Universal Design for Learning Science

Reframing Elementary Instruction in Physical Science

Deborah Hanuscin and Delinda van Garderen

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Foreword

I was thrilled when Debi and Delinda asked me to write the foreword for this book—almost as thrilled as I was six years ago when they invited me to join their advisory board for the Quality Elementary Science Teaching (QuEST) program, upon which this book is based! I knew of Debi and Delinda's meaningful work in inclusive science education and was piqued by the prospect of a professional development program that used Universal Design for Learning (UDL) and the 5E Learning Cycle as the framework for quality science opportunities for all students. I am happy to share that my experiences on the advisory board only confirmed and strengthened my belief in the power and usefulness of this framework for the entire science education field. I also (fortunately!) came to know Debi and Delinda personally and found them to be incredibly warm, insightful, knowledgeable, and passionate educators who together form a "dynamic duo" in the inclusive STEM education community. This book is the fitting culmination of their brilliant project's work.

Universal Design for Learning Science: Reframing Elementary Instruction in Physical Science is a unique classroom resource, first and foremost, because of its assumption of *ability* rather than *disability*. Through highly readable text describing actual classroom experiences, this book dispels the myth that accessible science means "lowering the bar." Quite the contrary, the authors show how UDL in the context of thoughtfully crafted lessons aligned with the *Next Generation Science Standards* can provide appropriately challenging and dynamic experiences for *all* students, including those with special needs. Nine vignettes provide the reader with a window into lesson implementation in diverse science classrooms, while the accompanying "Teaching Tip" boxes provide easy-to-implement UDL strategies that reduce or eliminate unnecessary barriers to learning. Each of these tips can easily be incorporated across the curriculum!

Another strength of this book lies in its use of teacher-authors' voices. Teacher-participants from the QuEST program wrote most of the vignettes, so the reader is assured of real-world, teacher-tested strategies. Teacher educators will also find a chapter written specifically for them to support their work with methods classes. I personally found the background information on the

5E Learning Cycle and the crystal-clear instructions on developing coherent science storylines in Part I particularly helpful both for my own curriculum development and for instruction of my teacher candidates. Even as a veteran science educator, I experienced many "Aha" moments as I read this wonderful book!

I sincerely hope you share my belief that every child is entitled to quality science learning opportunities; in my mind, it is a practical, legal, and moral necessity. The field of science benefits from many diverse voices while society benefits from a scientifically literate citizenry. But what motivates me in my work (and perhaps you in yours) is the unyielding belief that all children deserve to experience the incredible, incomparable, breathtaking beauty and wonder of science! For that reason, I am most grateful for *Universal Design for Learning Science*, as I know it will inspire elementary school teachers to inspire their students—*all* their amazing students—in science.

—Sami Kahn
Executive Director
Council on Science and Technology
Princeton University

Preface

Deborah Hanuscin

One of my most poignant memories of teaching elementary school took place on the playground. As I was watching a lively game of four square, I was joined on the sidelines by one of my students, Ricki. He had begun the year with me, transferred to another school for several months, and then rejoined our classroom just that week.

"I'm really glad that I'm back, Ms. H. I like being in your class better than my other one," he said. "Why's that?" I asked, my eyes still on the game. "Well, I'm not stupid in your class, but I was in the other one." I was taken aback. "What do you mean?" I inquired. "Well, I can do things in your class!" Ricki smiled, then ran over to take his turn at four square.

I was overwhelmed in that moment—not with joy over my apparent success as a teacher, but with renewed comprehension of how much the experiences of students in a classroom affect their self-perception. Here was a student—the same student—in two different classrooms, arriving at two drastically different conclusions about his abilities as a learner. While it might be tempting to conclude that I was a better teacher, I don't doubt that his other teacher was doing her best for Ricki to be successful. So, what were we doing differently?

Ricki was one of several students in my class with an individual education plan. I was helped in the implementation of this plan by a wonderfully talented special education teacher, Mrs. Branch, who insisted that Ricki could meet the same learning goals as other students, but that we needed to find alternative ways to support him in doing so. For example, if students were planning a science investigation, rather than having Ricki struggle to write out his plan in step-by-step detail, he was able to orally explain his ideas to Mrs. Branch, then fill in a graphic organizer summarizing the process he would use.

When creating a graph of his data to help with analyzing patterns, Ricki was able to use a calculator to find the average, rather than working out the computations by hand. When he needed to find information related to his investigation, Mrs. Branch would preselect nonfiction books at Ricki's reading level, and we would have students partner-read and share information they found in their books in small groups. Working with Mrs. Branch, I learned that the same learning activity could be implemented in a variety of ways, and that if one way posed a barrier for a student, another might allow him or her to be successful.

Given that we taught in the same school district, Ricki's other teacher was using the same curriculum materials as I was—curriculum materials that (unintentionally) were posing barriers to his learning. My best guess is that Mrs. Branch and I were more adept at recognizing these barriers and coming up with solutions. Because we held Ricki to the same standards as the other students, rather than "watering down" the learning goals, he felt just as capable as his peers when he was able to meet those goals. Ricki's story is not unique, though. Over the years I had many students who struggled—fourth graders who read at primer level or were still using invented spelling, students with dyslexia, kids with physical disabilities or emotional/behavioral disorders, and so on. What I noticed, however, is that despite their struggles, they experienced success in—and were therefore highly motivated for—learning science. Most of all, I found that adapting the activities to reduce barriers for these students did not lessen the challenge or rigor of the lessons—the students were succeeding at a level similar to their peers.

Though I certainly had a passion for teaching other subjects, I chose to specialize in science education during my graduate studies. I am now a teacher educator at a university. As an elementary school teacher, collaborating with a special educator enabled me to help all students be successful in science—and so, when I became a faculty member, I also sought out a collaborator in special education, my coauthor Delinda, who is also a former classroom teacher. Just as I learned from Mrs. Branch, I have learned a great deal from Delinda about meeting the diverse interests, needs, and abilities of students. (I think she's learned a little science from me along the way, too!) Our partnership, which began at the University of Missouri over a decade ago, has involved working with a variety of schools and teachers (and their students!) to promote "science for all" through the Quality Elementary Science Teaching (QuEST) program (see *https://sites.google.com/view/sciencequestprogram*).

Delinda van Garderen

As an elementary school teacher, I loved designing hands-on and engaging experiences for my learners. While science was not my favorite subject to teach, I tried to make sure that these experiences were motivating and fun. Though I ended up pursuing a career as a professor in special education, I've kept a strong focus on the content that teachers are helping students learn, and I'm particularly interested in struggling learners in mathematics. However, through my partnership with Debi on the QuEST project, I have expanded my knowledge of science.

Today, I no longer have my own elementary school classroom full of kids, but what I have are college students preparing to be K–12 special education teachers or teacher educators. Many of the ideas related to science teaching and Universal Design for Learning (UDL) have great applicability in my own instruction at the university level. Some of my favorite courses to teach use the 5E Learning Cycle as a way to create meaningful learning opportunities both face-to-face and online. One of my favorite assignments involves my special education students collaborating with a general education teacher (in science or social studies) to redesign a lesson using UDL to make it accessible for specific struggling learners in the classroom. My partnership with Debi has been a great model for this kind of collaboration.

Acknowledgments

We would like to acknowledge the many individuals we have collaborated with over the years through the Quality Elementary Science Teaching (QuEST) program, including our external evaluators (Mark Ehlert, Kristine Chadwick, and Tracy Bousselot), who gave extremely helpful feedback to refine our approach and improve our effectiveness. Additionally, we owe a debt of gratitude (and many cups of coffee) to our staff members (Karen King, Jesse Kremenak, Zandra de Araujo, Dante Cisterna, Tracy Hager, Betsy O'Day, Cathy Thomas, Annie Arnone, Kelsey Lipsitz, Kate Sadler, Jessi Keenoy, and Sarah Hill), who contributed their time, effort, expertise, and insights.

We are especially grateful to our contributing authors, and to all the teacher-participants in the QuEST program who gave up their summers, opened their classrooms to us, and dedicated their efforts to supporting the success of all students in science. Most importantly, we are grateful to *you* for purchasing this book—we hope that you, like us, have also found a collaborator, critical friend, or partner in crime to join you on your science teaching and learning journey!

Finally, we would like to acknowledge that this material is based upon work supported by the National Science Foundation under Grant No. DRL-1316683. Any opinions, findings, and conclusions, or recommendations expressed in this book are those of the authors and do not necessarily reflect the views of the National Science Foundation.

About the Authors and Contributors

Authors

Deborah Hanuscin is an experienced elementary classroom teacher and informal science educator, and since becoming a researcher, she has continued to find ways each year to teach elementary students. She received her PhD in science education from Indiana University and worked at the University of Missouri before moving to her current home in science, math, and technology education and elementary education at Western Washington University. She has led both state and federally funded projects working with teachers as well as students, and she has published more than 60 articles and book chapters for researchers, teachers, and administrators.

Debi's accomplishments include teaching awards at the campus, district, state, and national levels, and most notably she was named Outstanding Science Educator in 2014 by the Association for Science Teacher Education. She is the author of numerous articles in National Science Teaching Association (NSTA) journals and has served on the NSTA Research Committee, the NSTA Alliance of Affiliates, and the advisory boards of *Connected Science Learning* and *NSTA Reports*.

Delinda van Garderen is an experienced elementary and middle school classroom teacher in schools in New Zealand. Motivated by the questions she had about her own students and their diverse needs, she has focused her research in special education on struggling learners in science and mathematics.

Delinda received her PhD in special education from the University of Miami (Florida) and worked at State University of New York at New Paltz before accepting her current position at the University of Missouri in the Department of Special Education. She has led and been involved in both state and federally funded projects working with teachers and students in math and science, and she has published more than 40 articles and book chapters for researchers and teachers.

Contributors

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Shelli Thelen is a fifth-grade teacher at the Columbia Public School District in Missouri. After teaching 13 years in kindergarten, she made the jump up to fifth grade and has loved teaching science for the past four years. You can follow Shelli's classroom on Twitter (*@thelensthinkers*) or peek at her classroom blog at *www.thelensthinkers.blogspot.com*.

Cathy Newman Thomas was an associate professor at the University of Missouri when she worked with QuEST. She is now an assistant professor at Texas State University. Her interests are professional development and access to the general curriculum for diverse learners.

Introduction

We are grateful to you for picking up our book! As former teachers, we understand that your time is precious and that you have many choices for how to spend it. This book is intended to honor that, and to provide you with tools and resources that can help you maximize the time you have to plan science lessons as well as engage students in learning science.

This book is the result of more than a decade of work with teachers through the Quality Elementary Science Teaching professional development program. In this work, we used two frameworks that come together in powerful ways to support student learning in science—the 5E Learning Cycle and Universal Design for Learning (UDL). Using these frameworks encourages teachers to rethink how they have typically approached lessons, and to *re*frame them in ways that mirror how students learn, that provide depth and conceptual coherence, and that support the success of all learners.

Implementing these frameworks doesn't require adopting a new curriculum (after all, we know well that teachers already have enough on their plates). Rather, it involves working with *existing curricula and resources* to identify barriers to learning and possible solutions. In other words, it means using a sharper knife, a bigger fork, or a deeper spoon to more effectively deal with what's already on your plate!

The information in this book will be useful to individual teachers seeking to improve their craft, or to groups of teachers collaborating to support student success in science. In particular, general educators and special educators who are coteaching science may find valuable common ground in the ideas presented in this volume. Even if you are familiar with these frameworks, we believe you will find something new within these pages.

Part I: The Frameworks

Part I of the book provides an in-depth examination of the 5E Learning Cycle and UDL frameworks. We synthesize research that supports these frameworks and highlight common stumbling blocks to implementing them with success. For example, we emphasize the importance of including coherent conceptual storylines within a learning cycle sequence of activities and making assessment a "seamless" part of instruction. Embedded throughout this part are opportunities for you to "Stop and Consider" what you are reading and how the information aligns with your current ideas and practices for science teaching. For those already familiar with these frameworks, we will push you to deepen your understanding and self-evaluate what you know about how these can be implemented.

While Part I of the book will introduce you to the frameworks, we know that reading about them isn't enough for you to be able to implement them with success. The teachers in our program have reiterated the power of collaboration and the benefits of both experiencing new teaching approaches, as learners, and seeing them implemented by other teachers. Part II of this book provides examples of the successful implementation of these frameworks to teach physical science in elementary school classrooms. Rather than reading cover to cover, you may find it helpful to move back and forth between Part I and Part II to explore the examples and better understand these frameworks in action.

Part II: The Vignettes

The teacher-authors we worked with in Part II of this book have done their best to provide you with a detailed view into both their classrooms and their instructional decision making. Each vignette begins with an overview of the lesson and the conceptual storyline that builds throughout the 5E Learning Cycle. Personal commentary from the teacher-authors provides additional insights into their teaching context and background and how they approached the lesson design. Embedded throughout are "Teaching Tip" boxes and "UDL Connection" listings to help make the teachers' thinking and design intentions explicit. The chapters conclude with a section that further unpacks teachers' application of UDL in terms of meeting the needs of specific learners and the lesson's alignment with the *Next Generation Science Standards* (*NGSS*).

The lesson vignettes featured in Part II highlight a variety of physical science topics that were the focus of our professional development program. Because our program took place during the transition to the *NGSS*, our teachers' stories are reflective of their own work to better align their instruction with the new standards. There are multiple possible routes to take to support students in meeting the performance expectations in the *NGSS*, and each vignette represents but a single route. The starting point for our teachers is often finding out what students know—whether by asking them to evaluate a claim, predict an outcome, or attempt to answer a question or explain a phenomenon. While these vignettes may or may not reflect the route you might take, we believe there is value in accompanying teachers on their journey.

We acknowledge that our decision to focus on individual lessons, as opposed to entire units, comes with some trade-offs. While the lessons are aligned to particular *NGSS* performance expectations (PEs), these may represent only a portion of the instructional activities necessary to support students in meeting those PEs. We chose to focus on single lessons to provide a more detailed picture of instruction using the 5E and UDL frameworks. Where possible, we've tried to incorporate contextual information to aid the reader in understanding the larger unit; however, we recognize that some aspects of the teaching and learning picture may not be visible to readers without the entire set of lessons. Additionally, we acknowledge it is unlikely that students will develop an understanding of the *NGSS* crosscutting concepts (CCCs) within a single lesson; rather, CCCs are themes that connect learning across topics and science disciplines. For this reason, you will find that many of the summative assessments included in the lessons do not address this third dimension explicitly.

Similarly, a hallmark of *NGSS*-aligned instruction is the focus on figuring out phenomena.[1] This can be accomplished in different ways—and not all phenomena need to be used for the same amount of instructional time. An anchoring phenomenon might serve as the overall focus for a unit, along with other investigative phenomena along the way as the focus of an instructional sequence or lesson. Lessons may also highlight everyday phenomena that relate investigative or anchoring phenomena to personally experienced situations. Within each vignette, we emphasize the investigative or lesson-level phenomenon, as well as point out the relevant anchoring phenomenon, where appropriate, that frames the overall unit.

The grade 3–5 classrooms featured in Part II also highlight a diversity of learners, and as such, particular classrooms may be of more interest to you given the topics you teach and the diversity of learners within your own classroom. Not all aspects of "diversity" are covered in this book, but the solutions presented may apply to other types of diverse learners you work with. Further, while each teacher applied UDL to meet the needs of *all students*, we have focused more deeply on highlighting several particular learners in each case to illustrate specific ways that the teacher applied UDL to meet those students' needs. The solutions applied represent what the teachers actually did in their classrooms.

1. See "Using Phenomena in NGSS-Designed Lessons and Units," *www.nextgenscience.org/sites/default/files/Using%20Phenomena%20in%20NGSS.pdf.*

Therefore, it may be possible that we have overlooked viable UDL connections or you may not agree with the UDL connections that were made. Keep in mind that these chapters serve as examples that we hope will resonate with you and will help you envision how you might undertake similar approaches with the 5E Learning Cycle and UDL in your own classroom.

Part III: Applying the Frameworks

Part III of this book will provide you with additional resources to get you started reframing your instruction or using the book to support others in doing so. We highlight tools that we have used with teachers, as well as ways that we have integrated these frameworks into preservice teacher education courses—both in special education and elementary science education. We hope you will find ways of your own to make this book a useful part of your professional development or that of others, and we invite you to share with us what you do!

CHAPTER 3

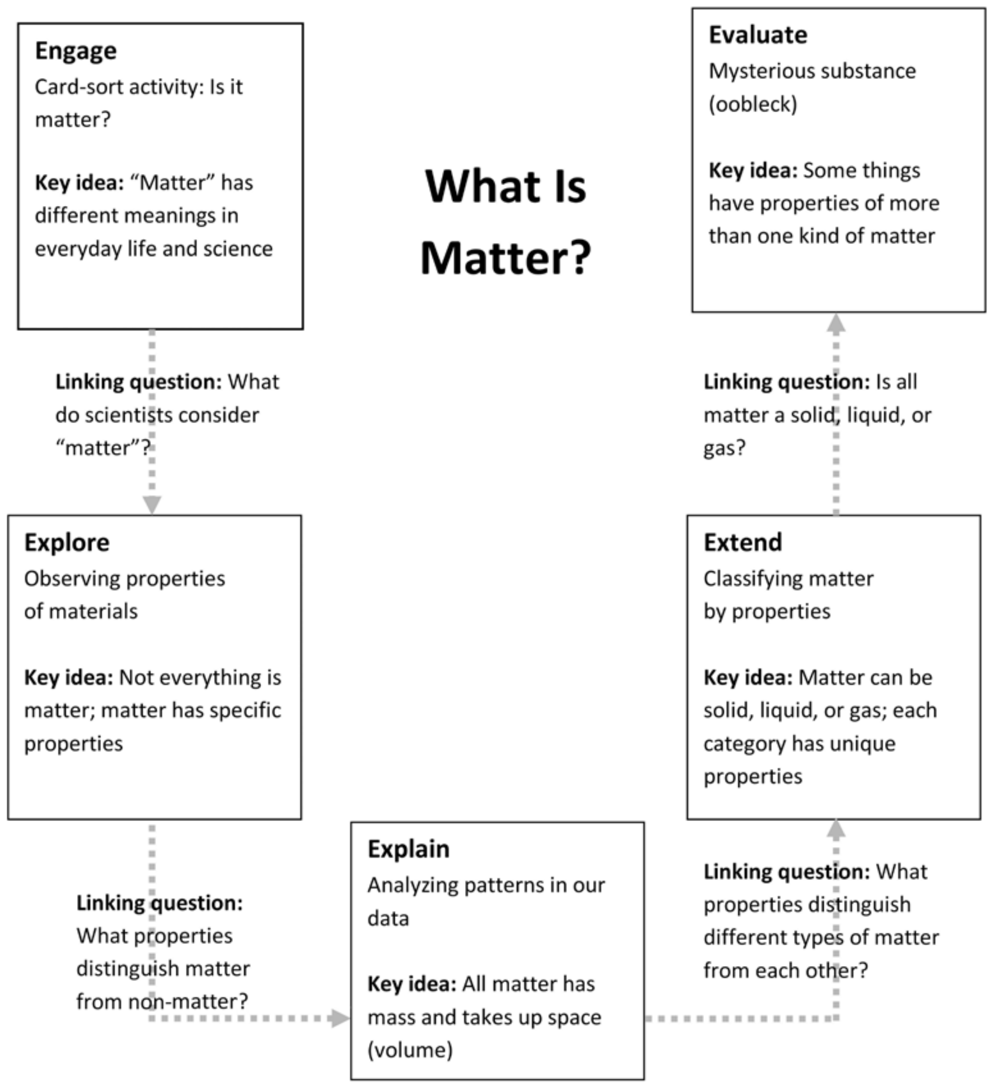
Why Does Matter *Matter*?

Shelli Thelen

This chapter introduces a lesson that engages students in developing an initial understanding of matter by observing and comparing properties, noting patterns for different kinds of materials, and then using that knowledge to identify an unknown substance. This learning cycle represents the first lesson in a fifth-grade unit about matter that engages students in figuring out how a ship might have become stranded in a desert nearly 100 miles from water.[1] The emphasis is on properties that can be used to distinguish matter from non-matter and on differentiating solids, liquids, and gases. See Figure 3.1 (p. 50) for the conceptual storyline of this lesson, "What Is Matter?"

1. See *https://en.wikipedia.org/wiki/Mo'ynoq*.

Figure 3.1. Conceptual Storyline of the Lesson



LESSON VIGNETTE

After many years of teaching kindergarten, I was reassigned to fifth grade. In many ways, I was learning along with my students as I implemented new curricula, addressed new standards, and taught new topics. My first year of teaching fifth grade was a much-needed change from my many beloved years spent teaching kindergarten. I started the beginning of my first year in fifth grade teaching the science units on Earth systems and space systems with gusto, and I felt accomplished. Then November hit and the unit of matter stared at me square in the face. Matter. "What is matter?" It's a big question to think about. Matter has multiple meanings. Matter can be a noun, or it can be a verb.

Admittedly, I was reluctant to teach matter. I was lacking confidence in my own understanding of the content. Simply put, the progression and implementation of teaching matter did not feel cohesive. I gave myself grace that it would be impossible to be an all-star teacher in a new grade level in all content areas.

Talking with my grade-level team, I expressed my lack of enthusiasm for teaching matter and how I found it to be one of my greatest challenges in teaching fifth grade. I shared my urgency for support with planning the matter unit and my longing for a sense of cohesion in the progression of the unit. Mapping out the curriculum's progression is something that usually comes easily for me, and I was feeling frustrated. Fortunately, my team and I had the opportunity that summer to attend the Quality Elementary Science Teaching (QuEST) professional development program, where I learned about planning a coherent conceptual storyline.

Using a conceptual storyline is complementary to backward lesson plan design (Wiggins and McTighe 2005). It requires the teacher to think about the sequence and progression of lessons so that the conceptual knowledge builds with each experience across lessons, units, and topics. This intentional, thoughtful progression is often embedded in a meaningful context or real-life scenario through the 5E Learning Cycle. The matter unit that we developed during QuEST contains eight 5E learning cycles that engage students in developing their conceptual understanding about matter. The first learning cycle of the progression engages them to define matter and to recognize that matter can be identified by certain characteristics.

What I also learned in QuEST about the conceptual storyline was to attend to *the ideas that students would be developing during these activities*. I was used to planning by starting with the activities that the students would be participating in—for example, a card-sort, hands-on exploration, or data analysis. This storyline (shown in Figure 3.1) focuses on the essential question "What is matter?" by

(continued)

(continued)

starting from students' prior knowledge of this term in everyday life and helping them develop understanding of the use of the term in science. Students build this understanding through their own observations of properties and patterns in properties, with specific examples of matter and non-matter, as well as solids, liquids, and gases. While we traditionally teach these as hard and fast categories, the final activity helps students realize that sometimes matter can have properties of both solids and liquids.

Organizing the lesson in this way helped me focus on how students might develop their knowledge in a logical sequence, the questions they would need to answer to move forward in developing their ideas, and the activities that would help them construct their understanding. It also helped me consider how students would be using their knowledge, as described in the *Next Generation Science Standards* (*NGSS*) performance expectation (NGSS Lead States 2013), to identify matter based on its properties (see Table 3.1). That is, knowing the properties of matter *matter* because they are useful in identifying and classifying materials. Additionally, it helped me ensure that students had the necessary knowledge and skills to prepare them to explain phenomena related to matter in later lessons, such as melting, evaporating, and dissolving.

In the sections that follow, I outline the lesson as it unfolded in my classroom, including teaching tips and other information alongside the lesson activities. You can also learn more about this lesson in my blog: *http://thelensthinkers.blogspot.com/search/label/Matter*.

TABLE 3.1. Alignment of the Lesson to the *NGSS*	
Connecting to the *NGSS*—Standard 5-PS1-3: Matter and Its Interactions	
www.nextgenscience.org/pe/5-ps1-3-matter-and-its-interactions	
• The chart below makes one set of connections between the instruction outlined in this chapter and the *NGSS*. • The materials, lessons, and activities outlined are just one step toward reaching the performance expectation listed below.	
Performance Expectation 5-PS1-3. Make observations and measurements to identify materials based on their properties. (Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property. Assessment does not include density or distinguishing mass and weight.)	
Dimensions	**Classroom Connections**
Science and Engineering Practices	
Analyzing and Interpreting Data Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships. Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.	Students analyze the patterns in their data to identify properties that distinguish solids, liquids, and gases. They use this as a basis to classify oobleck.
Disciplinary Core Ideas	
PS1A: Structure and Properties of Matter Measurements of a variety of properties can be used to identify materials.	Students examine properties including mass, volume, shape, and more to compare different materials. They recognize which properties are most useful for identifying a material and which depend on the amount you have.
Crosscutting Concepts	
Patterns Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.	Students analyze patterns in their data to identify properties that distinguish matter from non-matter and to classify solids, liquids, and gases. This can be related to patterns important in other units such as phases of the moon and layers in rocks.

Engage Phase (Day 1)

To begin this lesson, I asked my students to take a moment to think individually about the following:

- What the word "matter" means to them
- How they would explain what matter is to another person

> **Teaching Tip:** Providing time for students to think and respond individually is important to learning, and it also can help the teacher document and assess the development of individual students' ideas as they work in groups.

These questions helped activate the students' background knowledge and provided them with the opportunity to consider the many meanings of matter.

After sampling a few students' responses, it became clear to the class that *matter* was a term that could be used in a variety of ways:

- "A *matter* of life and death"
- "It doesn't *matter*."
- "What's the *matter*?"

I explained to the students that scientists also use the word *matter* ("And anti-matter!" as one student called out) and that we were going to try to understand this meaning of matter better in our lesson. It's important to me that I help students recognize differences in the ways they may use words at home and in a scientific context.

UDL Connection
Principle I: Representation
Guideline 3: Comprehension
Checkpoint 3.1: Activate or supply background knowledge

The students were already placed in groups; however, before they worked as a group, I asked students to individually review a checklist and mark the items they believe are examples of matter. At the bottom of the checklist, they responded individually to the following question: "How did you decide whether something could be an example of matter? Explain your thinking."

After each group member had a chance to think and respond on his or her own, I provided the following guiding instructions and questions for the group discussion on the student recording sheet: "Compare your ideas with your group. What similarities and differences do you notice? Try to explain your thinking about why you did or did not check the items above."

As I circulated around the room, I encouraged students to jot down any additional notes or ideas from the group discussion that may have fit with their own thinking, contradicted their thinking, or created a question for further exploration.

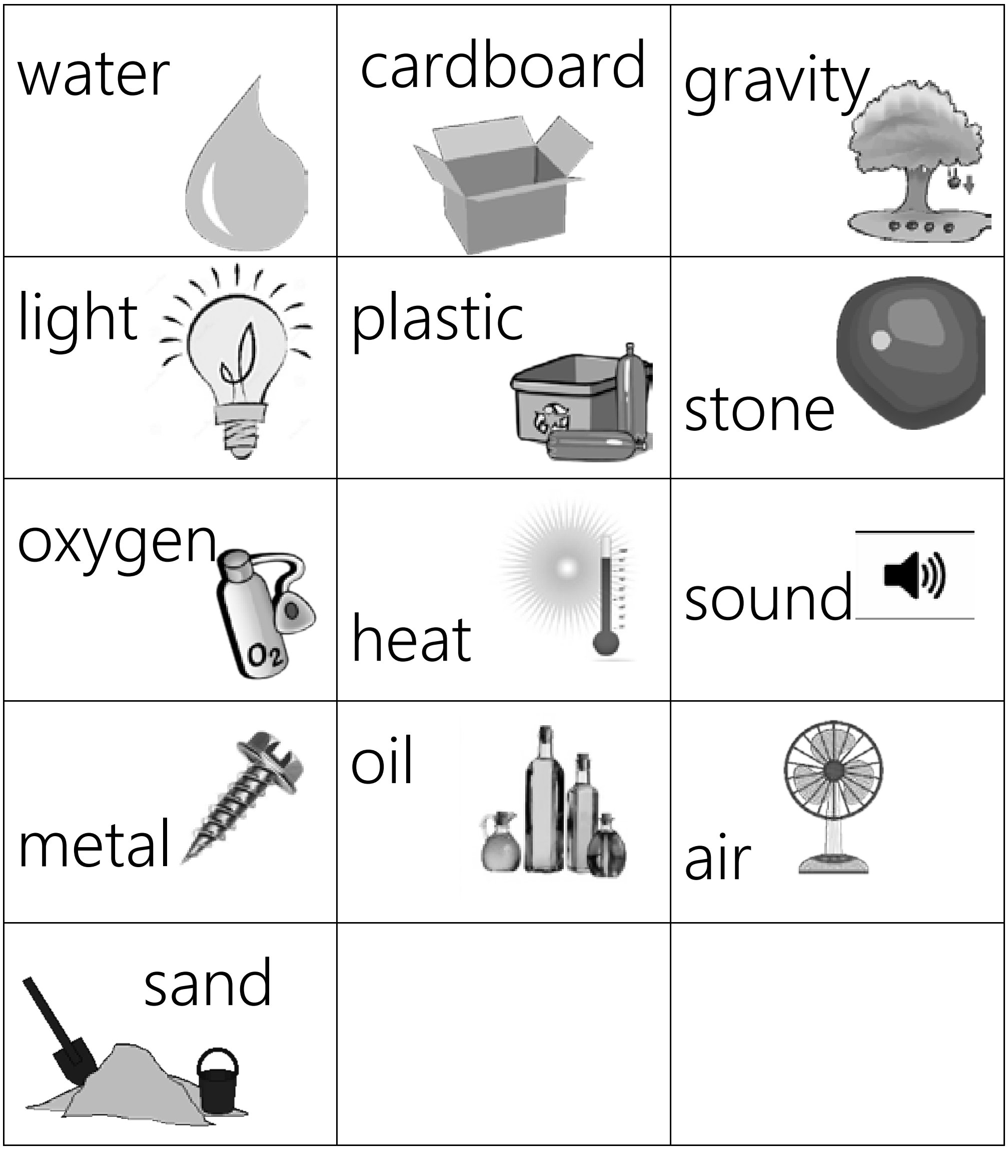
UDL Connection
Principle III: Engagement
Guideline 7: Recruiting Interest
Checkpoint 7.3: Minimize threats and distractions

UDL Connection
Principle II: Action and Expression
Guideline 6: Executive Functions
Checkpoint 6.4: Enhance capacity for monitoring progress

Next, I asked students to work together to complete a card sort (see Figure 3.2, p. 56) that matches the list they just reviewed independently. The cards contained visuals of the words to support understanding across the languages for students who were English language learners (ELLs) and to make text accessible for my struggling readers. Students were to sort the cards collaboratively into two categories: *matter* and *not matter*.

Teaching Tip: Comparing a student's checklist with the group's card sort allows the teacher to ask the student to elaborate on his or her thinking. For example, "I noticed on the checklist that you marked that air is not matter. But when I look at your group's card sort, I noticed that *air* is in the matter category. Can you tell me about that change?"

Figure 3.2. Card Sort for the Engage Phase



UDL Connection

Principle I: Representation
Guideline 2: Language and Symbols
Checkpoint 2.4: Promote understanding across languages

If your students are anything like mine, expect them to disagree on where some of the cards are placed. In this case, I suggested they might make a third pile. Many students in my class were conflicted with the cards labeled *sound*, *energy*, *air*, and *oxygen*. This seems developmentally appropriate as those examples are more abstract. If students cannot see or touch something, they can find it difficult to qualify it as matter.

Teaching Tip: One way to build interest and engage students in this phase of the lesson is to hold a gallery walk in which students can circulate around the room to view how their own ideas line up with those of other groups in terms of sorting the cards. When there are disagreements, this can prompt a desire to find the information—and it can be a great segue to exploration by emphasizing that when scientists disagree, they test their ideas against evidence.

To draw further on students' background knowledge, I asked each group to create a new card (using the blank spaces) with an example of their choice, and then as a class we discussed which group it belongs to. This assessment helped me identify any follow-up discussion that may be needed as I reviewed my plans for the next day.

Explore Phase (Day 2)

During this phase, students had the opportunity to test out ideas. Working in their small groups as a way to keep those with behavior challenges focused and persisting in the lesson, the students rotated through a series of stations to explore the properties or characteristics of five items (light, air, water, stone, and sand) featured in the last activity. (Please see the "Materials and Safety Notes" box, p. 58.) Sand is included purposefully as one of the items because it forces students to clarify their thinking—their answers vary in whether they mean a *grain* of sand or the entire *bag* of sand—and it provides a way to differentiate the degree of complexity for the task to motivate some learners who need more of a challenge. This makes for great discussion in the next lesson phase!

UDL Connection
Principle III: Engagement
Guideline 8: Sustaining Effort and Persistence
Checkpoint 8.2: Vary demands and resources to optimize challenge

Materials and Safety Notes

Materials

Water	Oil	Cups
Stone	Metal	Strainers
Sand	Plastic	Flashlights
Plastic tubs	Balloons	Oobleck in paper cups
Plastic bottles	Containers	Wax paper

Safety Notes

1. Direct supervision is required during all aspects of this activity to ensure that safety behaviors are followed and enforced.
2. Make sure that any items dropped on the floor or ground are picked up immediately after working with them—a trip-and-fall hazard.
3. Immediately wipe up any water or other liquids spilled on the floor—a slip-and-fall hazard.
4. Never taste or drink any materials or substances used in the lab activity.
5. Wear nonlatex aprons when working with oobleck.
6. Use caution when working with glassware or plasticware. It can shatter and cut or scrape skin.
7. Keep all liquids away from electrical outlets to prevent shock.
8. Follow the teacher's instructions for disposing of waste materials.
9. Wash your hands with soap and water after completing this activity.

As students were exploring the materials in the station tubs (see the photos on the next page), they were asked to make sense of and answer each of the following questions on their student recording sheet:

1. Does it take up space?
2. Does it have mass?
3. Does it hold together? Can you pick up the whole thing?
4. Can you easily push another object or your hand through it?
5. Does it have a definite shape? (Does it keep the same shape when transferred to a different container?)
6. Does it have a definite volume? (Does it stay the same if you try to compress it?)
7. Can you pour it?

The students recorded their observations and ideas as they completed each of the seven activities as a tool for sharing and comparing ideas as a class. The stations do not have to be completed in any particular order, so the students are able to work at their own pace. To help those students who struggle with keeping organized and monitoring their progress, I provided data tables for them to record their findings.

Photos of students examining properties of matter in the Explore phase of the lesson. Having materials in tubs or containers that are clearly labeled allows groups to work independently as materials are organized.

UDL Connection
Principle II: Action and Expression
Guideline 6: Executive Functions
Checkpoint 6.3: Facilitate managing information and resources

As the students circulated through the stations, I observed, documented, and anticipated what questions might benefit each group to help them with their understanding: "What are you noticing?" "How is ______ like ______?" I listened to the ways that students exchanged ideas, observed what vocabulary they used, and assessed what misconceptions they might have.

Teaching Tip: Students might point out the expression "light *filled* the room," but that doesn't mean that light can fill a cup or take up space the way that water does.

Explain Phase (Day 3)

The activity in this phase of the lesson was designed to help students clarify and refine their current understanding, first by talking with their group, and then by making sense of their data as a class with teacher support. Using the data collected in the Explore phase, the students completed a data chart to help them look for patterns and use the evidence to explain their thinking. I purposefully structured the data chart (see Figure 3.3) as a scaffold for data analysis, so that when students color-coded their responses, it allowed them to visually recognize patterns with greater ease.

Once each group filled in the chart and discussed their ideas, we compared the results—were there any disagreements? Sand provided a great topic for discussing how granular materials (such as sugar, sand, or salt) can have different properties when you consider questions such as "Can you pour it?" or "Can you pick up the whole thing?" in terms of a single grain or the entire amount you have. Students agreed that sand did not pour the same way that water did, so we marked that "No."

We revisited any other items that prompted ambiguous or inconsistent answers to reach a consensus about the properties of each. For example, students struggled with the idea of air having mass. In the Explore phase, the students tried filling a balloon with air and putting it on a digital scale and comparing the mass to an empty balloon. It often showed no difference. Comparing this to the weight of a single grain of sand as opposed to a bucket of sand can provide a useful analogy to make sense of it. The students realized that air is light enough that a small amount doesn't have much mass, just as a single grain of sand would not register on the digital scale.

Figure 3.3. Data Chart Used in the Explain Phase

Question	Light	Air	Water	Stone	Sand
1. Does it take up space?					
2. Does it have mass?					
3. Does it hold together in one piece when you pick it up?					
4. Can you easily push something through it?					
5. Does it have a definite shape?					
6. Does it have a definite volume?					
7. Can you pour it?					

Note: The students color-code their "Yes"/"No" responses to identify patterns.

Next, I asked students to color-code the different responses in their data chart (e.g., coloring the "No" responses), to help the students who have difficulty identifying important or relevant ideas, as a way to highlight patterns and to help them recall these ideas for later tasks. Once the students reflected on their data chart, they were able to make the generalization that the first two characteristics (mass and volume) were shared by all items they considered to be matter. For light, which they considered *not* to be matter, they noted that they had not been able to demonstrate that light takes up space or has mass. This helped the class construct a formal definition of *matter* as something that both has mass and takes up space. Up until this point we had been using the phrase "taking up space." We clarified what that means (based on their evidence), and I indicated that this is referred to as *volume*. We also differentiated the use of the word to indicate loudness of a sound, and we linked the word to students' learning about area and volume in mathematics.

UDL Connection

Principle I: Representation
Guideline 3: Comprehension
Checkpoint 3.2: Highlight patterns, critical features, big ideas, and relationships

UDL Connection
Principle I: Representation
Guideline 3: Comprehension
Checkpoint 3.4: Maximize transfer and generalization

Extend Phase (Day 4)

In this phase, students extended their understanding by examining how properties of matter that *differed* between objects and materials might help us classify different types of matter further. Using the same core questions from the Explain phase, the students combined their data with new observations for oil, metal, plastic, and oxygen. Checking off the properties of each object listed on the chart, they were again looking for similarities or patterns in their data. Each small group was encouraged to reach an agreement and, if needed, go back to the materials in the previous lesson phase and retest them.

Teaching Tip: Be sure to have enough testing materials for students to test the items on the list. For example, have containers, cups, strainers, a flashlight, and other items available that will help with the investigation.

Using the data from the chart, students devised a way to sort the items into new groups. The order in which I placed the items was intentional, so that similar types of matter were clustered together (see Figure 3.4). The students used color coding to indicate these groups. I asked them the following questions:

- Looking at the sections that are grouped similarly, what do you notice?
- What might you call each group?
- What other items do you think might belong in each group?

In my experience, with color coding, students could begin to see certain patterns emerge. Many quickly recognized that matter could be grouped into a solid, a liquid, or a gas. In some cases, students needed support and encouragement to recall what they observed in the Explore phase of the lesson, or I asked prompting questions such as "What one word could you use that would mean water, oil, or milk?" (*liquids*)

Teaching Tip: As I work with students, I ask myself, "What misconceptions do my students hold, and what experience could I provide for them to further test their ideas?" I often challenge them with new examples or materials "on the fly," so it's helpful to have some extra materials on hand. I suggest salt, rubber, and aluminum foil.

Though students were familiar with the terms *solid*, *liquid*, and *gas*, this was a light-bulb moment for them in terms of how these classifications came about—and how they are defined by common properties. This

Figure 3.4. Data Chart From the Extend Phase of the Lesson

Matter	It holds together in one piece	It is easy to push something through it	It has definite shape	It takes the shape of the container	It has definite volume
Oil					
Water					
Sand					
Stone					
Metal					
Plastic					
Air					
Oxygen					

was also a light-bulb moment for me, as I would have typically introduced the classifications of solids, liquids, and gases first, then introduced students to their properties.

To wrap up the lesson, we constructed a class chart to help organize the information—and make explicit the critical ideas that some students need extra support in drawing out—as a way to solidify (pun intended!) the students' understanding (see Figure 3.5, p. 64).

UDL Connection
Principle I: Representation
Guideline 3: Comprehension
Checkpoint 3.3: Guide information processing and visualization

Evaluate Phase (Day 5)

By this point in the learning cycle, I wanted my students to be able to use the properties of an object to identify it as matter and classify it as solid, liquid, or gas. Providing students with the opportunity to apply what they know to a new experience would give me information to determine if the students have a better conceptual understanding of what matter is as a result of my instruction and whether they can analyze and interpret their data to classify a substance as a solid, liquid, or gas.

Figure 3.5. Summary Chart Identifying Properties of Solids, Liquids, and Gases

Properties shared by the group …		
➢ Holds together in one piece	➢ Takes the shape of the container	➢ Without a definite volume
➢ Has a definite shape	➢ Easy to push something through	➢ The volume fills the whole container
Members of this group …		
➢ Stones, sand, metal, plastic	➢ Oil, water	➢ Oxygen, air
Name for this group …		
➢ Solid	➢ Liquid	➢ Gas

In the final activity, I chose to present students with *oobleck*, a non-Newtonian substance that uniquely behaves as both a liquid and a solid—and it provides a great medium to challenge students' ideas about matter. While the version I use is a combination of cornstarch and water, a quick web search for "oobleck" will provide an assortment of recipes and variations for making your own. I prepared the oobleck ahead of time and distributed a portion of the "mystery substance" in a small paper cup for each student. I also provided each student with a sheet of wax paper as a placemat for easy cleanup. Before handing out these materials, however, I reviewed the exit slip on which students would be asked to individually record and self-assess their thoughts, to gauge and monitor their current understanding about matter. This review helped some of my learners better understand what they were monitoring, as a way to guide their own learning, because some of my students struggled to pose questions while completing tasks.

The exit slip that I used included the following questions:

- Is this substance matter? Provide evidence to support your claim.
- Can you classify this substance as a solid, liquid, or gas? Explain your reasoning.
- Can you think of something else that behaves like a liquid *and* a solid?
- What questions are you still wondering about? What is something that seems confusing or conflicting at this time?

For students who were struggling with a written response, I allowed them to either dictate their thinking to me as I scribed their responses or use voice-to-text on a tablet to support them as they were communicating their ideas.

UDL Connection
Principle II: Action and Expression
Guideline 6: Executive Functions
Checkpoint 6.4: Enhance capacity for monitoring progress

UDL Connection
Principle II: Action and Expression
Guideline 5: Expression and Communication
Checkpoint 5.2: Use multiple tools for construction and composition

As the students received their oobleck, there were many *ooh*s and *ahh*s! Some immediately reached into their cups to touch it, while others attempted to pour it out onto the wax paper. As they explored, students noticed that it pours like a liquid but can be rolled in a ball and picked up in one piece like a solid.

For students who were hesitant to explore, I found action-testing questions (Elstgeest 1985) to be helpful. These "What happens when you … ?" questions can only be answered by students if they try out the action and observe what happens. Examples include the following:

- "What happens when you jab or push on the oobleck slowly? Quickly?"
- "What happens when you squeeze the oobleck in your fist?"
- "What happens when you open your fist?"
- "What happens when you try to stir your oobleck?"

By asking these questions, I could ensure that my students were able to see the full range of properties of the oobleck to prepare them to answer the questions on the exit slip.

All students were able to justify that oobleck is matter, and most accurately identified that it has properties of both solids and liquids (though some were stuck with feeling that it needs to be one or the other). Other examples that students raised include pudding and gelatin—or things like chocolate that are solid at room temperature and behave like a liquid when the temperature increases. Asking students to share their ideas and state something that they were still unsure about, or something that did not make sense, opens the door for me to address their confusion in future lessons and experiences. These examples from students' exit slips can be integrated easily into future lessons about changes in matter!

Unpacking UDL: Barriers and Solutions

I teach in a suburban school district that is located in a university town in the Midwest. I am one of five fifth-grade teachers at the school, which has 724 students—63% are White, 28% qualify for free or reduced lunch, 18% are ELLs, and approximately 7% have an individual education plan (IEP). I firmly believe that all of these students should have access to learning science. Although I had laid out this storyline, I knew that the activities could still pose potential barriers for my students. Using the Universal Design for Learning (UDL) framework and principles (described in Chapter 2), I was able to anticipate challenges that might arise and put specific strategies in place to provide a supportive learning environment for my students. For example, I knew that providing information in text alone would make things difficult for my ELLs. I also knew that for most of the students in my class with behavioral challenges, keeping focused on the task would be difficult.

Although I planned with specific students in mind, I've found that the UDL strategies I implement will benefit most students, regardless of individual learning strengths and challenges. Table 3.2 summarizes the UDL principles, guidelines, and checkpoints that I applied when designing the activities for each phase of the learning cycle lesson to meet the *general* needs of the learners in my classroom—specifically, organizing information, comprehending, staying focused and persisting in a task, and monitoring understanding of learning. Following the table, in the "learner profiles," I provide some examples of how I identified barriers and strategized solutions to meet the *specific* needs of two of the learners in my classroom.

TABLE 3.2. Alignment of the Lesson With Principles of UDL	
Connecting to the Principles of Universal Design for Learning	
Principle I: Representation	
Guideline 2: Language and Symbols	
Checkpoint 2.1. Clarify vocabulary and symbols	During the English language arts lesson, students completed a Frayer Model on the word matter to support vocabulary development for ELLs.
Checkpoint 2.4. Promote understanding across languages	Pictures were added to words on the cards used during the card sort to support understanding for ELLs.

(continued)

TABLE 3.2. Alignment of the Lesson With Principles of UDL (*continued*)	
Guideline 3: Comprehension	
Checkpoint 3.1. Activate or supply background knowledge	Students discussed the different meanings for the word matter to activate and provide background knowledge for a shared understanding to complete the learning cycle.
Checkpoint 3.2. Highlight patterns, critical features, big ideas, and relationships	During the Explain phase, students were provided highlighters and a color-code key to highlight findings for identifying patterns.
Checkpoint 3.3. Guide information processing and visualization	During the Extend portion of the learning cycle, a class chart was created to help make ideas explicit and to solidify student understanding.
Checkpoint 3.4. Maximize transfer and generalization	During the Explain phase, the data were color-coded to facilitate the transfer of ideas about matter for the remaining phases of the learning cycle.
Principle II: Action and Expression	
Guideline 5: Expression and Communication	
Checkpoint 5.2. Use multiple tools for construction and composition	For students struggling with writing, they were provided different tools (dictate to a scribe or voice-to-text) to communicate ideas.
Guideline 6: Executive Functions	
Checkpoint 6.3. Facilitate managing information and resources	When collecting data during the Explore phase, students were provided data tables to manage and record findings.
Checkpoint 6.4. Enhance capacity for monitoring progress	In the Engage phase, a checklist with questions asked students to reflect on what they knew and as a way to promote group discussion. Additionally, before completing a task, students reviewed the questions that would be asked on the exit slip, to prompt self-assessment and understanding.
Principle III: Engagement	
Guideline 7: Recruiting Interest	
Checkpoint 7.3. Minimize threats and distractions	Students were provided a checklist to individually complete to ensure that they all had ideas to contribute to a group discussion.
Guideline 8. Sustaining Effort and Persistence	
Checkpoint 8.2. Vary demands and resources to optimize challenge	During the Explore phase, students rotated through stations that were designed to explore the properties of different items, including one item that would challenge thinking and vary the demands of the task.

Learner Profile: Derek

"Derek" was a student who received special education services in the learning disability category. He performed academically on a third-grade level in reading, writing, and math. His IEP included goals for developing executive-functioning skills and comprehension. I anticipated that the Explain phase would be particularly challenging for Derek, as there was a lot of information to make sense of from the Explore phase. Knowing that identifying patterns across the data could be a potential barrier, even though it was organized in a data table (to help students keep information organized and in mind), we planned the activity to include color-coding of the data. I took it one step further and added a "color-code key" to help students interpret the data.

Derek was given a piece of paper that had him use specific colors for "Yes" and "No." As a result, he did the following:

- Recorded all of the Ys for "Yes" first, with a green highlighter (green means *go*/*yes*), as he went across each row.
- Marked the empty spaces with an *N* for "No." He double-checked his data from the Explore phase to ensure that the empty spaces were really a "No" in his data. He then highlighted the No boxes with a pink marker (red means *stop*/*no*, but pink allows the student to still see the work and it is easily connected to the color red as they are similar in tone).

After Derek had color-coded his table in this way, he was told to focus on all of the green boxes as a way to identify and see the pattern across the data table. While this was planned with Derek in mind, I noticed that his group members were also struggling with identifying patterns when the table initially contained just "Yes" or "No." Once all students had visually coded their data, they were able to identify a pattern and explain that the properties that were green (mass and volume) were unique to matter.

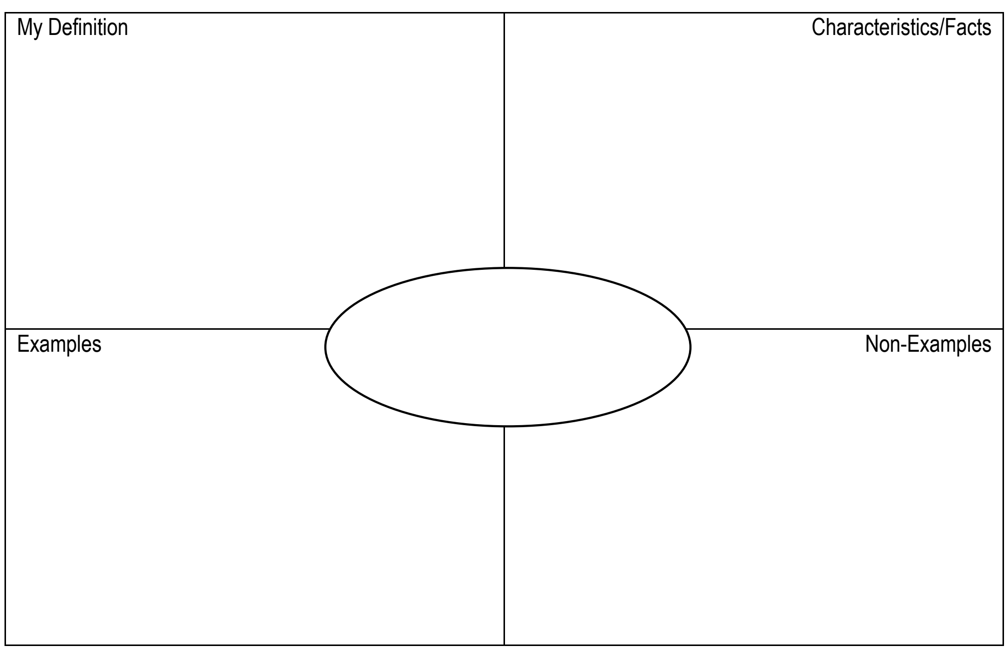
Learner Profile: Thanh

At my school, we commonly encounter students from other countries who are visiting in our city because they have family members doing research at the local university. "Thanh" was proficient in her native language, and she had a working understanding of English. However, she struggled with content-specific academic language.

In the first phase of the learning cycle (Engage), I incorporated pictures along with the words on the cards, so that students could make sense of any unfamiliar objects. For Thanh, I also anticipated that using the term *matter* in a scientific sense could be a barrier—particularly because in English we use the word in many nonscientific ways. I decided to acknowledge this at the beginning of the Engage phase, to signal to students that a familiar word was going to be used in a specific way for a specific purpose.

To further help students define *matter* in a scientific context and support their science learning in other content areas, I introduced the Frayer Model (Frayer, Frederick, and Klausmeier 1969; see Figure 3.6) during English language arts time as we reviewed vocabulary that was being used in the different assigned readings. We constructed this on chart paper and kept it posted in the room as a reference. Adding picture images to the class chart provided another layer of support for ELLs to help them not only make meaning, but also remember these new words in the context that they were learned. This tool was helpful not only in this lesson, but also throughout the unit to define academic vocabulary, including *gas*, *evaporation*, *condensation*, *chemical*, *property*, and other abstract words. Thanh was not the only student who referenced these charts during the lesson—other students also found them helpful when writing in their science notebooks and explaining their ideas to their peers.

Figure 3.6. Frayer Model Chart



Source: Frayer, Frederick, and Klausmeier 1969.

Supporting All Learners: Working in Groups

My students often work in groups. While this can be a source of support for some learners, I also have noticed at times that this can be a barrier as well. Sometimes, certain students will share their ideas immediately—before others have had a chance to think about the question or problem for themselves. As a result, the other students in the group might shut down their own thinking to defer to the authority of the student who is a "quick thinker." These same students, while they mean well, can dominate group discussions, often limiting the contributions of other group members.

In the Engage phase of the lesson, the students were placed in groups to complete a picture card sort activity. Immediately before that activity, I embedded a solution (see Table 3.2, p. 66) that was designed with specific learners in mind. The solution was designed to provide thinking time and facilitate active contribution to the discussion from all students in the group.

Specifically, in the Engage phase of the lesson, I first had the students individually complete a checklist with their own ideas about what is or isn't "matter"—this allowed all students to consider their own prior knowledge and experience before sharing with their group. After the students responded to the checklist, I provided instructions and questions for them to use to guide them in their group discussion. It also helped highlight any areas of disagreement in ideas among the members of the group—which I've found can be a motivator for students to find out what is correct.

While my students sometimes have asked me whether an answer was correct, in this lesson I really tried to empower the students to figure it out for themselves by testing their ideas with evidence. It's important to me that they don't accept answers based on authority, but that they learn to question ideas that aren't supported by evidence.

Questions to Consider

- To what extent did the activities that this teacher chose align with the purpose and intent of each phase of the 5E Learning Cycle?
- Could you envision other activities that would be appropriate for each phase?
- Were you able to follow the sequence of activities and the ideas students developed in the learning cycle that the teacher created?
- How did the storyline of the lesson progress?
- In what ways was the teacher able to assess students during each phase of the lesson? How did this inform her instruction?
- As you read through this lesson, did you come across any activities that might pose a barrier for your own students? What principles of UDL might you apply in those instances?

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Page numbers printed in **boldface type** indicate information contained in tables or figures.

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