Generation Science Standards (NGSS)* and many contemporary state science standards. Each example of an instructional sequence has clear connections to the *NGSS* and *Common Core State Standards.*

Foreword

In the final chapter, "Leadership Can Make the Difference," Patrick Brown lists lessons for teachers—for example, focus on science phenomena, emphasize *explore-before-explain* teaching, plan 5E and POE lessons that incorporate *NGSS* domains, and recognize that changing one's mind-set about teaching takes time and conscious effort.

I was originally drawn to this book because of Patrick Brown's use of the 5E Model. Reading the book reinforced my first engagement with the book. Soon, however, I found other compelling reasons to recommend this book to all science teachers. The book is written by a teacher for teachers; it provides model lessons with a personal narrative that includes the decisions Patrick Brown had to make as a teacher and weaves in connections of the three dimensions of *NGSS*; finally, the book uses the 5E Instructional Model and presents descriptions of the model with insightful examples. Without any hesitation, I recommend this book.

—Rodger W. Bybee, author of *The BSCS 5E Instructional Model: Creating Teachable Moments* (NSTA Press, 2015)

Acknowledgments

I am very grateful to some key educators who have contributed in numerous ways to my understanding of *explore-before-explain* teaching. To Dr. Patricia Friedrichsen and in memory of Dr. Sandra Abell, who provided me with opportunities and encouragement to develop 5E lessons and to research the development of teacher knowledge. To my close friend and colleague Dr. James Concannon for his continued collaboration in creating 5E lessons for K–12 students. To Mrs. Kathryn Hopkins (an *explore-before-explain* teacher in social studies) for always sharing ideas about effective teacher professional development.

Thank you also to the Fort Zumwalt School District. To the administrators, curriculum coordinators, and teachers for their strong support of teacher scholarly work and professional development. I am indebted to my students, and their intellectual work learning science transformed my understanding of *explore-before-explain* teaching.

I would also like to express my sincere gratitude to Claire Reinburg, Rachel Ledbetter, and Deborah Siegel at NSTA Press for their outstanding work. I am very appreciative to the educators who reviewed the first version and offered comments about its strengths and suggestions for changes and additions. I would like to give special thanks to Susan German, who provided insightful feedback on earlier versions of this book.

My deepest gratitude goes to my family. To my children, Finn and Lua, who validate for me that young kids have instinctive scientific aptitudes and use these capabilities to better know, understand, and appreciate the world they live in. Lastly, to my wife, Cathy, who is a skillful and compassionate leader in her own field of disability rights advocacy and motivates and supports me in all of my endeavors. This book is richer because of my family's support.

About the Author

Dr. Patrick L. Brown is the Executive Director of STEM and Career Education for the Fort Zumwalt School District in St. Charles, Missouri. Before arriving at Fort Zumwalt, he received a PhD in curriculum and instruction from the University of Missouri, Columbia. He completed a postdoctoral fellowship at Washington University in St. Louis and was the Assistant Director at the university's Teaching Center .

Dr. Brown has a range of K–12 and postsecondary teaching experience. He has taught middle school courses in physical science and high school classes in biology. In addition, he has taught both undergraduate and graduate courses for prospective elementary, middle, and high school teachers. Dr. Brown has won various awards for his science methods course teaching.

Dr. Brown makes frequent presentations at international, regional, and state conferences and is known for his scholarship on instructional sequences to teach science. His science teaching ideas have appeared in *Science and Children*, *Science Scope*, *The Science Teacher*, *Science Activities*, and a recently published book on using classroom inquiry to address the *Next Generation Science Standards*. His research in science education has been published in *Science Education*, the *Journal of Science Teacher Education*, and the *International Journal of Science Education*.

Introduction

Young kids are natural scientists. For instance, they are puzzled when rainbows appear in the sky, when the leaves change colors, and when the Moon goes through different phases. Their observations can lead to questions about how the world works. Ever curious about their world, children instinctively try to answer their scientifically oriented questions by looking for patterns and causal relationships. In this way, they propel themselves to understanding from what they can investigate firsthand. Young children enter school as scientists and use firsthand explorations to explain the natural world. I firmly believe that a major task of science teaching is cultivating the innate skills child scientists bring to school. Bringing an *explore-before-explain* mind-set to science teaching is a way to developing the budding scientists in each of your students.

Two popular ways to put an *explore-before-explain* mind-set into practice is to use the POE and BSCS 5E Instructional Models. Both build students' conceptual foundation that helps them generate fundamental insights into how our world works. In addition, the POE and 5E Models allow students to derive content knowledge using science practices, a productive approach that mirrors how science is done in the real world.

If you are already aware of the power of *explore-before-explain* teaching and the POE and 5E Instructional Models, this book may help you begin to reflect on ways to make instruction even more effective for students. However, I hope it will do more than that. Others have written about using the 5E and POE Models in teaching (see Abell and Volkmann, 2006; Haysom and Bowen 2010). My approach is consistent with their ideas, but at the same time, it is unique. I hope the research, techniques, and activities that follow will help you with national reform aimed at putting *A Framework for K–12 Science Education (Framework)* and the *Next Generation Science Standards (NGSS)* into practice.

The *Framework* and *NGSS* have raised many questions for teachers. Some of the first that come to teachers' minds are "How is the *NGSS* going to change my teaching? How do I convert the *NGSS* into practice?" Although the new standards reflect advancement in how we structure lessons for students, having an *explore-before-explain* mind-set and using the 5E and POE Models allows for the seamless transition of the *NGSS* put into practice. Here is my journey to translating the *NGSS* into practice.

A General Overview for Using This Book

This book provides a self-guided professional development experience. My goal is that teachers will read the chapters, reflect on their practices, learn from the examples, and use the design principles to start creating 5E and POE lessons that align with the *NGSS*. This book draws heavily on the research on effective professional development that highlights the important role of active learning in context and explicit reflection on practice (Reiser 2013). In addition, research from *The Cambridge Handbook of Expertise and Expert Performance* recognized that developing knowledge is most meaningful if it is integrated into practice (Ericsson et al. 2006). As such, teachers will need time to think about the sequence of science instruction and the *NGSS* to become experts and will probably not be perfect right at the start.

Each chapter of this book grew out of research experiences and working with students and through teacher preparation and professional development. I have embedded activities aimed at sparking your thinking about your own experiences and designing *explore-before-explain* instructional sequences (see the activity boxes throughout the chapters). I have learned through research that teachers can have difficulty embracing the 5E Model because this instructional sequence is different from their experiences as students and their mind-set toward science teaching (see Brown, Friedrichsen, and Abell 2013). Success in K–16 science and experiences provide robust ideas about what science teaching could look like and how to best prepare students to develop their understanding. You can use the discussion questions to reflect on, both individually and with colleagues, your beliefs about science teaching and experiences as a learner. Our experiences as learners, current work with students, and beliefs about effective instruction can be powerful evidence for our ideas and inform our future practices. During the reading activities, make note of ideas so you can easily reflect on their initial discussions after experiencing model lessons. The combination of reflection questions, research chapters, and model lessons strongly supports an *explore-before-explain* mind-set.

I start with the research (e.g., Chapter 1, "Rethinking Development and Learning") on learning and cognition. This chapter takes you through some of the emerging ideas about students' intellectual abilities and the implications for instructional sequence. Chapter 1 closes with some suggestions for how to get started.

Chapter 2, "Modern Sequences of Instruction," discusses the key components of two contemporary sequences of science instruction. You will read about the phases of the POE (Predict, Observe, and Explain) and 5E (Engage, Explore, Explain, Elaborate, and Evaluate) Instructional Models. The activity boxes are aimed at helping you reflect on hands-on practices you currently use and how they may be sequenced to promote even higher levels of learning.

In Chapter 3, "Content and Process Working Together," I describe the construction of the *NGSS*. I share some activities for you to reflect on lessons you currently use and the connection to components of the *NGSS*.

Next, Chapter 4, "Where to Start," provides guidance on how you can create your own 5Es that translate the *NGSS*. I present activities following each factor you should consider when planning 5Es so they can provide planning ideas for designing *explore-before-explain* instructional sequences.

In Chapters 5–9, I share model lessons for putting the explore-before-explain mind-set into practice using either a POE or 5E instructional sequence. In addition, the model lessons illustrate how both the POE and 5E Models easily translate into the *NGSS*.

The model lessons have activity boxes to develop your abilities to design POE and 5E instructional sequences. In addition, the narrative portions of the model lessons are coded with specific elements of the *NGSS* (Appendixes F and G from NGSS Lead States 2013). An *NGSS* summary table is also provided to show the close connection between student actions and *NGSS* dimensions. The model lessons allow you to see the POE or 5E Model and *NGSS* in action.

Chapter 10, "Leadership Can Make the Difference," takes you through five key points to putting an *explore-before-explain* mind-set into practice using POE and 5E sequences and the *NGSS*. The final chapter can help emphasize the steps necessary for supporting colleagues and developing collaborative teams interested in developing POEs and 5Es into practice.

Conclusions

Teacher educators and professional developers can easily implement these lessons to model best practices in science education. Beginning teachers can use the model lessons so they have research-based strategies to improve student learning during their first years of teaching. Many experienced teachers who already value hands-on approaches but find that their lessons fall slightly short in influencing students how they intended can benefit from simple reorganizing activities. Reading and discussing the chapters provides valuable insight into why some approaches may be more beneficial than others. Thus, teachers have real-life examples and a rationale for restructuring the hands-on approaches they are currently using. Regardless of the level of experience, from novice to expert teacher, educators can read, implement, and dissect each model lesson to help reflect on how the sequence of science instruction promotes long-lasting understanding.

The chapters build on one another so you can consider why some activities may be even more effective than others and so you can try them out with your students. Many teachers realize that simple shifts in the arrangement and combination of activities can positively affect student learning to promote long-lasting understanding. In addition, effective science teaching is not always about working harder—it is about working smarter. Reflecting on and experiencing exploration before explanation instructional sequences opens up opportunities to construct a theoretical model for classroom lesson design so all students gain higher levels of science literacy.

Chapter 5

Teaching About Heat and Temperature Using an Investigative Demonstration

Chapter 5

In professional development workshops and methods courses, I use this chapter as a starting point for eliciting teachers' views of the effective sequencing of science instruction in classroom demonstrations. Many teachers already value minds-on experiences from demonstrations; however, they are unsure what knowledge students can construct. In addition, beginning teachers are not sure when they need to provide explanations that build on students' experiences. After trying the lessons, I have found that many beginning teachers have the same inaccurate conceptions that students have about thermal energy transfer.

This lesson is designed to anchor student learning around the following phenomenon: How does energy flow into, out of, or between an air-conditioned house and the outside during a hot summer day if the door to the house is left open? This is a confusing subject, and research has indicated that many middle school students have trouble understanding that thermal energy naturally transfers from the warmer object to the colder object until both objects reach the same temperature (Driver et al. 1994; Keeley, Eberle, and Tugel 2007). I have created a lesson-level performance expectation (PE) to build students' understanding toward the broader expectation (i.e., the lesson-level PE is "develop and use a model to show that energy spontaneously transfers out of hotter regions or objects and into colder ones"). By working together, teachers can create a dialogue with students about energy transfer. The model lesson highlights the connections of the learning activities to the three dimensions of the *Framework* with specific footnotes that code the narrative to the SEPs and CCs.[1] This chapter is a tool for thinking strategically and helping teachers become more reflective practitioners.

1. Footnotes in Chapters 5–9 show the relationship between student actions that occurred during the activity and specific elements of the SEPs and CCs appropriate for grades six through eight. The specific elements of the SEPs and CCs were coded from Appendix F and Appendix G, respectively (see NGSS Lead States 2013).

Activity Box: Exploring the POE Model Lessons

Use the activities below to reflect on the model lessons in Chapter 5. Go back and forth between your reflection journal and the model lessons. You can use the activities individually or as a group to reflect on how the POE sequence of instruction influences student learning.

1. **Try out a model lesson from Chapter 5 (POE lesson) with a group of students or consider using the design structure and sequence for an activity of your own.**
2. **Reflect on students' responses to the lesson in terms of their motivation and learning. Think deeply about the research on cognition and sequence of instruction (e.g., How did students react when you asked them to make predictions? List students' misconceptions/prior thoughts. Were students' prior ideas similar to those identified in the model lesson? What were students' observations and evidence-based claims?).**
3. **Identify any salient research points you noticed when using the model lesson with students that you want to remember and use when designing your first POE.**
4. **Brainstorm a list of upcoming demonstrations or student investigations you could sequence in a POE lesson.**
5. **Use the footnote connections to interpret how the narrative translates to the *NGSS*.**

Predict (Three to Four Minutes)

The demonstration begins by having students predict what will happen when two half-full beakers of water at different temperatures are mixed. Students' predictions are intimately connected to questions about what will happen when two different temperatures of water are mixed and tied back to the phenomena driving the unit (i.e., transfer of thermal energy). I involve students in the investigation by having volunteers take the temperature of the two containers of water. Later on, students will continue to play an investigative role, collecting data to answer overarching questions about energy transfer.[2]

2. Students engage in SEPs and investigate "questions that require sufficient and appropriate empirical evidence to answer" (NGSS Lead States 2013, p. 51).

Students find that one beaker contains water at 30°C and the other beaker contains water at 15°C. At this point, students commit to their predictions by recording (on a whiteboard or a piece of paper) what they think the water temperature will be after the two beakers of water are combined (see Table 5.1). Predictions that are not graded encourage students to take a risk and communicate their scientific understanding of phenomena without having to worry about the grade they will receive for their ideas.

Table 5.1. *Students' Preconceptions and Postconceptions of Heat Transfer*

- The *subtraction* conception means that students thought that the lower-temperature water would be subtracted from the higher-temperature water.
- The *average* conception means that students thought that the two different temperatures of water would reach a temperature that is the average of the two different temperatures of water.
- The *addition* conception means that students thought that the two different temperatures of water would combine and equal a new temperature of water that is greater than the two containers of water individually.

Conception	Preconceptions (n = 23) % (number of students)	Postconceptions (n = 22) % (number of students)
Subtraction	57% (13)	10% (2)
Average	30% (7)	86% (18)
Addition	13% (3)	4% (1)

Share (Three to Four Minutes)

During the next stage of the demonstration, students share their predictions with a partner and provide an explanation for their thinking while I circulate around the room and listen to their conversations. Through listening to students' explanations, I observed that some students believe their prediction to be accurate because their peer holds the same idea, while other students change their initial predictions based on their conversations, and some disagree with their partner and retain their initial conceptions.

At the end of the Share stage, students usually hold one of three conceptions of heat transfer. Most students think that the water temperature of the combined beakers will be 15°C. They explain that combining the two beakers will result in the colder water because "the 15°C water would be subtracted from the 30°C water." Some students think that the water temperature of the combined water will be 22°C. As one student explained, "The combined water temperature would be the average temperature of the two beakers." A few students think that combining the beakers will result in water that is 45°C, claiming that "the two water temperatures will add together."

Observe (Two minutes)

During the Observe stage, students collect data to help them confirm, refute, or refine their scientific ideas. Next, I combine the two beakers of water and have a student volunteer take the temperature of the water, which is approximately 22°C.

It is important that during the Observe stage students can make scientifically accurate claims based on evidence. Teachers should make sure when choosing two different temperatures of water that the difference between the two temperatures of water is not also the same as the average between the two temperatures of water. For example, if the demonstration involved water with temperatures of 5°C and 15°C, students would have difficulty formulating scientifically accurate conceptions from their observations because the difference (15°C – 5°C) and the average (15°C + 5°C) both equal 10°C.

Explain (Three minutes)

During this stage, students provide an explanation for their observation that when equal amounts of 30°C and 15°C water combine, the resulting water temperature is approximately 22°C. It is important that students develop a written artifact so that they externalize their ideas in a concrete form. Individually, students write down on an index card their explanations and what they learned from the demonstration. I grade students' responses on the spot during the Explain phase. Many students explain that the resulting water temperature is in the middle of the two combined containers of water.[3]

After their firsthand experiences with the demonstration, we discuss that the term *thermal equilibrium* describes when objects transfer heat until both objects reach the same temperature.

Investigating Convection and Conduction (Five to Seven Minutes)

Because the mixing-water demonstration does not make this explicit, students have additional experiences to learn that the transfer of thermal energy naturally occurs only in one direction—from "warmer" to "colder" objects. To help students learn this concept, they participate in an activity exploring convection and conduction.

In pairs and wearing chemical splash goggles, students fill a coffee cup with hot water (approximately 70°C) and place a glass beaker filled with water at room temperature on top of the coffee mug. (The beaker is larger than the coffee mug, so it balances on top of the mug.) Students begin by making predictions about what will happen to a drop of dye placed in the beaker and provide a reason for their thinking. Using a pipette, students then place one drop of red food coloring at the bottom center of the beaker directly above the coffee mug. (Students need to slowly and carefully

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3. Students' questions and data collection during the Predict and Observe phases, respectively, lead directly to an SEP in the Explain phase, and they "construct a scientific explanation based on valid and reliable evidence obtained from their own experiments" (NGSS Lead States 2013, p. 61).

place a small amount of red dye in the beaker or they will not be able to observe the red dye's movement.) Next, students repeat the procedure, this time using cold water (close to 0°C) in the coffee mug. When using hot water in the coffee cup, students will observe that the red food coloring slowly moves from the area that contains warmer water located at the bottom of the beaker to an area that contains cooler water located at the sides and top of the beaker. Conversely, when using cold water in the coffee cup, students observe that the red dye remains at the center bottom of the beaker and does not move significantly. This experience serves as an investigation that provides qualitative data for their evidenced-based claim.

To demonstrate their understanding, students create a model that explains thermal energy transfer. In their models, they describe the direction in which energy transfers. In addition, students use the length of the arrows to indicate the "rate" at which molecules move. In this way, students' models have a "predictive value" and students can represent how varying the "warmness" of the water can influence the rate that energy transfer (i.e., warmer temperatures transfer energy faster). I remind students that models are useful in science for explaining and making accurate predictions about phenomena.

Using "Molecular Talk" to Learn About Heat Transfer (15 Minutes)

The final activity in the lesson is a whole-group discussion, which I initiate by asking students to explain whether the demonstrations could be explained using what we call molecular talk. Molecular talk refers to when students go back and forth between hands-on experiences and their knowledge of molecular properties and behaviors that are too small to observe. (Note: Earlier in the school year, students learned about energy transfer and the properties and phases of matter.) I have students close their eyes and visualize how "warm" water molecules might look different from "cold" water molecules. Students explain that warm-water molecules move rapidly and vibrate more than cold-water molecules. I encourage students to act out their ideas, as student-driven visual representations provide additional support for what they have learned. For example, a pair of my students had one student wiggle and move around the room to represent a warm-water molecule while the other student remained relatively still to represent a cold-water molecule. Another student used his hands to represent molecules, moving his fingers rapidly on one hand (to represent warm-water molecules) while he moved his fingers slowly on his other hand (to represent cold-water molecules) to show differences in thermal energy.[4]

I use probing questions and ask students to describe how thermal energy transfers in a closed system if the warm-water molecules encounter cold-water molecules. Based on their prior knowledge, students talk about "warmer" molecules having more kinetic energy than "colder" molecules. They explain that when warmer molecules (with more kinetic energy) encounter colder molecules (with less kinetic energy), energy transfers from warm to cold. At this point in the discussion, students want my approval of their ideas. I introduce a formal explanation from their textbook and discuss that thermal energy transfers through the collision of molecules that are too small for firsthand observation. In the demonstrations, thermal energy transfers from "warm" molecules with more thermal energy to the "cold" molecules with less thermal energy due to the collision of molecules. Over time, the molecules reached a state where all of the energy was equal; hence, no more thermal energy transfer. I tie students' developing conceptual understanding in this activity to a theme in the course that thermal energy transfer drives the motion of molecules.[5]

The final activity in the investigation involves a reading from their textbook. Students learn from reading their textbook that the term *convection* describes heating by the movement of currents in a fluid such as water. In addition, students learn that the term *conduction* describes when heat transfers from one molecule to another molecule in a substance without matter moving. Next, I ask students where they see conduction in the coffee mug and beaker demonstrations. Students explain that heating by conduction occurs where the coffee mug and beaker touch each other. Thus, the exploration they did before the new terms (convection and conduction) were introduced helps students attach the meaning of these new concepts to data they observed and explanations of science phenomena they generated.

Developing Long-Lasting Science Knowledge

More than 10 weeks after I first taught the thermal energy lesson (24 weeks into the semester), students completed the paper-and-pencil formative assessment worksheet described by Keeley, Eberle, and Tugel (2007) as part of an end-of-semester assessment. The formative assessment worksheet asked students to predict what the temperature of the water would be when two half-full glasses of water of the same size—

4. Students use the convection demonstration and wiggle about the room to simulate molecular motion highlights. Students are using the SEP of modeling, and they "develop a model to predict and describe a phenomenon" (NGSS Lead States 2013, p. 6). Modeling is a theme of how they can explain science and is direct evidence for the CC they use throughout the class. Students' models "can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems" (NGSS Lead States 2013, p. 93). Finally, the modeling activities directly tie to another SEP, and students "communicate scientific information through presentations" (NGSS Lead States 2013, p. 65).

5. Students' experiences with thermal energy relate to many themes in physical science, and their experiences add additional evidence for the CC that states "Within a natural or designed system, the transfer of energy drives motion and/or the cycling of matter" (NGSS Lead States 2013, p. 94).

one containing 50°C water and the other containing 10°C water—are combined and to provide reasoning for their answer. Students had the following selected response answers: (A) 20°C, (B) 30°C, (C) 40°C, (D) 50°C, and (E) 60°C. (See Keeley, Eberle, and Tugel [2007] for the full formative-assessment-probe worksheet.) I also added a second selected-response item to the formative assessment probe worksheet in which students identified the direction in which heat is naturally transferred: (A) only from "hot" to "cold," (B) only from "cold" to "hot," (C) both directions simultaneously, and (D) none of the above. When I assessed students' responses, I was pleased by their ideas, given that many students' initial misconceptions about energy transfer are persistent and survive in spite of learning about these concepts (Driver et al. 1994). Most students selected 30°C and reasoned that "when two temperatures are mixed together, they even out" and that they "found the middle between the two different temperatures." Some students still thought that "you take the higher temperature (50°C) and minus the lower temperature (10°C) and they equal 40°C." Very few students thought that the temperature would be 60°C (see Table 5.1, p. 40). In addition, most students held scientifically accurate postconceptions of heat transferring naturally only from "hot" to "cold" (see Table 5.2).

Although teachers would expect that students would learn this content after being taught it, the small number of students with inaccurate conceptions speaks to the resiliency of students' misconceptions in spite of firsthand experiences learning content. For most students, the experiences in the PSOE lesson helped them develop long-lasting, scientifically accurate conceptions of heat transfer. This lesson also addresses the three dimensions of the *NGSS* (see the *NGSS* connections in Table 5.3)

Table 5.2. *Students' Postconceptions of the Direction in Which Heat Transfers*

Postconceptions	**Breakdown of Student Responses (*n* = 22) % (number of students)**
"Hot" to "cold"	86% (19)
"Cold" to "hot"	5% (1)
Both directions	9% (2)
None of the above	0% (0)

Table 5.3. *Unwrapping the Standards in Chapter 5*

MS. Energy	Connections to Classroom Activity
Performance Expectation	
MS-PS3-4: Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.	Students investigate the transfer of thermal energy using food coloring and different colors of water (hot vs. cold). Students' observations are supported by "molecular talk" when they describe the relationship among temperature, thermal energy, and the motion energy of particles (kinetic energy).
Science and Engineering Practices	
Asking questions and defining problems	Students make predictions about how different temperatures of water interact when they encounter each other.
Analyzing and interpreting data	Students use qualitative data from their observations of the demonstration to learn which direction thermal energy transfers.
Developing and using models	Students use water that is colored using dye as a model for understanding how heat transfers. In addition, students wiggle around the room to explain how molecules interact on the microscopic level. The model helps them make sense of how molecules interact and transfer thermal energy.
Planning and carrying out investigations	Students carry out investigations to learn how "hot" and "cold" water interact.
Constructing explanations and designing solutions	Students formulate claims based on evidence statements.
Obtaining, evaluating, and communicating information	Students act out how "warm" and "cold" molecules move and interact as they move and wiggle around the classroom.

Continued

Table 5.3 (*continued*)

Disciplinary Core Ideas	
PS3.B: Conservation of energy and energy transfer. Energy is spontaneously transferred out of hotter regions or objects into colder ones.	Students observe that when different temperatures of water that have been dyed with food coloring come into contact with each other, water moves from areas that are "hot" to "cold." During students' molecular talk conversations, they discuss how energy transfers from "hot" to "cold" molecules.
PS3.A: Definitions of energy Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.	Students talk about motion energy (kinetic energy) on a molecular level and compare the movement of molecules for "hot" versus "cold" water.
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.	During molecular talk conversations, students talk about how the movement of molecules (motion energy) is related to the temperature of the object.
Crosscutting Concepts	
Systems and system modeling	Students investigate how "warm" and "cold" water interact. They use food coloring as a tool for learning how energy is transferred between "warm" and "cold" water
Energy and matter: Flow, cycles, and conservation	Students track the flow of movement of thermal energy to understand how heat transfers in a system.

Note: The materials, lessons, and activities outlined in this chapter are just one step toward reaching the performance expectation listed in this table. Additional supporting materials, lessons, and activities will be required. See *www.nextgenscience.org/msps-e-energy* for more information.

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Instructional Sequence Matters

Grades 6–8

Structuring Lessons With the NGSS in Mind

"[This book] uses the 5E instructional model and presents descriptions of the model with insightful examples. Without any hesitation, I recommend this book."

—Rodger W. Bybee, author of *The BSCS 5E Instructional Model: Creating Teachable Moments* (NSTA Press, 2015)

Instructional Sequence Matters, Grades 6–8 is a one-stop resource that will inspire you to reimagine how you teach middle school physical science. The book discusses two popular approaches for structuring your lessons: POE (Predict, Observe, and Explain) and 5E (Engage, Explore, Explain, Elaborate, and Evaluate). It also shows how simple shifts in the way you arrange and combine activities will help students construct knowledge, while allowing you to put the *Next Generation Science Standards* into practice.

Designed as a complete self-guided tour, *Instructional Sequence Matters, Grades 6–8* helps you understand

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