Introduction

Misconceptions are sneaky. They lurk just under the surface, and many times, we are unaware that they exist. However, when we discover them, it can be unsettling and downright preposterous to even entertain the idea that what we have believed to be true is **not**. It can take a **lot** of convincing, mental acrobatics, and time to change incorrect ideas. Think about all of the students who visit your classroom every day. Each one has misconceptions; we all do. Pondering how to uncover those misconceptions and then what to do with incorrect information can feel overwhelming. Luckily, you have come across this resource. It will guide you through detecting, confronting, and replacing some of the commonly held misconceptions we encounter in science classrooms.

To begin, let's define the term *misconception*. What is a misconception? Take a minute and reflect on how you define it.

As defined by Merriam-Webster, a misconception is "a wrong or inaccurate idea or conception" (2022). To expand on that, misconceptions are something we learn incorrectly due to faulty thinking or understanding. Some misconceptions are more ingrained and complex than others. Let's take a few minutes to define each type of misconception.

- **Vernacular Misconceptions:** This type of misconception is perhaps the least time-consuming to correct. Vernacular misconceptions occur when we use scientific words in a conversational manner. For example, when teachers say, "Rotate to the next station," students know that means they need to move to another location. However, in science, rotate means to spin in place on an axis. Students can rotate all day and never make it to the next station. Instead of conversationally saying, "Rotate to the next station," replace *rotate* with *move*, *advance*, or *go*. Being aware of how we use words can make a difference for students, especially our Emergent Bilingual Students/English Learners who must simultaneously learn English and the language of science.

- **Factual Misconceptions:** This type of misconception usually takes hold at an early age and is never corrected. Many of these misconceptions originate as superstitions and other sayings that get passed down from one generation to the next and become accepted as factual. The most commonly known example of this misconception is that lightning never strikes twice in the same location. Who wants to test that out? No? Always remember to fact-check and do your research. Encourage your students to do the same.

- **Preconceived Notions:** This type of misconception occurs based on our everyday encounters and experiences. For example, why do some bruises have darker pinpointed spots in them? Depending on where the bruise is located and the extent of a person's knowledge of how the body works, it might be plausible to think that those darker spots are due to damaged hair follicles. When researched though, one would find those darker

spots signal that tiny capillaries have burst causing blood to escape. Eventually, that blood is reabsorbed by the body and the bruise goes away. Another example of a preconceived notion is when someone explains why we get chilled walking in refrigerated areas of grocery stores. Is it because cold air hits our skin or that heat from our bodies moves to the cooler area? Good question, right? Heat always moves to a cooler area, but that is not what initially makes the most sense.

- **Conceptual Misunderstandings:** This type of misconception is potentially the most complex and time-consuming to address. Its best friend is preconceived notions, and together they work to reason out what seems like a logical explanation for why something is or occurs. For example, the veins in our wrists look blue. Therefore, the blood in those veins lacks oxygen and needs to be run back through our lungs, right? No. Blood is always red. The way light penetrates our skin causes veins to look blue. This misconception type is not addressed in this book.

Knowing which type of misconception we are challenged with can help us figure out how to address it. For example:

1. How long has it been there? How deep-seated might it be?
2. What is the misconception based on? An incorrect fact or faulty complex reasoning that seems to make sense?

Answering these questions helps us gauge the amount of time and number of new exposures to learning that a student may require to correct a misconception. So, let's get started.

Detecting, Confronting, and Replacing Misconceptions

This book works through a series of three steps to address misconceptions.

1. The first step focuses on **detecting**, or uncovering, misconceptions.
2. The second step creates cognitive dissonance to provide students the opportunity to **confront** incorrect thinking or ideas.
3. The third step involves **replacing** the misconception with correct information or thinking.

Now we will dig deeper into each step of the process.

Detecting Misconceptions

The first step is detecting a misconception. This involves anticipating, planning for, and uncovering misconceptions. How do we do that you ask? Through formative assessment, of course! Those well-placed checks for understanding in a lesson cycle can provide a window into student thinking. If we anticipate the potential existence of the misconception, we can detect it as soon as possible. In this case, formative assessment would occur at the beginning of the lesson cycle. However,

misconceptions can also surface in the middle of a lesson when we may not necessarily be looking for them, and that's okay too. If we know a misconception exists in any part of a lesson cycle, we can and should address it.

One way to detect a misconception is to listen to student discussions. If you hear something suspicious, be inquisitive. Ask the student why or how, or say, "Tell me more." Do this regardless of whether a student is on the right track or not so that they become accustomed to explaining their thinking. Determine whether students have a conceptual understanding or have simply memorized or copied an answer or restated what someone else said. Also, equal opportunity questioning keeps students from automatically assuming they are wrong when you question them. Another way of truly understanding how students think is through their writing or drawings. Provide open-ended questions as prompts. Allow anywhere from 3 to 15 minutes for students to answer depending on the time available and the complexity of the question or concept being addressed. Some students may find writing or drawing less threatening than verbally explaining their thinking in front of the class. If students struggle with writing, implement a quick think-pair-share activity to allow verbal processing in a safe setting before writing explanations. You can further support their writing through the use of sentence stems or sentence frames.

Various formative assessment strategies exist to detect misconceptions. You will see some of these strategies used to detect the misconceptions addressed in this book. Templates for creating your own activities to detect misconceptions can be found in the Appendix.

Confronting Misconceptions

Once we know that a misconception exists, we have to provide an opportunity for students to confront it. Confronting a misconception is much more difficult than detecting or replacing it because we have to create cognitive dissonance, the mental discomfort that occurs when faced with two conflicting ideas (Cherry 2022). Effective cognitive dissonance requires deep thinking and often results in an uncomfortable encounter for the student and the teacher. The brain seeks to make new information fit within existing schema, or how that person understands an idea or concept. When new information clashes with existing schema, the person is forced to mentally struggle to make sense of the new information. Changing incorrect thinking requires reconfiguring brain pathways and replacing existing schema. This is a mentally exhausting task! An established safe learning environment is critical for students to more readily engage in this step because it can be unsettling to own and reconcile faulty thinking in front of one's peers and a teacher. Students are more likely to face their misconceptions when they are in an open-minded, supportive physical and mental space.

As with *Detect*, more than one way to confront misconceptions exists. If students built a model or drew an illustration for the *Detect* activity, an effective *Confront* activity would be asking students to compare and study their models or drawings to a model, illustration, phenomenon, or investigation that demonstrates the correct idea or concept. This could also be accomplished

with concept maps, reading passages, videos, or guided discussion. No matter the method, students need evidence that contradicts faulty thinking. As a side note, students without misconceptions can simultaneously work through this process. It would be beneficial for them to reinforce and strengthen their ideas.

More than one encounter and several pieces of evidence may be required to alter incorrect thinking. The amount of time involved with this step depends on the depth and complexity of the misconception. You may also find that you need to revisit misconceptions throughout the year if students revert back to incorrect thinking. You will see a variety of strategies used to confront the misconceptions addressed in this book. We have also provided a list of ideas in the Appendix for creating your own activities.

Replacing Misconceptions

Of the three steps, the *Replace* activities firmly place control in the hands of the students. They have the opportunity to engage in activities of their choosing to reinforce new learning. We can provide different options that appeal to diverse learners and their needs. Some ways to replace misconceptions include:

- Story telling
- Song writing
- Playacting
- Picture drawing
- Video recording
- Model building
- Concept mapping

Building as many new brain pathways as possible is key not only to replacing misconceptions but also to retaining the new information. When a learner interacts with an idea or concept in different ways (e.g., reading, writing, speaking, drawing, movement, music, models), each interaction can create a new and different pathway to that idea or concept. The more brain pathways a learner has, the more ways that learner can retrieve that idea or concept. Repetition can make these pathways more permanent, helping students retain information. Each of these strategies involves both sides of the brain as students think logically **and** creatively to infuse learning using a selected strategy. Consider providing students a choice around whether work is achieved independently, in pairs, or in small groups. When attempting to replace a misconception, the key point to remember is providing the learner with opportunities to interact with new learning in meaningful ways that demonstrate their understanding.

Refer to the Appendix for ideas on how to create choice boards that provide options for students as they work to replace their misconceptions. You will see examples of how we have incorporated choice boards with the *Replace* activities throughout the book.

How to Use this Book

Each misconception represented in this book is addressed by a set of three activities: the first to detect, the second to confront, and the last to replace. We will refer to the three activities that address a misconception as an *activity* set.

As we began to think through detecting, confronting, and replacing misconceptions, we found ourselves pondering how these activities fit with the 5E Instructional Model (Bybee 2015). Here is our major takeaway: the two processes are similar but separate.

Misconception Activity Sets	
Activity	**Comparison to 5E Phases**
Detect 	Similar to an Engage part of the 5E Instructional Model, detecting a misconception involves accessing prior knowledge. Teachers use or design a formative assessment activity to find out what students know in order to uncover any potential misconceptions.
Confront 	Similar to the Explore and Explain parts of the 5E Instructional Model, confronting a misconception requires a sense-making experience where students observe, think, reason, discuss, and question what they know. In other words, students perform heavy mental lifting here with teachers acting as facilitators and guides.
Replace 	Similar to the Elaborate and Evaluate parts of the 5E Instructional Model, replacing a misconception requires students to interact with and produce evidence of their new learning. Students need to build new brain pathways making as many connections as possible to new, correct information. Teachers check frequently to reinforce new conceptual understanding.

The activities that address a misconception can be built into a 5E lesson. The depth, complexity, and number of students affected by a misconception may affect pacing. However, anticipating student misconceptions becomes easier over time which makes pacing easier to gauge.

After much discussion and debate, we chose to write this book as a K–5 strand because knowing how concepts build and grow from one year to the next is important. Familiarity with vertical

alignment helps avoid teacher and student learning gaps. Elementary teachers greatly influence and impact how students learn foundational science. Secondary teachers are then able to extend the learning. You may find only certain misconceptions addressed in this book are embedded in the curriculum or standards you teach. Regardless, please take the opportunity to read **all** of the misconceptions in order to build your content knowledge.

We purposefully did not label misconceptions by grade level for two reasons.

1. The standards or curriculum you follow will determine at what age or grade level a misconception may be encountered by students.
2. It is entirely possible that an upper elementary student may have a misconception from primary grades. The last thing we want to do is unintentionally insult the intelligence of older students by handing them an activity labeled as a previous grade level.

Activity Layout

You will see a **Content Builder** for every misconception. This piece is meant to provide extra information and build background knowledge for teachers.

If an activity requires **Materials**, those will be listed at the beginning of an activity. We strive to make the materials affordable and easy to find. In some cases, materials can be substituted based on what you already have on hand.

Advance Preparation is included for any activity that requires prework for the teacher. This may be a card sort that needs to be copied, laminated, cut out, and bagged. It could be materials that need to be gathered and set up. Regardless, these are tasks that need to be completed prior to students arriving in the classroom.

Teacher Instruction details how to conduct an activity. This section includes step-by-step directions on how to engage and keep students working through an activity with the teacher acting as a facilitator and guide.

Reproducible Masters (RMs), or student handouts, will be shown as a thumbnail image within the activity as a quick reference for the teacher. The full-page RMs follow at the end of the activity set after all of the teacher pages. The naming convention will be the title of the activity followed by "DETECT," "CONFRONT," or "REPLACE" (e.g., Mass and Weight: DETECT).

Facilitation Questions and ideal responses are provided to help teachers guide students through activities and the sense-making process. This list of questions is not comprehensive and should not be limiting.

Answer Keys are provided when necessary. In many cases, an answer key serves as a foundation, but additional answers may exist. Give students the chance to justify their answers. If they provide evidence that makes sense, grant them credit.

The **Appendix** provides tools for creating additional activity ideas and templates.

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