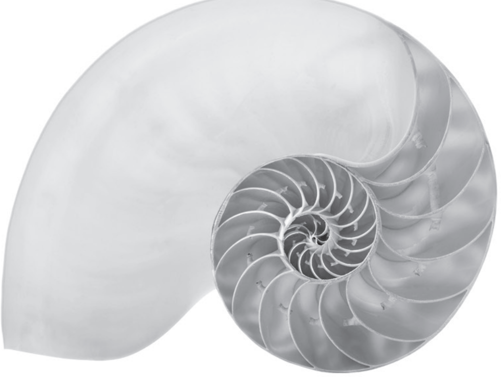

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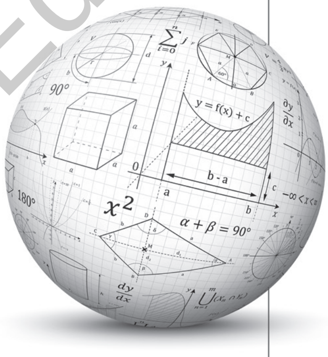

LESSON IMAGING in MATH + SCIENCE

Anticipating Student Ideas and Questions for Deeper STEM Learning

ALEXANDRIA, VA USA

Hawker Brownlow EDUCATION
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LESSON IMAGING in MATH + SCIENCE

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Introduction

To me, lesson imaging is a visualization process. You often hear about athletes visualizing their game. Imaging is a process in which teachers visualize what will take place in their classroom when they present a task.

—George McManus, middle school mathematics teacher, Florida

Imagine that your parents or grandparents are celebrating their 50th wedding anniversary this year. You and your siblings want to plan a special event with lots of family and friends, so you decide to throw a party for them three months from now. With the date decided, you need to think through numerous details carefully. Where will the event take place: the city where they currently live? The city in which most of your family lives? Somewhere central to all? Also, what kind of venue will be needed—a formal setting or more of a "party" atmosphere? Whom will you invite? When do invitations need to be sent? Will it be a surprise? And so on.

As the day gets closer, you excitedly begin to imagine the event in your mind, playing it out activity by activity. You imagine where you will seat certain relatives; you know, for example, that Uncle Lee does not get along well with cousin Meagan, so you should place them far away from each other. As you let the image unfold, you realize that there aren't enough non-alcoholic beverages at the party for those who do not drink, such as cousin Christine. Then you remember that even though your parents love pastries, Auntie Donna is on a diet, so you must make sure there are healthy snacks,

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STEM Literacy: The Nature of STEM Teaching and Learning

> *Mathematics in the work place makes sophisticated use of elementary mathematics rather than, as in the classroom, elementary use of sophisticated mathematics.*
>
> —Lynn Arthur Steen, *Quantitative Literacy*

Before getting into lesson imaging and its implementation in STEM classrooms, let's take a moment to think about the desired outcomes of a standards-based STEM program with a strong inquiry instructional model. STEM has become a buzzword used by many in hopes of capturing the synergy behind the demand for qualified workers in science, technology, engineering, and mathematics, and many schools have thus embraced the term to describe their programs or their curricular emphasis. STEM magnets and charter schools are popping up with great frequency, attempting to capitalize on the national trend and the increased funding. Adopting a tag, however, doesn't necessarily mean that schools have significantly changed their practices or curriculum in the ways necessary to prepare students for college-level STEM studies or the technical entry-level STEM job market. A meaningful view of what STEM education means is central to developing ideas about effective teaching and learning. This chapter provides one way of conceptualizing STEM education, with the intent of establishing some common perspectives that will guide the development of strategies for effective lesson imaging and teaching.

The Four Pillars of Learning

UNESCO's four pillars of learning (Nan-Zhao, 2008; Zollman, 2012) provide a useful framework from which to develop powerful ideas about STEM teaching and learning:

1. Learning to know
2. Learning to do
3. Learning to live together
4. Learning to be

These four pillars promote a continuum on which STEM literacy can be characterized, and they will move us toward a common vision of what it means to have STEM literacy.

Learning to Know

The first pillar, *learning to know*, involves increasing students' literacy in each of the four content areas: science, technology, engineering, and mathematics. These content area literacies are central to the development of lesson imaging as a planning tool to promote effective instruction. As with most publicly popular terms, definitions of content literacy are so diverse that it is hard to pinpoint just one. Regardless, being literate in each of the four content domains serves as the crux of lesson imaging for STEM education, and we will thus define what these literacies mean for us in the context of this book.

Scientific literacy involves constructing the content and process skills necessary to understand the natural world. Beyond having a conceptual understanding of the world, being scientifically literate also means being able to "use the methods of science; apply science to social, economic, political, and personal issues; and develop an appreciation of science as a human endeavor and intellectual achievement" (Hurd, 1958, p. 13). The most important aspects of scientific literacy involve knowing the content and practices of science well enough to make informed decisions about the natural world around us. For example, individuals who are scientifically literate can understand both positive and negative implications of building a nuclear facility in their town and can make reasoned, factual arguments for and against such a proposal.

Technological literacy goes beyond the ability to simply use digital devices—it is the "ability to use, manage, assess and understand technology" (International Technology Education Association, 2007, p. 7). Being technologically literate involves using the scientific method employed by engineers and scientists to create new technologies and being able to assess both the value of a technology and the potential harm it might create—in other words, determining whether a technology is worth pursuing.

Engineering literacy involves knowledge of and facility with the design method that is employed in creating and testing new innovations and understanding the implications of such products.

Mathematical literacy refers to the "capacity of students to analyze, reason and communicate effectively as they pose, solve and interpret mathematical problems in a variety of situations involving quantitative, spatial, probabilistic or other mathematical concepts" (Organisation for Economic Co-operation and Development, 2007, p. 304).

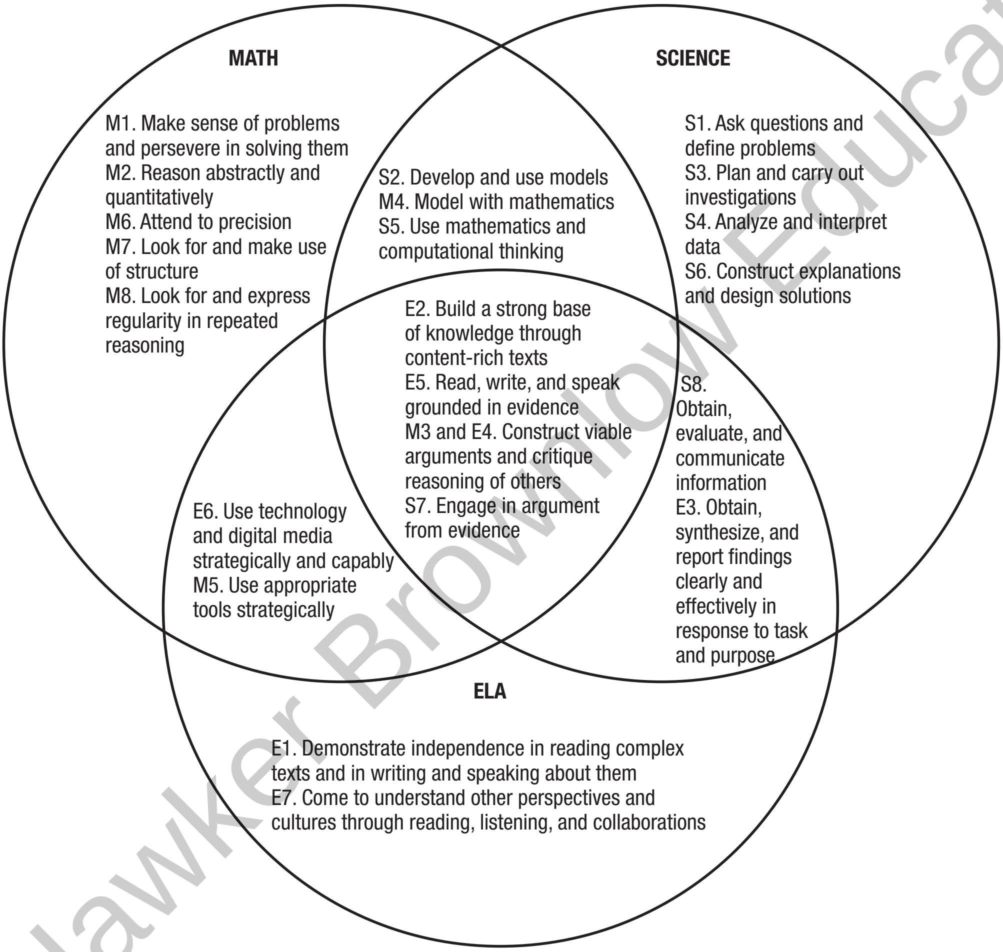
It is clear that STEM literacy includes knowing the content of the discipline at more than a rote level, being able to employ the scientific method or engineering design process when exploring a domain or designing new tools, and assessing and communicating the impact of any findings on the natural world.

Learning to Do

Teaching and learning in STEM extend beyond an emphasis on memorizing content. STEM literacy also involves *learning to do*, the second pillar of learning. Employing inquiry-guided instructional methods gets students involved in ways that incorporate the higher cognitive skills that are indicative of 21st century learning. Exploring innovative problems provides interesting and challenging opportunities for students to develop problem solving, optimization, and visualization in mathematics, science, and engineering contexts (Binkley et al., 2012).

FIGURE 1.1

Commonalities Among Science, Mathematics, and English Language Arts



Source: From "Relationships and Convergences Among the Mathematics, Science, and ELA Practices," by T. Cheuk, 2012, Palo Alto, CA: Stanford University. Copyright 2012 by Tina Cheuk. Reprinted with permission.

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Imaging Mathematically Powerful Whole-Class Discussions

The lesson image process is like a rehearsal before the performance. It can help a teacher determine what to expect from student responses and how to create a whole-class discussion centered on students' mathematical ideas.

—Ashley Dickey, middle school mathematics teacher, Florida

In conversations with STEM teachers, the question most frequently asked of us is, "How do you know what questions to ask in a whole-class discussion?" We acknowledge that this segment of lesson implementation can be the most difficult activity of one's inquiry practice. However, the four important activities outlined in the previous chapters will make imaging your whole-class discussions much more powerful:

1. Unpack the STEM learning goals that are targeted for the lesson.
2. Choose appropriate tasks that allow for exploration of the goals.
3. Launch the task to engage students in the constraints and possibilities involved in problem solving.
4. Anticipate how students might solve the problem, both correctly and incorrectly.

Note that we did not say the process will be *easier*—but it will be more productive for you and your students.

This chapter reflects on these four imaging activities and illustrates how they can be used to envision a well-organized discussion, with students' solutions and explanations as the driving force.

Important Elements in Imaging a Whole-Class Discussion

One of the final components in lesson imaging is imagining the flow of the whole-class discussion so that the mathematical ideas identified at the beginning of the imaging process can be addressed. This process entails an intermingling of all the imaging from the previous chapters:

- What mathematical ideas are the activities designed to elicit?
- If students solve the problem in the way we anticipated, which solution strategies should we select, and in what order should they be presented, so that the mathematical ideas emerge?
- Which student representations would be most helpful for advancing the discussion, and how should we symbolize their thinking to aid in the discussion?
- What questions should we ask, and when should we interject them?

The answers to these questions will be different for every lesson and will also depend on prior work in the lesson imaging template.

Let us think through these questions with an example. Recall the problem involving ratios that was introduced in Chapter 2, where students had to determine whether there were enough food bars to feed a certain number of aliens. Students solve three problems as part of the first inquiry cycle. A 6th grade mathematics team has partially completed the lesson image template for the next lesson in the unit (Figure 5.1).

Since the goal of the lesson is to capitalize on students' symbolizing in order to introduce a ratio table, the teachers analyze the anticipated strategies with an eye to solutions that would lead toward this goal:

- While Solutions C and D are correct, they "hide" the linked composites (i.e., that there are three aliens fed by each food bar) and are too abstract for students who are just beginning to create these links.

FIGURE 5.1

Lesson Image for Cycle 2 of a Unit on Ratios

Science, Technology, Engineering, or Mathematics Goal(s): The idea of this lesson is to encourage students to link two composites together and to begin to organize these links when there are large quantities involved.

Rationale: Students need to find a way to organize the links as they increase in size. A ratio table should be introduced from students' work on this page.

State Standard(s): CCSS.Math.Content.6.RP.A.3: Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.

Cycle 2

Launch (Task presentation)

[Note: 1 food bar feeds 3 aliens.]

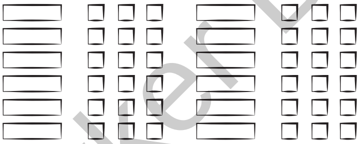
1. Will 12 food bars be enough to feed 36 aliens? Explain.
2. Will 24 food bars be enough to feed 72 aliens? Explain.
3. Will 6 food bars be enough to feed 18 aliens? Explain.
4. Will 8 food bars be enough to feed 20 aliens? Explain.
5. How many food bars are needed to feed 39 aliens? Explain.

To launch this task, ask students what the picture above means. Tell them that their goal for the next 5–10 minutes is to determine the answers to the five questions—but most importantly, they should put some type of writing or drawing on their paper to show others in class how they found their answers. Use the Think-Pair-Share strategy by having students work independently for about three minutes, then let them know that they should work with their partner as soon as they are ready.

Exploration (Anticipated student thinking—include class structure [in small groups, with partners, individually] and potential correct and incorrect strategies or solutions)

Question 1 is our headliner. We expect the following solution strategies from students:

Solution A



Solution B

1	2	3	4	5	6	7	8	9	10	11	12
3	6	9	12	15	18	21	24	27	30	33	36

Solution C

36 ÷ 12 = 3

Solution D

36 ÷ 3 = 12

Solution E

1	1	1	1	1	1	1	1	1	1	1	1
3	3	3	3	3	3	3	3	3	3	3	3

Whole-Class Discussion (Include tools, symbolizing, technologies, and questions you might pose)