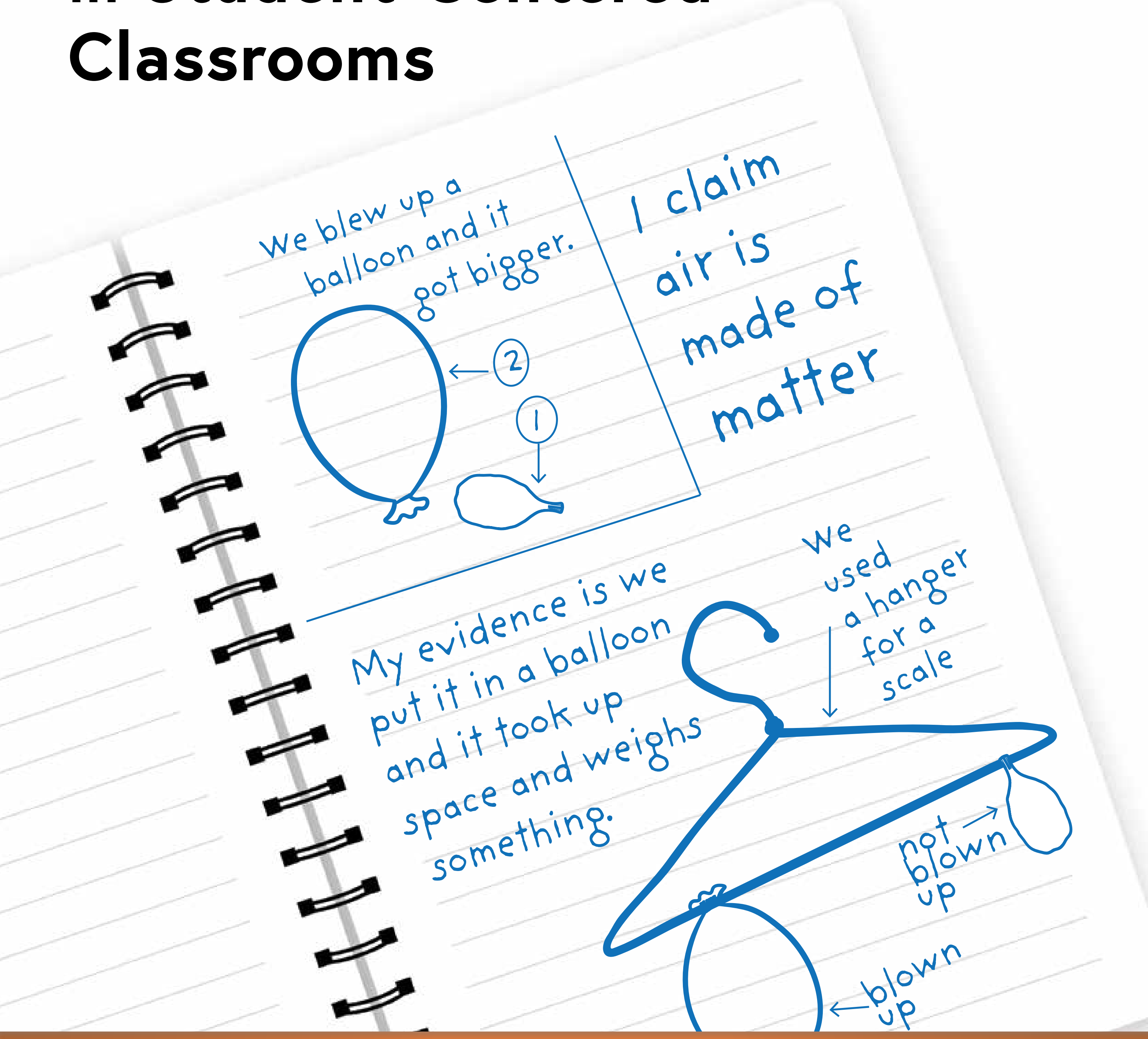
SCIENCE NOTEBOOKS

in Student-Centered Classrooms



Jessica Fries-Gaither

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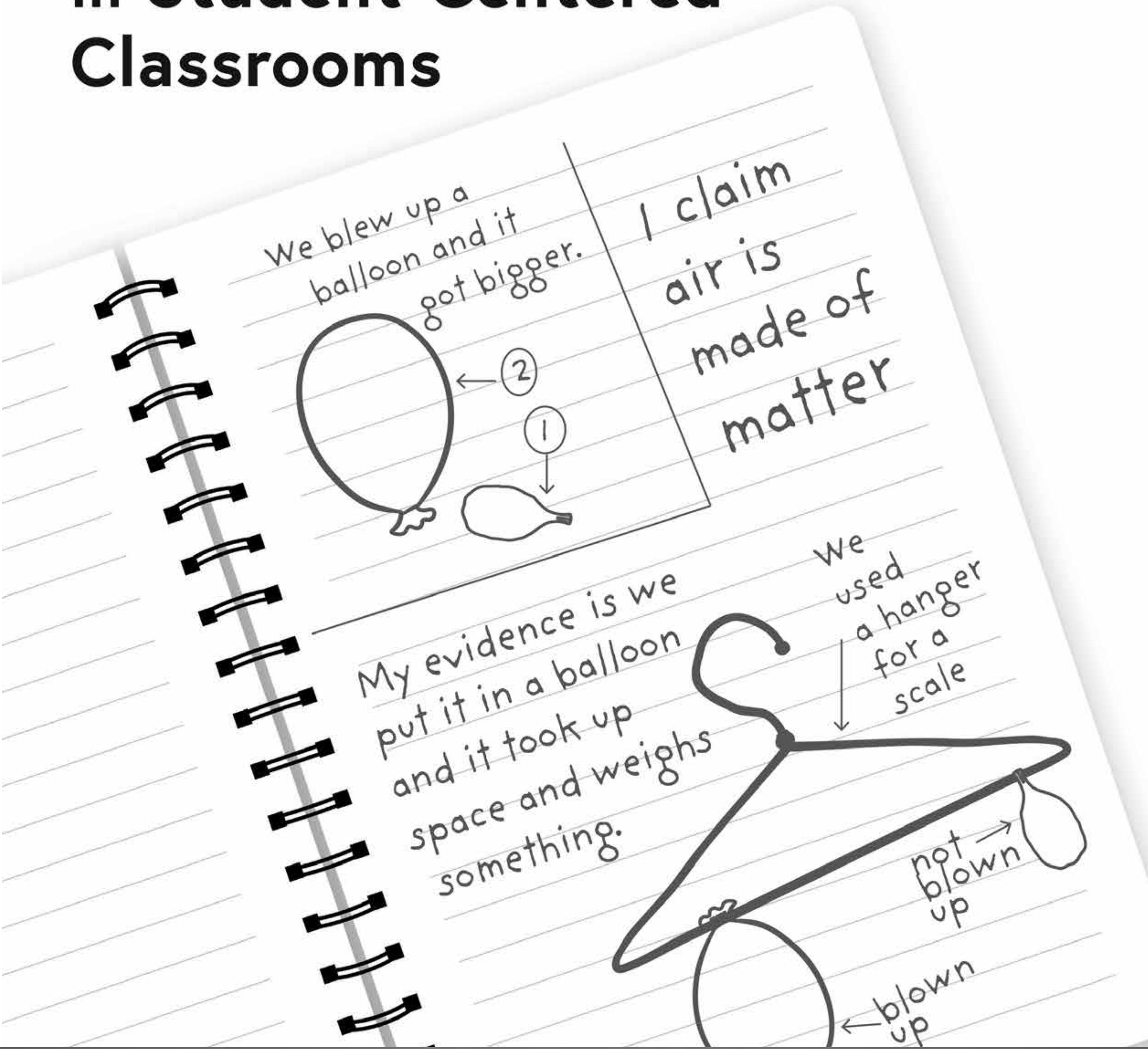

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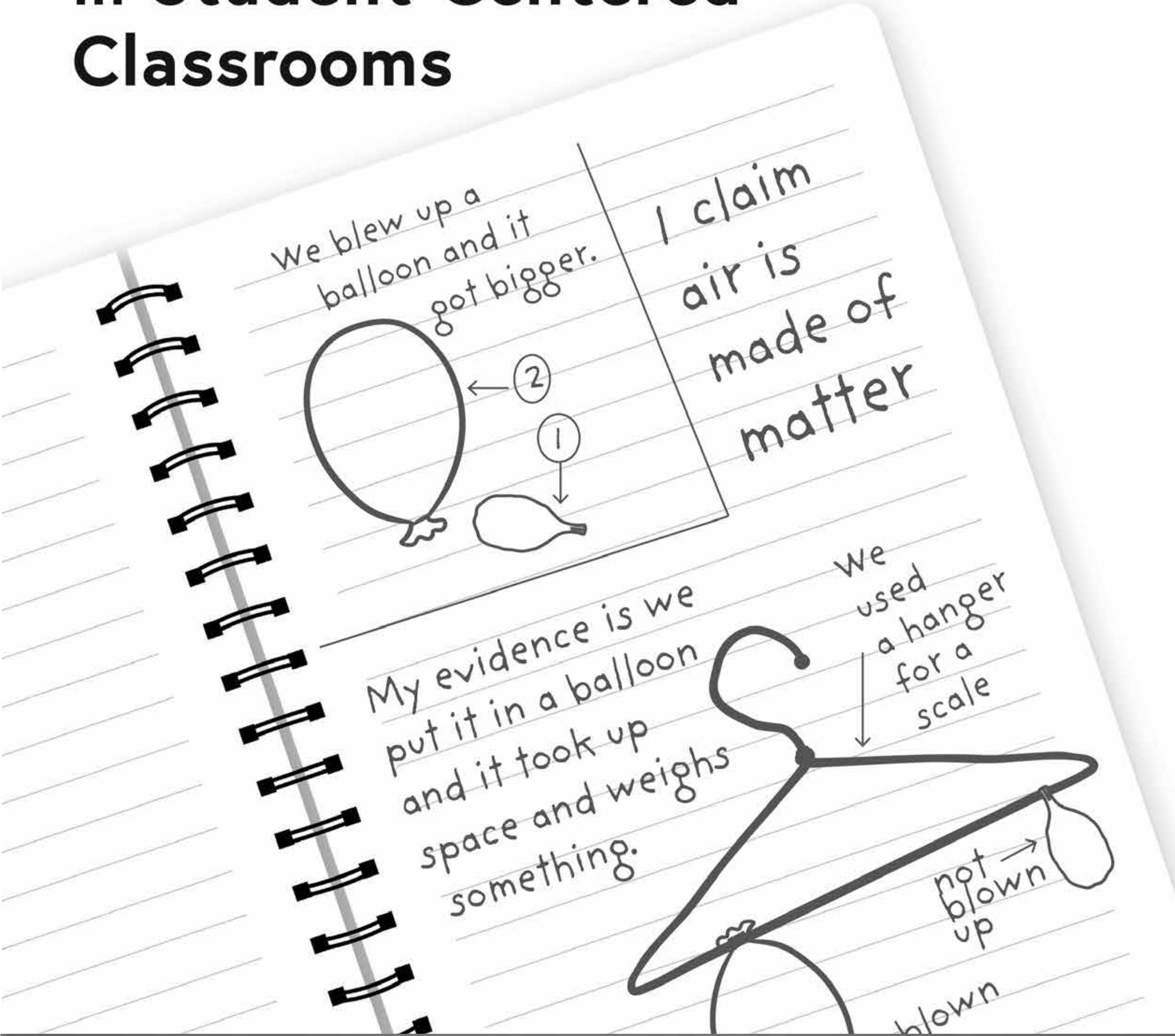

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I thank my parents for fostering my love of learning and, in particular, my passion for reading, writing, and science. The weekly library visits, walks in our local metro parks, time to splash and tromp around in nature, and summer workshops at our science museum all set me on this path.

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ABOUT THE AUTHOR

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INTRODUCTION

Imagine a classroom full of third-grade students, hard at work investigating the effects of friction on the movement of objects. Students are clustered in small groups around the room, taking turns sending furniture sliders down ramps and measuring how far the sliders travel on different types of paper placed at the bottom: printer paper, waxed paper, and sandpaper. The room buzzes with excitement as the students pepper their teacher with observations and questions.

"It went really far on the waxed paper, but it didn't move on the sandpaper."

"I think we messed up on this one. We bumped the ramp, and the slider went farther than the other two times."

"Can I draw a picture to show my data?"

"What would happen if we made the ramp steeper?"

In almost every case, the teacher encourages her students to document these observations and questions in their science notebooks. They take this work seriously, meticulously detailing their findings. When it appears that the groups have finished collecting data, the teacher directs the students to write a claim and support it with evidence from their investigation. The lesson concludes with a class discussion in which students share their claims and respond to each other's thinking.

A look inside the students' notebooks at the end of the lesson reveals highly individualized and meaningful work. Some students have created simple tables to organize their data, while others have listed their measurements in rows. Some have included sketches of the experimental setup and results, while others have written narrative text about their findings. Some entries are brief and lack important information, while others are lengthy and quite detailed. Yet despite these many differences, there is an important commonality. All students were clearly engaged in the *practices* of science: asking questions, analyzing and interpreting data, engaging in argument from evidence, and so on. Their work is a tangible record of their emerging understanding and proficiency—their thinking made visible.

As the teacher reviews her students' work, she not only learns how they are beginning to understand the concept of friction and the crosscutting concept of cause and effect but also ascertains each student's strengths and challenges in participating in the academic work of science. The interdisciplinary nature of this investigation provides students with a meaningful and relevant context for English language arts skills and mathematical practices (incredibly helpful in a crowded elementary curriculum) and provides the teacher with cross-curricular formative assessment. Using notebooks as a source of formative assessment will allow her to plan future lessons to support students in developing science and engineering practices, understanding relevant concepts and vocabulary, and identifying the crosscutting concepts that underlie all scientific content.

The vision set forth in this example demonstrates the power of science notebooks to engage students as active participants in the practice and learning of science. This is the approach I use in my own classroom. As an elementary science specialist, I have successfully used science notebooks with students in first through fifth grades for the past nine years. Though I have made small tweaks and improvements each year in the ways I launch, use, and assess my students' notebooks, the core of my approach has remained the same. I want my students to view their science notebooks as a safe place to write down their thoughts, try out new ideas, pose questions, and work through puzzling data. Although notebook entries serve as a vehicle to help students learn to organize their writing in discipline-specific ways, I also want their entries to reflect their unique voices whenever possible. Above all, I want each student's notebook to be a record of his or her meaningful and personalized learning over the course of our year's work—one that the student may keep and look back on in years to come. These desires influence every aspect of my approach to notebooking, from the model I choose to the ways in which notebooks are used and assessed in my daily lessons.

This book provides what you need to know to adopt a similar approach in your own classroom. I begin by describing an approach to elementary science that aligns with the vision set forth in *A Framework for K–12 Science Education: Practices, Concepts, and Crosscutting Ideas* (NRC 2012) and the *Next Generation Science Standards* (NGSS Lead States 2013), then share research that supports the use of science notebooks in an elementary classroom. Next, I review popular models of science notebooks and explain why I believe that a student-centered approach is the most appropriate for a three-dimensional science classroom. After that, I give details on specific approaches and resources to help you use science notebooks with your students: how to kick off a notebooking practice, ways to help students learn to organize information while also preserving student voice and choice, and lessons and instructional routines that pair well with science notebooks. I discuss how a student-centered approach is a wonderful way to support differentiation, as well as the use of science notebooks in assessment. Finally, I explain my thought processes as I assess student work and plan for future lessons. Additionally, though I recommend having students create their own tables and organizers whenever possible, the appendix includes a sampling of blackline masters for organizational elements (such as a table of contents) and instruction (graphic organizers) for use at your discretion.

As an elementary teacher, I know that every class is unique in its interests, strengths, and challenges—as is every student. It is my hope that you will be inspired by the approach detailed in this book, adopting what works and modifying what doesn't, to implement student-centered notebooks in your own classroom.

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CHAPTER 3

Choosing the Right Notebook Model

The only difference between screwing around and science is writing it down.

—Alex Jason, *Mythbusters*

Elementary science notebooks are enjoying a surge in popularity, with many resources online and in print. Even a quick web search shows many different approaches and models for notebooks, but not all are appropriate for the developmental needs of elementary students or the vision of three-dimensional learning discussed in Chapter 1. In this chapter, I review several popular models of notebooks and discuss the approach that I've found to be the most effective.

It is important to keep in mind differences between *science as a discipline* (what is practiced by researchers) and *school science* (what is practiced by students). To be sure, there are many significant overlaps between the two. In effective three-dimensional science classrooms, students engage in many of the same behaviors as scientists: collecting and analyzing data, reasoning about evidence, constructing and refining models, working cooperatively, sharing information orally and in writing, and so on. In fact, teachers' ultimate goal as science educators is to help apprentice students into the cognitive discipline of science (Collins, Brown, and Newman 1989; Collins, Brown, and Holum 1991). Yet there are key differences that should be considered, particularly in terms of the background knowledge that each group brings to the table. Scientists have done research, made evidence-based claims, extensively read the literature, and are by-products of extensive formal schooling (K–12 and higher education). These experiences contribute to a rich background knowledge that informs their methods, approaches, and ways of thinking about data. While students also have background knowledge, it is mostly from their lived experiences and prior classroom experiences and is thus limited in scope compared with that of scientists.

Although elementary students come to school with a wealth of knowledge about the natural world and are capable of sophisticated reasoning (NRC 2007), they still need carefully planned learning experiences to deepen their content knowledge and appropriately label science concepts with discipline-specific vocabulary. An elementary student's science notebook thus might include graphic organizers such as Frayer models to assess whether students have ownership of the concept behind the term or occasional space for taking notes on or responding to nonfiction text, which are not typically found in researchers' notebooks. Additionally, elementary students are developing proficiency in academic skills (such as reading and writing), executive functioning skills (such as organization), and discipline-specific skills (such as measurement and argumentation). Effective approaches to instruction in general, and notebooks in particular, provide support and scaffolding in these areas.

Any effective science notebook model should reflect the integrated, multifaceted approach to science education that is three-dimensional learning. This approach does not separate content and process, but instead weaves them together throughout instruction. These two lenses—using a three-dimensional approach to learning and meeting the specific needs of elementary students—aid in examining several popular models of notebooks: lab notebook, field journal, and interactive notebook, summarized in Table 3.1.

Lab Notebook

A lab notebook is a formal record of experiments performed and data collected. This type of notebook is quite formal and structured. Entries are dated and typically contain a hypothesis or purpose (or both), materials and experimental procedure, raw data, and some analysis of the data. The emphasis is on the documentation of the exact procedure followed, so others may replicate the experiment, and the collection of data.

In a research lab, the notebook is a legal document. Strict guidelines are thus in place: Bound notebooks are often used so that pages cannot be removed without notice, and entries are written in ink so that they may not be erased. While lab notebooks used in classrooms are not official documents in the same way, some of these guidelines may be implemented by teachers who had personal experience with keeping lab notebooks in college science courses.

Alignment With Three-Dimensional Learning

Lab notebooks, as a record of activity and findings, emphasize process over content and are thus most closely aligned with a single dimension (i.e, SEPs) instead of the interwoven emphasis on science and engineering practices, disciplinary core ideas, and crosscutting concepts. And while the lab notebook certainly includes a heavy emphasis on certain SEPs (planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking), others are less emphasized or absent altogether (developing and using models; engaging in argument from evidence; obtaining, evaluating, and communicating information). Furthermore, lab notebooks epitomize the stereotypical view of science as a discipline: a single scientist working alone in a lab and following a rigid procedure of doing science (often referred to as the "scientific method"). Some researchers do follow this approach, but studies have shown that "there is no single 'scientific method' universally employed by all" (NRC 2010, p. 19) and that scientists use a much more diverse set of approaches in their work. Additionally, the science education community recognizes that science is a social enterprise, unlike the solo record of work kept in this type of notebook.

Table 3.1. Comparison of popular notebook models.

	Primary use	Characteristics	Alignment with 3D learning	Benefits for elementary students	Drawbacks for elementary students
Lab notebook	Formal record of experiments and data in research labs	• Dated entries • Purpose and/or hypothesis • Materials • Experimental procedure • Raw data • Data analysis	• Some SEPs emphasized: * Planning and carrying out investigations * Analyzing and interpreting data * Using mathematics and computational thinking • DCIs and CCCs not an explicit focus	• Organized and easy to read • Predictable structure • Opportunity to develop strong data collection and analysis skills • Alignment with mathematical practices	• Some SEPs ignored • Emphasizes process over content • Emphasizes stereotypical view of science • Little opportunity for sensemaking • No opportunities for note-taking or practice using vocabulary • Reflects solo work
Field journal	Used in field to describe conditions, observations, and collections	• Dated entries • Time, weather, and other salient conditions • Quick notes or coding system that may be transcribed later • Sketches	• Can provide a basis for documenting and describing phenomena • Real-world context and data	• Integrates sketching and description • Engages students who prefer artistic forms of expression	• Emphasizes documentation over sensemaking • No opportunities for note-taking or practice using new vocabulary • Reflects solo work • Better suited to some science disciplines than others
Interactive notebook	Used in classrooms to aid in acquisition of science content knowledge	• Two-page spreads: input and output • Notes • Graphic organizers • Foldables	• Addresses disciplinary core ideas	• Engages students with content • Adds creative and interactive elements • Includes elementary-specific tasks	• Emphasizes content over practices • Structure can be limiting • Emphasizes teacher as content provider • Can lead to checklist assessment

Meeting the Needs of Elementary Students

Lab notebook entries are highly structured and predictable, two characteristics that can help build students' confidence in their abilities to plan and conduct investigations and collect and analyze data. The structure helps students organize their thinking and makes entries easier for both students and teachers to read. The emphasis on data collection and analysis strongly aligns with mathematical practices and standards, such as the measurement and data domain of the *Common Core State Standards for Mathematics* (NGAC and CCSSO 2010) and can help students develop these important skills. For these reasons, elementary teachers may find utility in using this model with their students as appropriate.

Despite these benefits, this model is not sufficient as a single approach for elementary classrooms. It does not provide the support and scaffolding necessary for the cognitive needs of young students, and it emphasizes the documentation of process over sensemaking and knowledge construction. Moreover, it affords no opportunities for the range of other instructional activities used in elementary science classrooms. Finally, the rigid structure may become a challenge for students who struggle with writing, leading to a loss of confidence and interest in the subject.

Field Journal

As the name implies, a field journal is taken into the field to document what is observed or collected. Entries are dated and include the physical location, the weather, other salient environmental conditions, and observations. These might include descriptions of species encountered, behavior of animals, and any specimens collected. Some advocate taking quick notes or using a coding system to document animal behavior and then transcribing these notes into more formal writing later on. Some field journals also include sketches of organisms observed or the locations of objects and organisms.

Alignment With Three-Dimensional Learning

The observation and explanation of phenomena is a key component of three-dimensional instruction (see Chapter 1). Field journals can serve as vehicles for documenting observations of a phenomenon that students may return to throughout a lesson or over the course of an entire unit. Field journal entries can also provide real-world qualitative and quantitative data that students can use to construct explanations of a phenomenon.

However, just as with lab notebooks, there are limits to the degree to which field journals align with three-dimensional instruction. Many of the science and engineering practices do not naturally emerge from the use of a field journal, and the focus is on documentation, not sensemaking. This means that like lab notebooks, field journals are not the best model for the understanding of disciplinary core ideas and crosscutting practices.

Meeting the Needs of Elementary Students

There is great value in teaching elementary students to be careful observers of the natural world, and you will see many field journal–inspired pages in my approach to notebooks throughout the remainder of this book. I've found that students who observe closely are more likely to generate thoughtful questions that lead to rich investigations. Field journals also provide opportunities for interdisciplinary learning, including art and descriptive writing. Additionally, this type of documentation is accessible and nonthreatening. All students, regardless of language or writing proficiency, can make their own observations and interpretations that can be celebrated and refined.

As with the lab notebook model, the field journal cannot be the only model used with elementary students, for a variety of reasons. The range of disciplinary content studied by elementary students exceeds what is typically found in a field journal; physical science concepts, for example, don't mesh well with this approach. Furthermore, the purpose of a field journal is often primarily documentation, and any approach used with students must include opportunities for sensemaking, practice using newly acquired vocabulary, argumentation, and so on. Finally, field journals tend to be the product of solo work and don't reflect the communication and exchange of ideas that occur in elementary science classrooms. Despite these limitations, you can selectively use this model at appropriate times within a broader approach to notebooks.

Interactive Notebook

Unlike lab notebooks and field journals, an interactive notebook is a model specifically created for students and school science. This model can be described as an "organizational system for class notes … and a creative outlet for students as they process information from class" (Robinson 2018, p. 20). An interactive notebook blends teacher-directed information (input) and student-generated responses (output). Typically, this information is organized in a two-page spread, with input on the right-hand page and output on the left, or vice versa. Input may take the form of notes from a lecture or video, vocabulary, a graphic organizer, or a foldable with science content. The output pages are for students to interact with the content through brainstorming, written reflections, drawings, diagrams, or other higher-order thinking activity (Chesbro 2006). Proponents of this model explain that it aids in the learning of scientific content through increased participation and processing (Young 2003).

Alignment With Three-Dimensional Learning

Although there is inherent value in increasing students' engagement with scientific content, this particular model is not ideal for three-dimensional instruction for several reasons. First, and most important, the underlying premise of an interactive notebook is that the teacher delivers information while the students are responsible for responding to and ultimately learning it. This is opposed to the vision of science teaching and learning as a continual process of obtaining and analyzing data to create and refine models for scientific phenomena—a vision in which students are explorers, not simply recipients. Copying down information, whether as traditional notes or on a graphic organizer, reflects outdated thinking about effective science instruction.

Interactive notebooks also often prioritize scientific content over practices and process, a dichotomy that is not supported by educational research in science. Learning scientific concepts and acquiring new vocabulary to describe these concepts are important components of science education, but they should not be done in isolation. Students need to regularly engage in science practices such as generating questions, designing methods to answer them, analyzing data, and constructing explanations based on evidence. Their notebooks should be a place to do this work, not just to write down content to memorize.

Meeting the Needs of Elementary Students

As a model specifically created for the classroom, interactive notebooks do provide some benefits for students compared with other notebook models. First, adding foldables and other creative elements can capture student interest in a way that other types of notebooks do not. These creative elements help engage students with disciplinary core ideas and scientific content, not just practices. And unlike lab notebooks and field journals, interactive notebooks necessarily include elementary-specific tasks, such as opportunities for vocabulary development and note-taking.

Proponents of interactive notebooks point to the structure and predictability of entries as a benefit for students. To be clear, there is value in structure and some predictability when it comes to teaching students how to organize their thinking and writing. However, the overly structured approach of an interactive notebook can be limiting for you and your students alike. What happens when content from a lesson doesn't fit neatly onto a two-page spread? Can students have the opportunity to personalize their own learning and work in meaningful formats? Where (and when) do students have the opportunity to revisit and revise their thinking? Decades of research have found that learning is a complex, transactional, and often messy process. Any approach to science notebooking should reflect this understanding.

Finally, the interactive notebook model can be a slippery slope toward valuing and rewarding compliance over deep thinking and learning. The input-output model easily leads to a checklist approach to assessment: Are all output assignments complete? Have directions been followed? Are entries neat and organized? Focusing on these types of criteria for assessments distracts from the true purpose of a notebook: to support students' sensemaking of phenomena and scientific content.

I am not implying that there is never a time or place for note-taking, and a well-timed graphic organizer or foldable can certainly boost student understanding. Such elements are reflected in my approach to science notebooks later in this chapter and throughout the entire book. However, I use these tools sparingly, and only when other approaches do not suit the content or my purpose.

Digital Notebook

Although a digital notebook is not a model in and of itself, many teachers (and their students) use software, tools, and apps to create digital science notebooks. It is easy to understand the appeal: Such notebooks are characterized by easier organization, the ability to integrate photographs and data from probes and other electronic measuring tools, and the possibility of universal access thanks to the cloud. Saving paper and appealing to students' interest in all things technology-related are also quite compelling. Moreover, digital notebooks provide access for students with disabilities through audio recording, text-to-speech programs, and other features. Recent research (Paek and Fulton 2016; Fulton, Paek, and Taoka 2017) has demonstrated that elementary students are capable of using a digital notebook successfully, although there are specific developmental needs to consider, such as writing on a tablet versus typing with a keyboard (Paek and Fulton 2014). Additionally, a study using a web-based science notebook based on Universal Design for Learning (UDL) principles found improved science learning outcomes, as well as high levels of student and teacher interest, feelings of competence, and autonomy (Rappolt-Schlichtmann et al. 2013).

While some teachers find digital notebooks to be superior to traditional paper notebooks (Constantine and Jung 2019), they are not a one-size-fits-all solution. Research findings suggest a real benefit to handwriting in physical notebooks, including greater idea generation (Berninger et al. 2006, 2009), better learning of content (Mueller and Oppenheimer 2014), and better memory (Smoker, Murphy, and Rockwell 2009). For some teachers, these benefits outweigh the convenience of digital notebooks. Others do not have the devices needed to support the effective use of a digital notebook platform. And still others might use both in tandem to take advantage of the strengths of each format.

In my mind, the format (paper or digital) matters less than the pedagogical approach being used. The chapters that follow include many examples from paper notebooks, as this is what I have used—and continue to use—in my elementary science classroom. Though I occasionally use technology to create notebook entries and do offer typing as an alternative for students with writing-specific learning differences, most of our notebook work is done by hand. However, the approach to notebooking that I present in subsequent chapters can be applied to both paper and digital formats.

My Flexible Approach to Notebooking

I do not follow any one specific model for my students' notebooks. Instead, I use a more flexible approach in which I borrow and adapt specific strategies and templates from the various models, matching *format* and *task* to the *purpose* of a specific lesson or instructional activity. If my students are designing and conducting an experiment that follows a specific procedure or process, their notebook entries will reflect those of a lab notebook. If we are outdoors in the schoolyard or on a field trip, their entries might resemble those found in a field journal. On the rare occasion that I provide students with content (only if they cannot discover it themselves), I might ask students to respond to this information in a manner similar to an interactive notebook entry. I may choose to include a graphic organizer or foldable if I feel that it will truly enhance student understanding of a concept. I also provide scaffolds and exemplars to help students approach thinking, writing, and speaking in scientific ways. (For more information on how I plan a unit of study with the notebook in mind, see Chapter 9.)

I also strive to balance the number of teacher-directed entries with opportunities for students to use *voice* and *choice* in their science notebooks. To help my students learn to effectively represent and organize information, I choose to include organizational elements such as a table of contents and glossary pages. At times, I model how to set up a particular notebook page, dividing the space into sections or creating a table. This is especially true at the beginning of a school year, with new students, or when my students are working on a new type of entry. However, I make a pointed effort to also allow times when students are free to organize and represent their work in any way that makes sense to them. Although this means that entries can be messy and harder to read and assess, I know that the only way students will truly develop these abilities is through continued trial and error. (See Chapter 5 for approaches that help students learn from their peers and improve their notebooking skills, including the use of a document camera and notebook workshop time.)

Finally, it is worth stating that my students' notebooks look different from year to year and even from class to class. While there are elements that I have fine-tuned and use consistently each year, I know that my use of notebooks will be most effective if it is responsive to my students and their individual needs—as well as to my own learning and growth as a teacher. In the chapters to come, I share my most effective techniques to date and examples, knowing that you will adapt my ideas to suit your own particular situation and students.

♦ ♦ ♦

Various models of science notebooks exist, yet they are not all created equal in terms of their appropriateness for three-dimensional learning and the developmental needs of elementary students. Rather than adopt a singular model, I borrow elements from each as appropriate for the content and task at hand. This flexible approach allows me to tailor my notebooking strategies to individual classes. In the next chapter, I share strategies for effectively introducing science notebooks to your students.

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SCIENCE NOTEBOOKS
in Student-Centered Classrooms

Thinking made visible: That's what happens when elementary students record their thoughts in science notebooks. This practical guide shows how notebooks can become a tangible record of their emerging understanding of and proficiency in science. Students can use their notebooks to pose questions, write down observations, work through puzzling data, or think through new ideas. You can use them to ascertain each student's strengths and challenges in participating in the academic work of science.

Science Notebooks in Student-Centered Classrooms offers the following:

- **Specific guidance on how to start using notebooks—or improve what you already do.** Find out how to help students learn to organize information while also preserving their own voices and choices. Many of the samples are from actual student notebooks.
- **Advice on the best ways to use notebooks.** Explore lessons, instructional routines, and assessment techniques that pair well with science notebooks.
- **Practical techniques.** Discover how to use notebooks to assess student work and plan future lessons even as you integrate language arts and mathematics into your science class.
- **Blackline masters you can use at your discretion.** These are provided in the appendix for organizational elements (such as a table of contents) and instruction (graphic organizers).

Throughout, the book's approach aligns with the vision in *A Framework for K–12 Science Education,* the *Next Generation Science Standards,* and current research about notebooks.

You can be sure the strategies in this book really work because author Jessica Fries-Gaither is a veteran teacher who has personally tested every technique. She is also the author of the award-winning NSTA Kids books *Notable Notebooks: Scientists and Their Writings* and *Exemplary Evidence: Scientists and Their Data*. As she says in the book, science notebooks have the power "to engage students as active participants in the practice and learning of science."

GRADES K–5

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