A GUIDE TO THE USE OF

The Formative Assessment Process in SCIENCE

By Amelia Wenk Gotwals, Alicia Alonzo, Tara Kintz & Ed Roeber

Authored by Amelia Wenk Gotwals and Alicia C. Alonzo with Introduction and Overview of Formative Assessment by Tara Kintz and Edward Roeber

This text is one in a series of FAME guides to using the formative assessment process in the disciplines.

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NOTE to readers of print copies of this document: URLs for all hyperlinked text are available in the document's Endnotes. You can access the digital file with active hyperlinks in two ways:

- FAME participants can log in to the FAME website at www.FAMEMichigan.org. Search for the document by title in the FAME Resource Bank.
- All others can request a copy of the digital file from Kim Young at youngk1@michigan.gov.

Guide to Frequently Used Acronyms

CCC	Crosscutting Concept
DCI	Disciplinary Core Idea
FAME	Formative Assessment for Michigan Educators program
NRC	National Research Council
NGSS	Next Generation Science Standards
OMC	Ordered Multiple-Choice
PE	Performance Expectation
SEP	Science and Engineering Practice
SOLID Start	**S**cience, **O**ral Language and **Li**teracy **D**evelopment from the **Start** of School project.

NOTES

The central premise of this Guide is that disciplinary knowledge is essential to implement the formative assessment process and that teachers' implementation of the formative assessment process can promote deeper disciplinary knowledge.

Section I:
INTRODUCTION AND OVERVIEW

Tara Kintz and Edward Roeber

A. INTRODUCTION

How Effective Use of Formative Assessment Practices Can Deepen Disciplinary Understandings (and Vice Versa)

There is increasing attention on the need for educators to develop formative assessment practices that are rooted deeply in the specific disciplines in which they are implemented (i.e., Andrade, Bennett, & Cizek, 2019). Disciplinary knowledge is critical as teachers implement the formative assessment process to support student learning in meaningful ways. While many agree that teachers with deeper disciplinary understanding will be more effective users of the formative assessment process in their discipline, it is also important to address the needs of teachers who are in the process of deepening their disciplinary knowledge and learning about formative assessment. The intention of this *Guide* is to provide support as teachers deepen their knowledge in their specific discipline while also developing their formative assessment practice. The central premise of this *Guide* is that disciplinary knowledge is essential to implement the formative assessment process *and* that teachers' implementation of the formative assessment process can promote deeper disciplinary knowledge.

There have been different perspectives represented in the field about whether a teacher must first acquire deep disciplinary knowledge before learning about formative assessment. This includes questions about the extent to which a teacher may benefit from learning about formative assessment when it is not embedded in a specific discipline. It is evident that a teacher with deeper disciplinary understanding will be a more effective user of formative assessment processes. It is essential that a teacher have specific knowledge in a given content area to articulate learning targets, success criteria, and a progression of learning. The teacher will need this content knowledge to ask questions and to gather evidence of student understanding regarding the subject matter. A teacher's disciplinary knowledge will also inform how he or she identifies students' resources for learning, provides feedback, and uses evidence to inform instructional decisions. Thus, disciplinary knowledge is essential to implement the formative assessment process. At the same time, it is also possible, and beneficial, for a teacher to learn how to use the formative assessment process as he or she continues to deepen disciplinary knowledge and skills (which may take several years).

Coffey, Hammer, Levin, and Grant (2011) argued the importance of disciplinary substance in formative assessment. They presented instances of teachers using formative assessment strategies but not engaging with student ideas. In other

instances, teachers were more responsive to student thinking without the use of any particular strategies. The researchers argue for a shift from a focus on formative assessment strategies to attention on student ideas within a discipline. The implication is for teachers to engage with and respond to the substance of student ideas and reasoning, using discipline specific criteria, and identifying next steps along a progression of learning in the discipline.

While many agree on the importance of disciplinary knowledge for the implementation of formative assessment, it can be challenging to design and implement formative assessment practices based on core disciplinary content. Harris, Krajcik, Pellegrino, and McElhaney (2016) examined specific applications that blend disciplinary ideas in science with classroom formative assessment. Their work suggests the need to provide a design approach, examples, and implications for effective use of the formative assessment process in the context of a discipline.

… increased science content knowledge helped teachers engage with students' ideas, but the intervention did not help teachers to identify effective instructional strategies to respond to student ideas.

At the same time, content knowledge alone is not sufficient. A study on preservice teachers that involved an intervention to promote life science knowledge and formative assessment practice showed that increased science content knowledge helped teachers engage with students' ideas, but the intervention did not help teachers to identify effective instructional strategies to respond to student ideas (Sabel, Forbes, & Zangori, 2017).

This *Guide* focuses on how the use of the formative assessment process can help educators to deepen their understanding of a discipline and, in turn, how their deepening understanding of a discipline can guide them in better, deeper use of the formative assessment process.

The content of this *Guide* is organized as follows:

- Description of the content standards in the discipline
- Description of two examples (1 elementary and 1 secondary):
    - How the lesson can be planned (shown on the FAME Planning Template)
    - Vignettes of fictitious classrooms that describe how the lesson was implemented, when and how student understanding was checked, and what resulted, the formative feedback provided, and how instruction and learning were adjusted.

The sample lessons illustrate the formative assessment process as it is defined in the Formative Assessment for Michigan Educators (FAME) program. The sample lessons also point out that more experienced teachers will be better able to understand how student learning might occur, and how to either head off misunderstandings or help students to deepen their understandings and skills during the lesson.

The *Guide* shows where the formative assessment components and elements of the FAME program can be used as the lessons are planned and implemented. The goal ultimately is to show the importance of both the formative assessment process and deeper disciplinary understanding in promoting student learning. It will also suggest ways that educators can become more skillful and more knowledgeable about both formative assessment and their discipline.

B. Overview of Formative Assessment

A brief overview of the formative assessment process is provided in this section. For further information and a more comprehensive description, see the *FAME Learning Guide: Developing and Implementing the Formative Assessment Process in Michigan*, Michigan Department of Education (Kintz, et al. 2018).

The Michigan Department of Education adopted the formative assessment definition developed by the Council of Chief State School Officers (CCSSO) Formative Assessment for Students and Teachers (FAST) State Collaborative on Assessment and Student Standards (SCASS). and used in the FAME program: *Formative assessment is a planned, ongoing process used by all students and teachers during learning and teaching to elicit and use evidence of student learning to improve student understanding of intended disciplinary learning outcomes and support students to become more self-directed learners.*

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— Council of Chief State School Officers (CCSSO) Formative Assessment for Students and Teachers (FAST) State Collaborative on Assessment and Student Standards (SCASS), 2018

The key points in the formative assessment definition highlight:

- It is a planned, ongoing process
- It occurs during teaching and learning
- The intention is to elicit and use evidence of student learning
- The focus is on disciplinary learning
- The goal is to support students to become more self-directed learners.

The formative assessment process is based on three guiding questions posed by Sadler (1989):

1. Where are we (teacher and students) going?
2. What does the student understand now?
3. How do we get to the learning target?

The first question **"Where are we (teacher and students) going?"** includes an inquiry by the teacher of where students are going in their learning. This includes the identification of a clear learning target that students can understand. This helps the teacher and students to articulate their goal for learning. The teacher can help the students to understand a progression in their learning and the purpose of why they are learning particular subject matter at a particular time. The teacher and students must also clarify the success criteria so that students know what it looks like when they have met the learning target.

The second question **"What does the student understand now?"** involves gathering information and evidence of student understanding so that the teacher and the student can identify the current level of knowledge and skill. This also includes any incoming ideas or lived experiences the student may have. In order for the teacher and students to reach the learning target, they must first have a clear understanding of where the students are now so that they can determine next steps.

The third question **"How do we get to the learning target?"** allows the teacher and students to determine what is needed to close the gap between the current understanding and the learning target. Self- and peer assessment enable students to be active agents in the process as they reflect on their performance and provide feedback to one another. Formative feedback from the teacher is also a powerful tool to support student learning. The teacher makes instructional decisions and the students make learning decisions as they progress toward achievement of the learning target.

Working through the three guiding questions is an ongoing process in the classroom. The questions are interconnected as teachers and students are continually reflecting on learning, gathering evidence, and working toward learning targets. The specific application of the formative assessment process will be different depending upon the grade level and content area.

Table 1 outlines the 5 Components and 13 Elements for the formative assessment process.[i]

Table 1: FAME Components and Elements

Guiding Questions	FAME Components and Elements
Where are we (teacher and students) going?	**Planning** 1.1—Instructional Planning: planning based on knowledge of the content, standards, pedagogy, formative assessment process, and students. **Learning Target Use** 2.1—Designing Learning Targets: the use and communication of daily instructional aims with the students 2.2—Learning Progressions: connection of the learning target to past and future learning 2.3—Models of Proficient Achievement: examples of successful work for students to use as a guide.
What does the student understand now?	**Eliciting Evidence of Student Understanding** 3.1—Activating Prior Knowledge: the opportunity for students to self-assess or connect new ideas to their prior knowledge 3.2—Gathering Evidence of Student Understanding: use of a variety of tools and strategies to gather information about student thinking and understanding regarding the learning targets from *all* students 3.3—Teacher Questioning Strategies: the intentional use of questions for students to explain their thinking or to connect their idea to another student's response 3.4—Skillful Use of Questions: a focus on the purpose, timing, and audience for questions to deliver content and to check students' understanding
How do we (teacher and students) get to the learning target?	**Formative Feedback** 4.1—Feedback from the Teacher: verbal or written feedback to a student to improve his or her achievement of the learning target 4.2—Feedback from Peers: feedback from one student to another student about his or her learning in relation to a learning target 4.3—Student Self-Assessment: the process in which students gather information and reflect on their own learning in relation to the learning goal. **Instructional and Learning Decisions** 5.1—Adjustments to Teaching: teachers' daily decisions about changes to instruction 5.2—Adjustments to Learning: students' use of feedback for improvement.

Source: FAME Learning Guide (Kintz, et al. 2018).

The formative assessment process is outlined in the 5 Components and 13 Elements. The components and elements are interconnected and build upon each other. They are described separately to support teacher learning. Over time, the formative assessment process is ongoing with students as active agents in the learning process.

Lesson Planning

The Formative Assessment Planning Template shown in Figure 1 outlines the application of the Components and Elements that teachers may include as they are planning a lesson. The Components and Elements are used in planning the lesson, while the lesson is being enacted, and at the conclusion of the lesson before the next lesson. This form shows how the 13 elements occur and interact with one another.

Figure 1: Formative Assessment Planning Template — Science

PLANNING TEMPLATE		
Teacher: Discipline:	District/School: Course:	 Grade(s):
Lesson Plan Title		
Phenomenon: Driving Question:		
Content Standard		
Learning Target(s): •	Success Criteria: •	
Overview of the Lesson		
Summarize the instructional tasks/activities/strategies to be used to help students achieve the learning target(s).		
What questions might be used to gather evidence of student learning?	What strategies might be used to gather evidence of student learning?	
What incoming ideas and experiences might students have that you can leverage while learning?		
When and how will evidence of student understanding be used to modify instruction?		
How and when will feedback be provided to students (teacher to student/student to student/student to self)?		
COMPLETE AFTER THE LESSON HAS BEEN TAUGHT. What aspects worked well and will be used again, and what aspects are in need of improvement?		

The curricular context in which the lesson occurs — the learning progression or building blocks that occurred before and will occur following the lesson — is also very important. The teacher will think about how the different lessons build on one another to achieve the standards and learning goals for the content area. Plans will include individual lessons as well as the discipline-specific building blocks; the sequence of lessons; and how the teacher intends to gather evidence, provide feedback, and support peer and self-assessment over time.

Many experts have supported the development of this *Guide* to promote the use of formative assessment practices in the classroom. Teachers are at many different places in their learning. This *Guide* provides a useful tool for FAME program participants
to deepen their disciplinary knowledge and increase their use of the formative assessment process.

NOTES

The goal of Next Generation Science Standards is to promote "three-dimensional" instruction such that all dimensions are woven together to support rich opportunities for science learning and sensemaking.

Section II: USE OF THE FORMATIVE ASSESSMENT PROCESS IN SCIENCE

Amelia Wenk Gotwals and Alicia Alonzo

C. Overview of the Discipline: Science

The Next Generation Science Standards (NGSS; NGSS Lead States, 2013)[ii] and the associated Michigan Science Standards (Michigan Department of Education, 2015)[iii] are based on the *Framework for K-12 Science Education* (National Research Council [NRC], 2012)[iv]. The *Framework* summarizes research that suggests that students learn best when they are engaged in the practices of science rather than learning about content separate from the "doing of" science.

The *Framework* outlines three dimensions of science that are interwoven to create the standards. These dimensions are: (1) Science and Engineering Practices (SEPs); (2) Disciplinary Core Ideas (DCIs); and (3) Crosscutting Concepts (CCCs). While these dimensions are described separately, the goal of NGSS is to promote "three-dimensional" instruction such that all dimensions are woven together to support rich opportunities for science learning and sensemaking. In fact, each performance expectation (PE; i.e., standard) includes an SEP, DCI, and CCC, thus illustrating the commitment to this three-dimensional learning. We briefly summarize the dimensions below.[1]

Science and Engineering Practices

There are eight Science and Engineering Practices (SEPs)[v] that represent the multiple ways of knowing and doing that scientists and engineers use to study the natural and designed world. The SEPs are:

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematical and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

While listed separately, these practices work together[vi] and are often used in sequence in order to support the deepening of understandings and abilities to engage in scientific sensemaking. In fact, although each PE includes a single SEP, the SEP listed in the performance expectation should not be the only SEP that students use. Rather, instruction should provide opportunities for students to use multiple SEPs as they work through a unit with the goal of making sense of scientific phenomena.

1 NOTE: This document is **not** intended to be a comprehensive introduction to the NGSS. The *Framework* is the most thorough resource to learn more about three-dimensional science. We will link to additional resources throughout the document.

Students can learn to engage in these practices with increasing sophistication. There are learning progressions for the SEPs[vii] to illustrate what engagement in these practices might look like from kindergarten through high school.

Disciplinary Core Ideas

The DCIs are split into four main areas: (1) Physical Sciences;[viii] (2) Life Sciences;[ix] (3) Earth and Space Sciences;[x] and (4) Engineering, Technology, and Application of Science.[xi] Each of these areas include rich concepts that have broad importance within the discipline and provide a key for understanding and investigating complex ideas and solving problems. In addition, the DCIs are teachable and learnable over multiple grade levels with increasing sophistication. These levels of DCIs are organized into learning progressions[xii] to show how students' understanding of the DCIs should progress from kindergarten through high school.

Units of instruction often address multiple related PEs, which is called "bundling" PEs (see the National Science Teaching Association webpage for examples of bundling PEs[xiii]). The PEs are bundled together such that the DCIs from all of the PEs are used to make sense of a phenomenon.

Crosscutting Concepts

The third dimension, CCCs,[xiv] are concepts that can provide an organizational framework to connect the disciplines to support a coherent view of the world. The CCCs are:

- Patterns
- Cause and effect: Mechanism and explanation
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter: Flows, cycles, and conservation
- Structure and function
- Stability and change

The CCCs are revisited across units and years. Like the other two dimensions, there are learning progressions for the CCCs[xv] to illustrate how students can grow in sophistication from kindergarten through high school.

D. Tying Formative Assessment to the Discipline

The NGSS outline several "conceptual shifts"[xvi] that should be considered in order to achieve the vision for science teaching and learning called for by the *Framework*. An umbrella for many of these is a move from students "learning about" to "figuring out." For example, rather than learning about discrete scientific facts, students are expected to make sense of the world around them through the integration of the three dimensions.

When thinking about what this vision looks like in the classroom, there are specific instructional shifts[xvii] that teachers and students will need to make. In this document, we highlight three overarching shifts that have particular importance for formative

assessment (NRC, 2017[xviii]): (1) phenomena and driving questions; (2) science and engineering practices; and (3) learning progressions. First we describe each of these shifts, and then we illustrate how these three shifts work together to influence formative assessment in the classroom.

Scientific Phenomena and Driving Questions

Critical to achieving the new vision for science teaching and learning is using scientific phenomena[xix] and driving questions to guide instruction and learning. Scientific phenomena are specific events that occur in the world and that we can observe and use scientific knowledge to explain and/or predict. Driving questions[xx] are often linked to phenomena or problems and serve as a guide for students as they work toward explanations and solutions. Beginning units and lessons with phenomena and/or driving questions allows students and teachers to have a shared sense of purpose as they engage in science to figure out the phenomena or answer the driving question.

The focus on scientific phenomena and driving questions also promotes coherence in designing instruction so that students are building toward figuring out the phenomenon and not experiencing science as a series of disconnected activities. While some of the "content" that has been taught in science classrooms may stay the same, the way that students engage with the content and aspects of the formative assessment process will look very different because of this focus on building toward being able to explain phenomena and answer driving questions.

The use of phenomena has importance for multiple aspects of formative assessment. For example, teachers can use the central phenomenon as part of the learning targets for students. Rather than a focus on just the content that students should learn, the learning targets can illustrate what aspects of the phenomenon students will work on for that lesson. Phenomena can be very helpful to elicit students' incoming ideas. For example, teachers can have students attempt to explain or model the phenomenon at the beginning of the unit to elicit their incoming understandings. Throughout the unit, students revise their models and explanations to support their sensemaking. In addition, these revised models and explanations can provide evidence about student learning. This type of elicitation of student ideas allows for rich information about the range of ideas students may have. In addition, teachers can glean insights into the lived experiences students may have that relate to the phenomenon.

Science and Engineering Practices

SEPs, briefly described above, can be particularly powerful resources for formative assessment. For example, with the shift to supporting students in figuring out science phenomena, it is important that the learning targets teachers share with students do not "give away" explanations of phenomena or answers to driving questions (see STEM Teaching Tool #46[xxi] for more information). Instead of posting more traditional learning targets, teachers can use the SEPs to frame the learning for students. For example, a learning target may include something like, "I can [insert SEP, e.g., "ask questions about," "develop a model of"] [insert the phenomenon]…." This provides a clear target for both students and teachers without short circuiting the figuring out that students should do on their own.

Providing opportunities for students to engage with the SEPs throughout instruction allows teachers a rich way to elicit evidence of students' understandings. For example, as students are asking questions about or modeling a phenomenon, teachers gain insights into the ways students are able to use their understandings to make sense of the world around them. Using SEPs allows the teacher to learn more than whether students just "know the content"; they also can see how students are thinking and reasoning about a phenomenon.

Learning Progressions

Learning progressions[xxii] are "descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic" (NRC, 2007, p. 214). Consistent with the NGSS learning progressions described above, learning progressions may represent progress with respect to DCIs, SEPs, and/or CCCs. Although learning progressions cannot capture all of the variation inherent in students' learning, they provide a rough idea for how student thinking and sensemaking typically develop over time.

Learning progressions can inform work in all aspects of formative assessment. In this *Guide*, we consider two different kinds of learning progressions that can support formative assessment: those embedded in the NGSS and those produced by researchers to support formative assessment. Both types of learning progression help us to see students' performances not only in terms of whether or not they have met a given learning target, but also how their performance fits into a larger continuum of performance.

NGSS learning progressions. The NGSS learning progressions[xxiii] show how the PEs build across the grade bands: K-2, 3-5, middle school, and high school. These learning progressions are particularly helpful setting learning targets in the broader context of students' K-12 science learning.

Table 2: Performance Expectation Progressions for Physical Sciences

Early Elementary	Upper Elementary	Middle School	High School
K-PS2-1: Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.	3-PS2-1: Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.	MS-PS2-1: Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.	HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
K-PS2-2: Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.	3-PS2-2: Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.	MS-PS2-2: Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.	HS-PS2-2: Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

In this *Guide*, we present two examples related to the DCI *Motion and Stability: Forces and Interactions*. Moving from early elementary (K-PS2-1, K-PS2-2[xxiv]) to upper elementary (3-PS2-1[xxv]) to middle school (MS-PS2-2[xxvi]) to high school (HS-PS2-1[xxvii]), we see that students are expected to engage with the same core idea that forces cause *changes* in motion. Over the school years, students work with this relationship in increasingly precise and mathematical ways and expand their consideration of forces to include those other than pushes and pulls. As illustrated in the examples below, considering what students will learn next (in the kindergarten example) and what students have already learned (in the high school example) can help a teacher to establish appropriate learning targets.

Researcher-developed learning progressions. In contrast to the NGSS learning progressions, researcher-developed learning progressions typically seek to describe *how* students think—rather than only what they *should* be thinking—at different levels of sophistication. Learning progressions designed to support formative assessment are typically finer grained than those in the NGSS, providing information about how student understanding might develop as they engage with a particular learning target. In the high school example in Section F, we use a learning progression that describes how understanding of the relationship between force and motion might develop as middle or high school students engage with PE MS-PS2-2 or HS-PS2-1, respectively.

This learning progression, and others like it, provides information both about ideas students might have about a particular topic and about how those ideas might develop with instruction. Sometimes these intermediate ideas can serve as "stepping stones" on the way to more sophisticated understanding. Knowing how ideas might develop (i.e., what intermediate progress students might make on their way to mastery of a given PE) can help to identify intermediate (e.g., daily) learning targets and to design instruction that supports small steps necessary to bridge between students' current understanding and the PE. Knowing in advance what ideas students are likely to have can help teachers to plan to use tools and strategies that elicit these ideas and to interpret students' responses in terms of progress towards the learning target.

In the following sections, we provide one elementary and one high school vignette to illustrate what NGSS-aligned formative assessment might look like in the classroom. Both vignettes are based on PEs that include the DCI *Motion and Stability: Forces and Interactions*. The teachers in the vignette are fictional, but the examples of instruction and student responses are based on work with teachers in Michigan classrooms.

Knowing in advance what ideas students are likely to have can help teachers to plan to use tools and strategies that elicit these ideas and to interpret students' responses in terms of progress towards the learning target.

E. Elementary Formative Assessment Example: SOLID Start Boxcar Challenge Unit

Unit Overview

In this example, we will use a lesson from *The Boxcar Challenge Unit* (Wright & Gotwals, 2017; Edwards, Gotwals, & Wright, 2020), from the SOLID Start (**S**cience, **O**ral Language and **Li**teracy **D**evelopment from the **Start** of School) project. The SOLID Start website (at SOLIDStart.msu.edu) provides more information about the SOLID Start project and includes access to all SOLID Start curricula. The planning for this lesson is illustrated by the Formative Assessment Planning Template for Kindergarten, shown in Figure 2. This template serves as a handy place to document the teacher's planning steps.

Unit-Level Performance Expectations (PEs)

The unit is developed around these PEs:

- **K-PS2-1:** Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.
- **K-PS2-2:** Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.
- **K-2-ETS1-1:** Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.
- **K-2-ETS1-2:** Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.
- **K-2-ETS1-3:** Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

Note that this unit includes kindergarten-specific PEs in physical science (i.e., K-PS2-1, K-PS2-2) as well as K-2 PEs for engineering (i.e., K-2-ETS1-1; 1-2; and 1-3).

Unit-Level Phenomenon: Soapbox Derby Races in Lake County.[xxviii]

The unit-level phenomenon is a video that shows children getting ready to race the boxcars that they built.

- Driving Question: How can we make things (like a boxcar) move?
- Design Challenge: Make a model boxcar move through an obstacle course

Unit-Level Learning Goals

By the end of this unit, students will be able to:

- Use evidence from scientific investigations to explain the impacts pushes and pulls have on the motion of objects.
- Use scientific language to describe the speed and direction of objects in motion.
- Apply knowledge of pushes and pulls on objects to design and test a solution for making a model boxcar move through an obstacle course.

Unit-Level Teacher Thinking (before starting unit)

Ms. Chara is getting ready to start her kindergarten unit on pushes and pulls. She plans to follow the SOLID Start Boxcar Challenge Unit and is excited that the Boxcar challenge unit builds on students' natural curiosities about how things move and students' enjoyment of building and playing. Ms. Chara knows that young children are more capable of scientific reasoning than we sometimes give them credit for. Therefore, Ms. Chara wants to make sure that she finds ways of having children begin to think and talk like "scientists" (e.g., making careful observations, using evidence to support their claims). However, Ms. Chara also knows that it is important to think about developmentally appropriate pedagogies for supporting students. Therefore, she wants to make sure that the lessons allow students to explore and play as they learn about pushes and pulls.

Before starting the unit, Ms. Chara carefully reads the PEs in order to understand the overarching learning goals. She also thinks about the ideas and types of experiences her students may have about pushes and pulls. For example, she knows that students often play with toys that they have to push or pull. On the playground, they push each other on the swing to get it to move. Ms. Chara also thinks about the alternative (non-canonical) ideas that students may have regarding pushes and pulls (for example, that the speed of an object is part of the object itself). She also remembers ways that she was able to use previous students' alternative ideas and life experiences as "stepping stones" to help them to better understand what they are experiencing and observing. She finds this helpful in order to help students better understand what they observe.

In addition, Ms. Chara looks at the learning progression for PS2.A (Forces and Motion).[xxix] She notes that the idea of *changes* in motion is highlighted throughout the progression and begins to think about ways she can support her students in understanding that pushes and pulls cause changes in motion, not just motion.

Unit Planning and Vignette

In the Boxcar Challenge Unit, lessons build over time. In the formative assessment planning template and the vignette, we will focus on Lesson 5, but it is important to have a sense for what experiences and reasoning students have done to this point in the unit.

Lessons 1-4

Students watch the video of the soapbox derby and ask questions about what makes the boxcars move fast and far during the race. They explore playing with toys to discover and describe the different ways toys move and the different ways that students can make the toys *begin* to move, *stop* moving, and turn (i.e., change their motion). Through these explorations and related informational text readings, students are able to describe that "pushes" and "pulls" are two ways that they can make toys move.

They read a text about how engineers ask questions, build models, and design solutions to problems. They make connections between what engineers do and the soapbox derby. They then act as engineers and build a model boxcar that they will use to investigate how pushes and pulls can make their boxcar move fast and/or far.

Formative Assessment Planning Example for Lesson 5

Figure 2 illustrates how Ms. Chara used a formative assessment planning template to plan for Lesson 5. A vignette of the actual classroom instruction follows immediately afterwards on pages 23-28.

Figure 2: Formative Assessment Planning Example for Kindergarten SOLID Start Boxcar Challenge Unit, Lesson 5

PLANNING TEMPLATE		
Teacher: Ms. Chara	**District/School:** Spartan Elementary School	
Discipline: Science	**Course:** N/A	**Grade(s):** Kindergarten
Lesson Plan Title: Lesson 5—How can we make our model boxcar move faster and go farther using *pushes*? (from the SOLID Start Boxcar Challenge Unit)		
Phenomenon: *Soapbox Derby Races in Lake County*. The unit-level phenomenon is a video that shows children getting ready to race the boxcars that they built. **Driving Question:** How can we make things (like a boxcar) move?		
Content Standard	**K-PS2-1:** Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.	
Learning Target(s): • I can plan and conduct an investigation to explore how the strength of pushes affects speed and distance.	**Success Criteria:** • Students plan for and enact an investigation that only changes one variable.	
Overview of the Lesson: Students investigate how pushes (one finger push vs. whole hand push) influence their model boxcar's speed and distance.		
Summarize the instructional tasks/activities/strategies to be used to help students achieve the learning target(s). **Ask:** Introduce Lesson Question. Students share ideas about how to make things move slower and faster. **Explore:** Students plan and conduct an investigation about speed and strength of forces (one finger push vs. whole hand push). **Read:** *Move It! Motion, Forces and You* by Adrienne Mason. **Synthesize:** Students share their findings. Use Class Summary Table and Word Wall to talk about Driving Question: *What evidence do we have now about how we can make things move?*		

Figure 2: Formative Assessment Planning Example for Kindergarten SOLID Start Boxcar Challenge Unit, Lesson 5 *(continued)*

PLANNING TEMPLATE

What questions might be used to gather evidence of student learning?

Ask: What did we figure out yesterday about how things move? What questions did we have about our boxcars from yesterday?

Explore: What types of things get pushed? How can we make a boxcar move? What will make our boxcar move faster? How can you make the boxcars move fast and far? Why are we using two ways of pushing the boxcar (hand vs. finger)?

Synthesize: Why do you think you found … [what students find out during investigation]?

How does this new information help us to answer our driving question about how things, like the boxcar in the soapbox derby, move?

What strategies might be used to gather evidence of student learning?

- Use of an assessment sheet to keep track of student ideas heard during discussions
- Student worksheets where students write findings from their investigation

What incoming ideas and experiences might students have that can be leveraged during learning?

- Students often play with toys that they have to push or pull and can draw on those experiences and consider similarities/differences to boxcars.
- On the playground, students push each other on the swing to get it to move; can prompt students to think about how this is similar/different from boxcars.
- Students often think that force is something that is determined by the object itself, so may need to challenge students to make the *same* object move in different ways using different strengths of pushes and pulls.
- Students may not know how to conduct a "fair test" during investigations, so may need to support students in explaining why they are pushing with one finger and a whole hand. Could draw on ideas of "fair" in games to help students make sense of changing only one variable (size of push).

When and how will evidence of student understanding be used to modify instruction?

Ask: Based on students' questions and ideas, consider how to frame the investigation. For example, if students bring up pushes, can tell students we will further investigate their ideas. If they do not bring up pushes, may need to introduce this concept and have them think about different strengths of pushes.

Explore: If students struggle with what a fair test is, have students talk about whether it would be "fair" to have teacher use one finger vs. student use one hand. What is different there? Why would that make a difference?

If students do not use evidence to support their claims, encourage them to "explain like scientists." If they struggle with using evidence, ask them to recount what they did (e.g., pushed hard with one hand vs. soft with one finger) and what happened (their results).

Synthesize: If students are not building on each other's ideas, encourage them to use the sentence starters "I agree/disagree with ____, because…."

If students do not make connections to the soapbox derby, encourage them to think about what is similar and different about their investigation and the derby. (Remember students do not need to explain everything at this point in the unit. Just want to support them in making preliminary connections.)

Figure 2: Formative Assessment Planning Example for Kindergarten SOLID Start Boxcar Challenge Unit, Lesson 5 *(continued)*

PLANNING TEMPLATE

How and when will feedback be provided to students (teacher to student/student to student/student to self)?

Teacher to students: Feedback to students in conversations during all phases of lesson; feedback on students' worksheets before the next lesson (don't focus on spelling; give group feedback about how students represented their findings).

Students/Student: Feedback between students as they complete the investigation. Students can ask each other questions about what they are doing and what it means. Feedback between students during synthesis discussion as they use sentence starters to agree and disagree with each other.

Self: Comparison of their own findings in the investigation to what their classmates found. Is it the same or different? Why might that be? (This would need to be scaffolded — ask students to think-pair-share about how their results compared to those of their classmates.)

Natural World: Students will get direct feedback from testing their ideas with their boxcars (e.g., how many pairs found that a hard push made the boxcar move fast? What does this tell us?)

COMPLETE THIS SECTION AFTER THE LESSON HAS BEEN TAUGHT. (Example reflections below were completed by the teacher following the lesson described in the Figure 3 Vignette on pages 23-28.)

What aspects worked well and will be used again, and what aspects are in need of improvement?

Worked well:

- Asking students to "explain like scientists" supported them in remembering our norms for talking in science. They remembered that they cannot just make a claim; they have to be very descriptive and use evidence.
- Using sentence starters during the synthesis discussion allowed students to share ideas in respectful way. It also allowed students to compare their results with those of their classmates.

In Need of Improvement:

- Not all students had a chance to push the boxcar during the investigation and were upset. Next time I will assign roles and tell students to switch roles mid-way through the investigation.
- Students struggled to make meaningful connections to the soapbox derby. Next time I will ask scaffolding questions to support them in comparing their explorations with the soapbox derby.

Lesson 5 Vignette

The following vignette (Figure 3) provides a description of Ms. Chara teaching Lesson 5 in the classroom with students. The corresponding FAME Components and Elements are listed in the column on the left to highlight the formative assessment process.

Figure 3: Vignette for Kindergarten SOLID Start Boxcar Challenge Unit, Lesson 5

FAME Components and Elements	Lesson 5: How can we make our model boxcar move faster and go farther using *pushes*?
Planning 1.1 **Learning Target Use** 2.1	After completing Lessons 1–4, Ms. Chara gets ready to support her students in using what they have already figured out to explore the lesson-level driving question: *How can we make our model boxcar move faster and farther using pushes?* She notes that throughout Lessons 1–4, most students were able to use the ideas of pushes and pulls to describe how they were able move their toys and model boxcars. She also made note of a story that one student told about how they were allowed to *push* the grocery cart in the store when they went shopping with their parents that she wants to return to in this lesson. The SOLID Start curriculum has a lesson-level learning target for Lesson 5 that builds on the prior lessons, which is: "I can plan and conduct an investigation to explore how the strength of pushes affects speed and distance." (NOTE: it is important that the lesson-level, student-friendly learning targets include more than just the DCI. So, for example, each learning target should attempt to also have a SEP and/or CCC. This learning target includes the SEP of planning and conducting an investigation, the DCI of pushes; and the CCC of cause and effect). Ms. Chara also thinks about alternative (non-canonical) ideas that students may have regarding the DCI, SEP, and/or CCC, along with the ways she has helped previous students to better understand what they are experiencing and observing. For example, Ms. Chara knows that students often think that force is something that is determined by the object itself. Thus, she will often challenge students to make the *same* object move in different ways using different strengths of pushes and pulls.

Figure 3: Vignette for Kindergarten SOLID Start Boxcar Challenge Unit, Lesson 5 *(continued)*

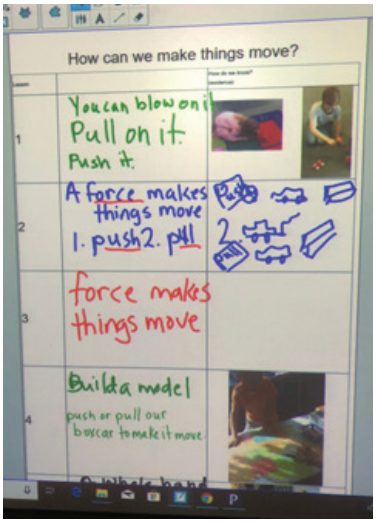
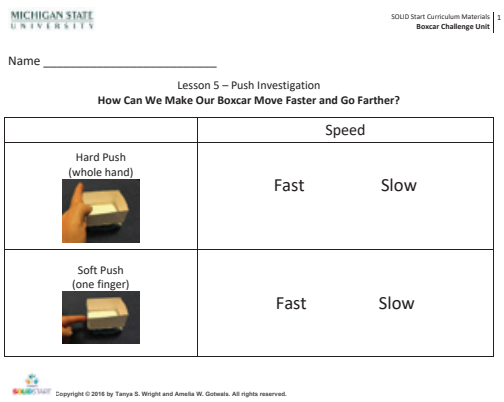
FAME Components and Elements	Lesson 5: How can we make our model boxcar move faster and go farther using *pushes*?
Learning Target Use 2.1, 2.2 **Eliciting Evidence** 3.1	Ms. Chara knows that it is important for students to see how each lesson and activity connect to each other. Therefore, Ms. Chara begins the lesson by pointing to the summary table that the class has filled out at the end of each of the previous lessons. (The summary table is often filled out by the class answering three questions: 1. What did we figure out today? 2. How did we figure it out? 3. What are still wondering? In the example below, Ms. Chara included the lesson number along with the first and second question. However, she had a separate table to keep track of students' wonderings.  Ms. Chara asks the students, "What did we figure out yesterday?" and "What questions did we have about our boxcars?" Students share their ideas, such as "We made our boxcar move by pushing it," and questions, such as "How fast can our boxcars go?". Ms. Chara knows that it is important to make sure that students know why they are doing each activity in each lesson. So, Ms. Chara follows up the discussion by saying, "Great, some of you asked how we can make our boxcars move fast. So today we are going to do an investigation about how to make our boxcars move far and fast."
Eliciting Evidence 3.1, 3.2, 3.3	Ms. Chara wants to discover what students already know about how *pushes* can influence speed and distance. To make sure that all students have a chance to share their ideas, Ms. Chara tells the students to turn and talk to their elbow partner about what they think they can do to make their boxcars move far and fast. Ms. Chara moves around the carpet listening to students' conversations, sometimes asking probing questions, such as "Why do you think that will make the boxcar move farther?" She takes notes of specific ideas that she wants to make sure she brings to the whole class. After a few minutes, Ms. Chara calls everyone back to the carpet and asks for volunteers to share their ideas. Students share ideas such as "we could push it really hard" and "we could put a string on it and pull it while we run." Ms. Chara writes down students' ideas along with their names so that students can feel ownership of their ideas. Ms. Chara does not evaluate students' ideas at this point because she wants students to feel comfortable sharing their ideas and knows that it is important that there is a range of ideas for students to think about.

Figure 3: Vignette for Kindergarten SOLID Start Boxcar Challenge Unit, Lesson 5 *(continued)*

FAME Components and Elements	Lesson 5: How can we make our model boxcar move faster and go farther using *pushes*?
Eliciting Evidence 3.2, 3.3	After students share their ideas, Ms. Chara tells them that today they are going to explore some of the students' ideas about how pushes can make the boxcars move farther and faster. Ms. Chara points to their word wall and asks the students what "push" means. Students read together that a push "moves something away." Ms. Chara shares that she remembers that Jordyn talked about "pushing" a grocery cart when shopping with his parents. She asks if there are any other volunteers to give examples of pushes that they have seen in their lives. One student shares that their mom pushes the lawn mower when she cuts the grass. Ms. Chara asks the student what is similar about pushing a lawn mower to pushing a grocery cart as a way to get students to explain their thinking and connect their idea to another student's response.
Learning Target Use 2.3 **Eliciting Evidence** 3.1	Ms. Chara says they are now going to investigate how different types of *pushes* can make the boxcars move. She reminds students that an investigation is an exploration that helps answer a science question. She tells the students that by the end of the lesson they should be able to use evidence from their investigation to explain how pushes can make boxcars move farther and faster. After a discussion of the different investigations that they will do (see curriculum materials), Ms. Chara gives each student the "Push Investigation" sheet to keep track of their results and gives directions for students to get their boxcars and begin the investigation. They discuss that they are trying to compare how far and how fast the boxcar moves when they use a one finger (soft) push versus a whole hand (hard) push.



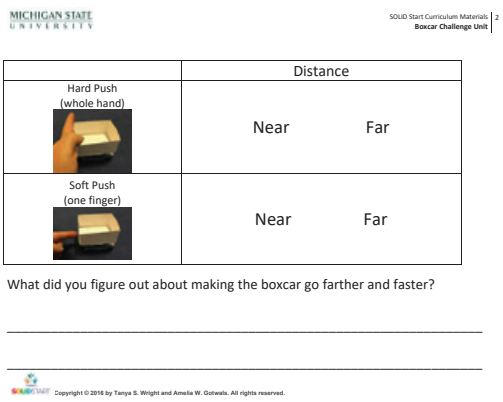
MICHIGAN STATE UNIVERSITY

SOLID Start Curriculum Materials | 1
Boxcar Challenge Unit

Name _____

Lesson 5 – Push Investigation
How Can We Make Our Boxcar Move Faster and Go Farther?

	Speed	
Hard Push (whole hand)	Fast	Slow
Soft Push (one finger)	Fast	Slow



MICHIGAN STATE UNIVERSITY

SOLID Start Curriculum Materials | 2
Boxcar Challenge Unit

	Distance	
Hard Push (whole hand)	Near	Far
Soft Push (one finger)	Near	Far

What did you figure out about making the boxcar go farther and faster?

_____

_____

Figure 3: Vignette for Kindergarten SOLID Start Boxcar Challenge Unit, Lesson 5 *(continued)*

FAME Components and Elements	Lesson 5: How can we make our model boxcar move faster and go farther using *pushes*?
Eliciting Evidence 3.2, 3.3	This investigation is an "assessment checkpoint" for the Boxcar Unit. This is a more formal opportunity for teachers to keep track of students' ideas. During assessment checkpoints, teachers observe what students are doing, look at their written work, talk with students to gather evidence of student progress, and record their evidence of student understanding. The assessment statement for this lesson is: *"Students can use evidence from investigations to support the claim that a bigger push or pull makes the boxcar move faster or farther."* As partners are working on pushing their boxcars, Ms. Chara walks around the groups asking them questions about what they are finding. Ms. Chara carries a clipboard in order to take notes about each student's progress on this assessment checkpoint. Specifically, Ms. Chara listens for students to make a connection between the strength of a push and how fast or far their boxcar moves.

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SOLID Start Curriculum | 78
Boxcar Challenge Unit Lesson Plans

Appendix B

Assessment Statement #1: Students can use evidence from investigations to support the claim that a bigger push or pull makes the boxcar move faster or farther (aligned with K-PS2-1).

Student Name	Record evidence of student progress (i.e., what students say, do, or write)	Student Name	Record evidence of student progress (i.e., what students say, do, or write)

SOLIDSTART

She also examines their written work for evidence of their understanding of the relationship between the strength of a push and the distance the boxcar travels.

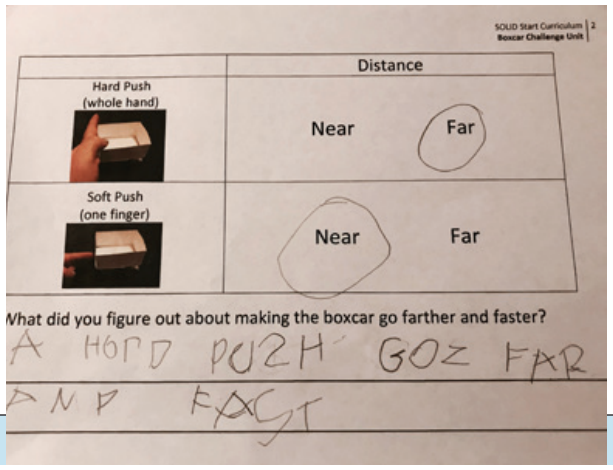


Figure 3: Vignette for Kindergarten SOLID Start Boxcar Challenge Unit, Lesson 5 *(continued)*

FAME Components and Elements	Lesson 5: How can we make our model boxcar move faster and go farther using *pushes*?
Formative Feedback 4.1	Ms. Chara finds investigations a great time to provide feedback on students' sensemaking. For example, when visiting Jaylin and Ahmed, she engages them in a conversation about what they are finding: Jaylin: *Ms. Chara, we made it go so fast.* Ms. Chara: *Great, how did you make it go so fast?* Jaylin & Ahmed: *We pushed it.* Ms. Chara: *Okay, how did you push it?* Jaylin: *like this…* (demonstrates pushing with his hand) Ms. Chara: *Nice. Now tell me more. I want you two to look at your data* (worksheet) *and let's explain like scientists. Remember that scientists use evidence to support their claims.* Ahmed: *We pushed hard with our hand and it went really fast.* Ms. Chara: *Great. Now let's see if you can write that down.* Ms. Chara circulates to other groups checking in on their work. She uses questions as a way to provide feedback to support students' progress. She asks students to think like scientists as feedback to encourage their use of evidence to support claims.
Formative Feedback 4.2	After the investigation, Ms. Chara calls everyone back to the carpet and does an interactive group read-aloud of a text (*Move It! Motion, Forces and You* by Adrienne Mason) that provides students with more information to support their understanding. Following the read-aloud, Ms. Chara asks for volunteers to share their ideas. She reminds students to use their sentence starters (e.g., I agree with _____ because…; I don't agree with ___ because…) as ways of respectfully agreeing and disagreeing with each other. This is one way for students to provide each other with feedback. For example: Shanae: *If you push the boxcar hard, it goes fast.* Janine: *I agree with Shanae because when we used our hand the boxcar went faster and when we used our finger it went slower.* Sasha: *I agree with Shanae and Janine, but it does not go very far.* James: *I agree with Shanae, Janine and Sasha that the boxcar goes fast when you push it hard, but I disagree with Sasha because our boxcar went very far when we pushed it hard.* After the class discussion, the class fills out their summary table to keep track of what they figured out (i.e., they can make their model boxcars go faster and farther by pushing harder) and their evidence (e.g., Ms. Chara posts student worksheets and photos of students pushing the boxcar with one finger vs. whole hand).

Figure 3: Vignette for Kindergarten SOLID Start Boxcar Challenge Unit, Lesson 5 *(continued)*

FAME Components and Elements	Lesson 5: How can we make our model boxcar move faster and go farther using *pushes*?
Instructional and Learning Decisions 5.1 5.2	Following the discussion, Ms. Chara asks, "What questions did we answer? What questions do we still have? How does this help us understand the Soap Box Derby?" Students share their ideas and questions. For example, Ella: *We know that hard pushes make the boxcar go fast and far.* Julie: *I wonder how you can push a boxcar really hard.* James: *Yeah, I did not see the kids push the boxcar to start it, so how did the boxcar go so fast in the derby?* Ms. Chara notes that students still have questions about the connections between their investigations of their model boxcars and the overarching phenomenon of the soapbox derby. Therefore, for lesson 6 she decides to re-watch the beginning of the soapbox derby video and ask the students to make observations of how the soap boxcars begin to move. She will then lead them into new investigations about the influence of pulls on boxcar speed and distance.

F. High School Formative Assessment Example: Force and Interactions

Unit Overview

This example takes place in a high school physical science class, during a unit on motion. The vignette focuses on a sequence of three lessons early in the unit. The planning for the third of these lessons is illustrated by the Formative Assessment Planning Template for High School, shown in Figure 7. This template serves as a handy place to document the teacher's planning steps.

Unit-Level Performance Expectations (PEs)

This unit is designed to address PEs HS-PS2-1, HS-PS2-2, HS-PS2-3, and HSPS3-1. We will focus on the first major section of the unit, which engages students with:

- **HS-PS2-1:** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

Although the teacher, Ms. Pham, has taught this content (Newton's Law 2nd of Motion, or ***F***=*m****a***) before, this year she is using the Michigan Science Standards[xxx] so she has identified a crosscutting concept (cause and effect) and two science practices that will also guide her instruction. The first practice (analyzing and interpreting data) comes from the PE, while Ms. Pham has selected the second practice (developing and using models) to further support students' sensemaking.

Unit-Level Phenomenon

The unit-level phenomenon is a video of cars crashing into each other.[2]

- Driving Question—Which does more damage: a car hitting a wall at 100 mph, or 2 cars colliding at 50 mph? Why?

At the beginning of the unit, Ms. Pham introduced her students to the anchoring phenomenon and elicited her students' initial ideas by having them create models of the two car crashes.

To introduce the vignettes and the formative assessment planning template, we first describe Ms. Pham's thinking about instruction prior to beginning this section of the unit. Following this introduction, we skip ahead to the heart of the section and dig deeper into a sequence of approximately 3 lessons—starting with a description of Ms. Pham's thinking before the lessons (Figure 4) and then describing what happened during the lessons (Figures 5–8). We provide varying amounts of detail about these lessons in order to highlight important features of Ms. Pham's formative assessment practices.

2 At the beginning of the unit, the video is shown from 2:22 until 3:23.
Video URL: https://www.youtube.com/watch?v=r8E5dUnLmh4

Ms. Pham considers the overall learning target represented by the high school PE, in relation to the corresponding PE at the middle school level:

- **MS-PS2-2:** Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

The middle school PE suggests that her students may have a qualitative understanding of the relationship between force and motion but that she will need to work on the quantitative relationship. In particular, although students should have investigated changes in motion, they will not have formalized this as "acceleration."

Therefore, Ms. Pham decides that the first step is for students to figure out how to describe the motion of one of the cars in the two-car crash. Once students are able to identify when the car is accelerating and when it is moving at a constant velocity (and have revised their models accordingly), Ms. Pham engages them in figuring out what *causes* the different types of motion they have described. She revises an old lab so that students can figure out, rather than simply verify, the relationship between force and motion. After students have used data from the lab to make claims that a constant force causes accelerating motion (i.e., ***F*** is proportional ***a***), Ms. Pham asks them to revise their models, this time indicating the force(s) acting on the car throughout its motion.

Teacher Thinking (before starting the first section of the unit)

Figure 4 illustrates Ms. Pham's thinking before starting the focus sequence (Lessons A-C). The corresponding FAME Components and Elements are listed in the column on the left to highlight the formative assessment process.

Figure 4: Teacher Thinking (before starting focus sequence)

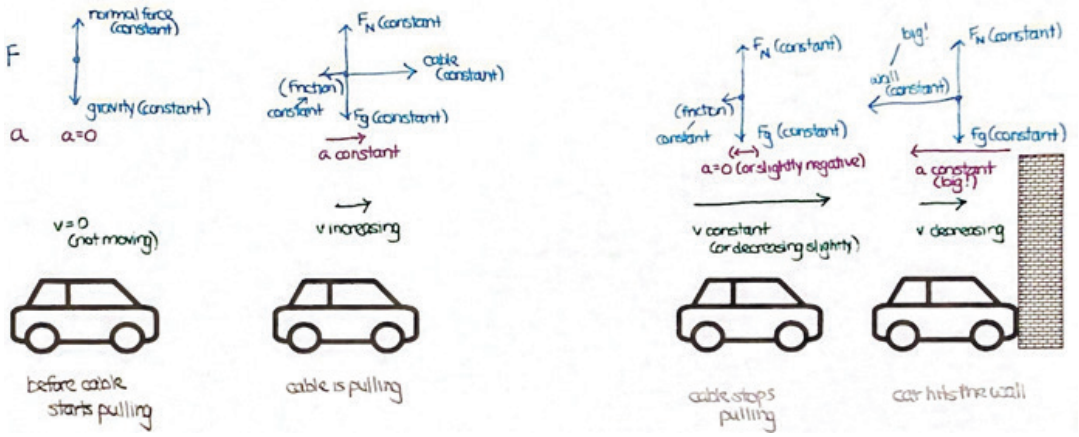
FAME Components and Elements	Planning
Learning Target Use 2.1, 2.3	For this series of lessons, the learning target is for students to be able to model the forces acting on the car. Specifically, students should accurately identify the forces acting at different points in the car's path *and* model forces in ways that clearly communicate their ideas. She envisions that students' models will look something like this:  Ms. Pham realizes that parts of this are similar to what she typically has her students do with "free body diagrams" and wonders if she will be able to borrow ideas from her previous instruction.

Figure 4: Teacher Thinking example (before starting focus sequence)
(continued)

FAME Components and Elements	Planning
Planning 1.1	Ms. Pham knows that even students who "know" ***F***=*m****a*** can struggle to identify forces acting on objects. To support students in developing and using models to figure out ***F***=*m****a***, Ms. Pham wants to find out as much as she can about their ideas. Ms. Pham notices that some students have indicated force and motion with a single arrow in their revised models and recalls that, in the past, her students have thought that forces cause motion (rather than *changes* in motion). However, she is unsure of how to make sense of other ways that students have used arrows and/or words to indicate forces. Ms. Pham consults a learning progression (Alonzo & von Aufschnaiter, 2018) to learn more about the ideas her students might have—and how she might support the development of those ideas over time. In addition to the idea that forces cause motion (which she had already identified), she learns about the "impetus conception," which is a common student idea that force travels with a moving object. She wonders if students in her past classes have had that idea. She hadn't thought to ask them!
Planning 1.1 **Learning Target Use** 2.2	Ms. Pham uses the learning progression to imagine how students with understandings consistent with different levels of the learning progression might think about the forces acting in different parts of the car's path. Ms. Pham realizes that some parts of the car's path should be relatively straightforward for all of her students to model, while others would make sense only to those with the most sophisticated understanding—and that many should be somewhere in between. From the learning progression, she recognizes that students can have a lot of ideas that might "lurk beneath the surface" of ***F***=*m****a***. These ideas would only become apparent when considering certain types of motion. She uses these insights to sequence her instruction, thinking carefully about the order in which to discuss different parts of the car's path.
Learning Target Use 2.1 **Eliciting Evidence** 3.1, 3.2	Ms. Pham's learning target for the next sequence of lessons is for students to clearly and accurately model the forces acting on moving and non-moving objects. The models that students produce throughout this sequence of lessons will elicit evidence of *how* students are modeling (i.e., how they are representing their ideas about forces), as well as *what* students are modeling (i.e., whether they are accurately identifying the forces). Even though Ms. Pham knows what she wants the free body diagrams to look like, part of modeling practice is learning how to represent ideas, so Ms. Pham's class will develop criteria for their models in Lesson A. In Lesson A, Ms. Pham plans to have students draw on their prior investigation to model objects that are accelerating in the direction of motion. This should be the easiest type of motion for students to model, as it requires direct application of ***F***=*m****a*** and is not likely to elicit the impetus conception.

Unit Vignettes

The following vignettes provide descriptions of Ms. Pham teaching Lessons A, B, and C in the classroom with students. To see an example that illustrates how Ms. Pham planned for these lessons, see Figure 7: Formative Assessment Planning Template for Lesson C.

Figure 5: Vignette for High School Forces and Interactions, Lesson A

FAME Components and Elements	Lesson A: What Forces are Acting on the Car?
Learning Target Use 2.1 **Eliciting Evidence** 3.1	At the beginning of the lesson, Ms. Pham asks students how what they learned in the previous sequence of lessons might help them to explain the car crashes. She puts a few student models on the document camera to illustrate variation in terms of representation and forces depicted. She asks, "How can we figure out which most accurately describe the car crash? What forces are acting on the car?" She explains that they will be working on those questions for the next few lessons.
Learning Target Use 2.3 **Eliciting Evidence** 3.2, 3.3, 3.4 **Formative Feedback** 4.3 **Instructional and Learning Decisions** 5.2	Ms. Pham asks students to work in pairs to model the force(s) acting on the car at the beginning of its path (when it is pulled by a cable). As students work, Ms. Pham circulates, observing their models and asking them to explain what they have drawn. She then invites two pairs to share their models with the class. Ms. Pham asks the class to compare the two models. After some discussion, the class agrees to draw all force arrows pointing away from the same point and to indicate force and motion arrows using different colors. Ms. Pham gives students a chance to revise their models using the new criteria.

Figure 5: Vignette for High School Forces and Interactions, Lesson A
(continued)

FAME Components and Elements	Lesson A: What Forces are Acting on the Car?
Learning Target Use 2.3 **Eliciting Evidence** 3.2, 3.3, 3.4	Once students have revised their models, Ms. Pham invites two other pairs to share their models. Jiwon explains that the force is constant, like in their investigation last week. Trevor explains that he thought the force should be increasing, since the car is getting faster. Another student, Priya, asks why the two models look the same, even though Jiwon said the force is constant and Trevor said the force is increasing. Ms. Pham asks, "How do you think we could tell the difference between a constant force and an increasing force in our models?" After some discussion, the students agree that they will label all forces as either constant or with a description of how they are changing. Isabel says, "Yeah, but which one is right?" Ms. Pham wants students to figure this out for themselves, so she opens up the question to the class. They vote, and just over half the class agrees that the car can be speeding up, even if the force is constant. Ms. Pham asks students to support their ideas with evidence. Eleanor argues that the force is constant, citing evidence that ***F***=*m****a***. So, force is already associated with acceleration. (The car speeds up, even if the force is constant.) Another student, Brian, says, "Yeah, but if I keep pedaling my bike, I don't get faster and faster and faster. I just go at the same speed." He argues that speeding up requires more and more force. Ms. Pham asks the students how they can reconcile these two seemingly correct statements. A couple of students say "friction" or "air resistance," but Ms. Pham isn't sure how they are thinking about these concepts. Students agree that Brian has to be pushing *against* something, and Ms. Pham suggests that they return to that idea in the next lesson. After additional discussion, the class agrees that—if there is no friction or air resistance—a constant force should cause acceleration.
Eliciting Evidence 3.2, 3.4 **Formative Feedback** 4.2 **Instructional and Learning Decisions** 5.2	Because so many students did not correctly apply ***F***=*m****a*** to the modeling activity, Ms. Pham decides to give students another, similar, example (a ball dropping from the top of the school). She tells them to ignore friction or air resistance for now. When students share their models this time, Ms. Pham does not need to point out where they are unclear. Other students ask questions, such as "Is that motion or force?" and "Is that a speeding up force?" Ms. Pham notes that both questions represent attention to modeling practice, but that the second one could indicate an association between force and speed (rather than acceleration). She asks the student to clarify what she means by a "speeding up force," and the student says "a force that is getting bigger." Ms. Pham asks, "Do we need a force that is getting bigger for the ball to speed up?" Most of the class indicates no, and Ms. Pham notes that almost all of the models show a constant force and accelerating motion. (The previous discussion seems to have led to improvements in their models!) Ms. Pham makes a note of the few students who still seem to be making a direct association between force and motion so that she can pay particular attention to their ideas in subsequent lessons.

Figure 6: Vignette for High School Forces and Interactions, Lesson B

FAME Components and Elements	Lesson B: Why Don't Objects Speed Up?
Eliciting Evidence 3.2, 3.3, 3.4	Ms. Pham asks students to model the situation that Brian used as evidence: riding your bike down the road. Because the bike's pedal introduces complexity (pushing in a circle to move horizontally), she suggests that students think instead about a child being pushed in a stroller. She says, "Suppose the child is riding along at a constant speed. What forces do you think are acting on her?" After working in small groups, the class reconvenes to share their models. Ms. Pham listens to students' ideas and how students are supporting their ideas with evidence.
Formative Feedback 4.4[3]	The class settles on the idea that the road is rough and that somehow this is making the force not have its full impact. Ms. Pham asks students to think about how they might test this idea (i.e., get feedback on their ideas from the natural world), and students decide to put some sandpaper on the track from their earlier lab investigation. They discover that if they gradually increase the force acting on the cart, they can get the cart to move at a constant speed. They also discover that if they increase the force more, the cart accelerates. For now, they reach consensus around the idea that rough surfaces can make a force cause constant—rather than speeding up—motion.
Eliciting Evidence of Student Understanding 3.1	Ms. Pham returns to her originally planned sequence, asking students to think about what forces are acting on the car *before* the cable starts pulling it. Through discussion of students' models, as well as other examples, Ms. Pham is able to build students' understanding of net force (the sum of force acting on an object) and the normal force (a force pushing up on the car from the ground). Towards the end of the lesson, the class makes an important connection between the car (motionless with zero net force) and the cart in their earlier investigation (motionless before they increased the force pulling it). They figure out that the pulling force on the cart must be balanced by another force, and Ms. Pham identifies this force as friction.

3 4.4—Feedback from the Natural World: empirical evidence (from invesigations from the natural world) that provides information about student learning in relation to the learning target.

Figure 7 illustrates how Ms. Pham planned for Lesson C.

Figure 7: Formative Assessment Planning Example for High School Forces and Interactions, Lesson C

PLANNING TEMPLATE

Teacher: Ms. Pham **District/School:** Spartan High School

Discipline: Physics **Course:** Physical Science **Grade(s):** 9-10

Lesson Plan C Title: What Forces are Acting on the Car Before, During, and After the Cable?

Unit Phenomenon: Video of cars crashing into each other[4]

Unit Driving Question: Which does more damage: a car hitting a wall at 100 mph, or 2 cars colliding at 50 mph? Why?

Content Standard **HS-PS2-1:** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

Learning Target(s):

- Clearly and accurately model the forces acting on the car after it has been released from the cable and on objects moving in the same way as the car.

Success Criteria:

- Model reflects class-generated criteria
  - Use different colors to indicate force and motion.
  - Indicate forces acting on an object with force arrows pointing away from the object.
  - Label forces with "constant" or a description of how they are changing.
- Model checks out against $\boldsymbol{F}=m\boldsymbol{a}$.
- Model checks out when tested using air track and cart.
- Model can be supported with an evidence-based argument.

Overview of the Lesson: Students model the forces acting on an object moving at constant speed, directly considering the impetus conception.

Summarize the instructional tasks/activities/strategies to be used to help students achieve the learning target(s).

Model: Students create new models of the phenomenon, focusing on the segments of the trajectory before the car hits the wall.

Compare: The class discusses two models of the segment after the car is released from the cable (one representing the impetus conception and one not).

Test Ideas: Students test what happens if the forces in their models were applied to a cart on a frictionless track.

Exit: Students respond to an exit ticket.

4 Video of cars crashing into each other: https://www.youtube.com/watch?v=r8E5dUnLmh4 (2:22 until 3:23)

Figure 7: Formative Assessment Planning Example for High School Forces and Interactions, Lesson C *(continued)*

PLANNING TEMPLATE

What questions might be used to gather evidence of student learning?

Model: What forces are acting on the car?

- What forces are acting on the car before it is pulled by the cable? While it is being pulled by the cable? After it is released from the cable?
- If gravity is acting on the car, what should be happening to it?

Compare: Which model most accurately represents the force(s) acting on the car after it is released?

- How does your idea relate to ***F***=*m****a***?
- How does your idea relate to our ideas from [previous day]?
- What would happen if a constant force is applied to the cable?
- Ordered multiple-choice (OMC) item (see Figure 7.1 below)

Test Ideas: What happens if the force(s) in your model are applied to the cart?

- How is the cart moving? Is it moving at a constant speed? Is it speeding up?
- What do you think would happen if the cart were on a surface with more friction than the track?
- Does your test change anything about your model?

Exit Ticket: (see teacher questions recorded in Figure 8 Vignette, page 41)

What strategies might be used to gather evidence of student learning?

Model:

- Students' engagement in SEP Developing and Using Models; students' written models
- Conversations with individual students about their models

Compare:

- Students' engagement in SEP Engaging in Argument from Evidence; students' oral contributions class discussion
- Students' responses to OMC item (see below) using individual whiteboards

Test Ideas:

- Conversations with groups of students about their tests
- Changes to students' written models based on their tests

Exit Ticket:

- Students' responses to written exit ticket

Figure 7: Formative Assessment Planning Example for High School Forces and Interactions, Lesson C *(continued)*

PLANNING TEMPLATE

What incoming ideas and experiences might students have that can be leveraged during learning?

Students will "know" ***F***=*m****a*** from previous lessons and will have had a bit of practice using the class criteria for modeling forces acting on an object.

Students have lots of experience with moving objects in the natural world. They are likely to have an intuitive sense of giving something to an object that they hit, throw, etc. They will also know that objects generally do not keep moving without continuing to be pushed or pulled. Taken together, these ideas suggest the common (alternative) impetus conception: that moving objects carry a force with them, imparted by a hit, throw, etc.

When and how will evidence of student understanding be used to modify instruction?

Model:

- Evidence from students' models will be used to guide discussions with individual students.

Compare:

- Evidence from students' contributions to a class discussion will be used to guide the discussion.
- Students' responses to the OMC item will determine whether to move on to model other objects moving at a constant speed or to continue working with the original phenomenon.

Test Ideas:

- Evidence from changes to students' written models will determine whether additional class discussion is needed.

Exit Ticket:

- Students' responses to question 1 will determine whether more instruction related to the impetus conception is required; question 2 will determine how to introduce the next type of motion (objects moving in a direction opposite an applied force).

How and when will feedback be provided to students (Teacher to Student/Student to Student/Student to Self)?

Teacher: Feedback to students in conversations during the Model and Test Ideas parts of the lesson

Teacher/Student: Feedback to students as they engage in Argument from Evidence during the Compare discussion, in the form of questions and counterarguments

Self: Comparison to class criteria for models (with reminder during Compare)

Natural World: Students will get direct feedback from testing their ideas with the cart and frictionless track.

Figure 7: Formative Assessment Planning Example for High School Forces and Interactions, Lesson C *(continued)*

PLANNING TEMPLATE

COMPLETE THIS SECTION AFTER THE LESSON HAS BEEN TAUGHT. (Example reflections below were completed by the teacher following the lesson described in the Figure 8 Vignette on pages 39-41.)

What aspects worked well and will be used again, and what aspects are in need of improvement?

Worked well:

- Having students create individual models at the beginning of class was very informative. I could quickly see which students were not yet comfortable with the idea of the normal force and which students were including an extra impetus force.

In Need of Improvement:

- I would have liked to involve more students in the Compare discussion. Even though all of the students had models with features in common with one of the two models on the board, I think it would be helpful for them to share their models with a partner before the whole class discussion. That way, all of the students will get to talk about their models, and some students may be more willing to talk in the whole class discussion after they've had a chance to share their ideas with a partner.
- I wasn't explicit enough about students changing their models in response to testing their ideas. Some students recognized that they should do this but others did not. This made it difficult to determine whether all of the students had gotten what I wanted from the Test Ideas activity.

Figure 7.1: Ordered Mulitiple-Choice (OMC) Item (with Learning Progression Levels)

A rocket in outer space is traveling toward a far off planet. An astronaut turns on the rocket's engines, which exert a constant force on the rocket. You may assume that there is no gravity or air resistance.

When the astronaut turns off the engines, what will happen to the rocket?	**Level**
A. It will steadily slow down until the force from the engines is gone.	2
B. It will steadily slow down because no forces are acting on it.	3
C. It will continue moving with a constant speed because no forces are acting on it.	4
D. It will continue moving with a constant speed because the force from the engines is still acting on it.	2

Source: Alonzo & Steedle (2008).

Figure 8: Vignette for High School Forces and Interactions, Lesson C

FAME Components and Elements	Lesson C: What Forces are Acting on the Car Before, During, and After the Cable?
Eliciting Evidence 3.2, 3.4 **Formative Feedback** 4.1	To check student understanding of ideas from the previous two lessons, as well as ideas she plans to address next, Ms. Pham starts by asking students to create a new model that incorporates what they have learned about forces so far. She calls students' attention to the two segments they have already considered (before and while the car is being pulled by the cable) and asks them to also think about forces acting on the car after it is released from the cable. Ms. Pham scans the students' models, paying particular attention to students who had not quite reached the learning targets in previous lessons. She checks in with students who neglected to include the normal force in their "before" models, asking questions such as "If gravity is acting on the car, what should be happening to it?" Ms. Pham is pleased to note that most students have accurately modeled the forces acting in their "before" and "during" segments and have represented the force and motion consistent with the class criteria. However, she also notices that many students have indicated a force acting on the car after it has been released from the cable.
Planning 1.1 **Learning Target Use** 2.1, 2.3	Ms. Pham recognizes that students' inclusion of a force acting on the car in the "after" segment is likely an indication of the impetus conception described in the learning progression and will spend the rest of the lesson addressing this idea. Because she anticipated that students would likely have this idea, she is ready with plans to address it. Her learning target is for students to clearly and accurately describe the forces acting on an object moving at constant speed. In particular, students should indicate that zero net force (either no forces at all or a set of forces adding to zero) is required for an object to travel at constant speed. In communicating this learning target to the students, Ms. Pham highlights the goal of clearly representing forces, reminding students about the criteria the class agreed upon. Students also know that they should be modeling the forces accurately, but Ms. Pham does not explicitly state the relationship (constant speed corresponding to zero net force) that they will be figuring out during the lesson.
Eliciting Evidence 3.1 **Formative Feedback** 4.1 **Instructional and Learning Decisions** 5.2	Ms. Pham begins by pointing out what she noticed about students' models: "I see that most of you are in agreement about the forces acting before and while the cable is pulling. But there seems to be some disagreement about what is happening after the car is released." She asks students to recall how, in their earlier models, they had described the motion of the car at this point in its path, and the class agrees that the car is moving at a constant speed. Ms. Pham reminds students of the class criteria that both forces and the motion of the car should be labeled, and several students make quick additions to their models.

Figure 8: Vignette for High School Forces and Interactions, Lesson C *(continued)*

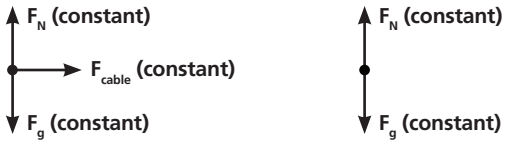
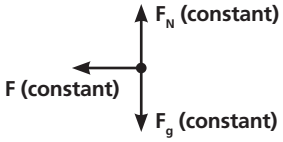
FAME Components and Elements	Lesson C: What Forces are Acting on the Car Before, During, and After the Cable?
Eliciting Evidence 3.2, 3.3, 3.4	Ms. Pham then recreates two models of the forces on the whiteboard at the front of the classroom:  Ms. Pham invites students to provide an argument for the model they think most accurately represents the force(s) acting on the car after it is released, pressing students to connect their arguments to what the class has already learned about ***F***=*m****a***. For example, Xavier says, "I choose the model on the left. There has to be a force pushing the car forward. Otherwise, how could it be moving?" Ms. Pham responds by asking, "How does that fit with our ideas from Monday?" She points to a list of things students have figured out, including "F causes a." After some discussion, with pressing questions from Ms. Pham, the students conclude that the acceleration is zero. However, the following exchange takes place: Xavier: *But the force can't be zero! It's moving forward.* Brianna: *Maybe it's like the sandpaper. There's a force from the cable, but it doesn't make the car accelerate because the surface is rough.* Ms. Pham: *What if the surface were perfectly smooth? Can the car move at a constant speed with no force?* The conversation continues. As above, sometimes the teacher asks challenging questions to prompt students to rethink their ideas, and sometimes students challenge each other.
Eliciting Evidence 3.2	At this point, the students who have been involved in the conversation appear convinced that there is no force acting on the car. However, Ms. Pham is concerned that many students have not spoken. She does a quick check-in, using an ordered multiple-choice (OMC) question (with options connected to levels of the learning progressions) to gauge student understanding with respect to the impetus conception: A rocket in outer space is traveling toward a far off planet. An astronaut turns on the rocket's engines, which exert a constant force on the rocket. You may assume that there is no gravity or air resistance. When the astronaut turns off the engines, what will happen to the rocket? A. It will steadily slow down until the force from the engines is gone. B. It will steadily slow down because no forces are acting on it. C. It will continue moving with a constant speed because no forces are acting on it. D. It will continue moving with a constant speed because the force from the engines is still acting on it. Students write A, B, C, or D on individual whiteboards, which they hold up to show Ms. Pham their choices.

Figure 8: Vignette for High School Forces and Interactions, Lesson C *(continued)*

FAME Components and Elements	Lesson C: What Forces are Acting on the Car Before, During, and After the Cable?
Formative Feedback 4.4 **Instructional and Learning Decisions** 5.1, 5.2	Because many students selected options A and D (indicating the impetus idea at level 2 of the learning progression), Ms. Pham decides to do some additional instruction related to the impetus idea. She asks students to test, using the cart and a frictionless track, what would happen if the forces in their models were applied to the cart. This allows them to get direct feedback on their models from the natural world. A few students make changes to their models after observing that an applied force makes the cart speed up. Through subsequent discussion, the class comes to consensus that no force is required for the cart to move at a constant speed on the frictionless track. However, Ms. Pham is concerned that some students may still think that, although no *applied* force is required, an impetus force must still be keeping the cart in motion. Class is almost over, but she will be able to check on this hunch with her planned exit ticket.
Eliciting Evidence 3.2, 3.4	As an exit ticket, Ms. Pham asks students to respond to the following questions: 1) Sabine claims that it is possible for a cart on a frictionless track (like our lab) to move at a constant speed without anyone pushing it. Alex disagrees, saying someone had to push the cart to begin with. He says that force is what makes the cart move at a constant speed. Who is right? How would you explain to these students what force(s) are acting on the cart? 2) Julia has modeled the forces acting on a toy car:  How would you describe the motion of the car? Is it possible for the car to be traveling to the right? The first question directly elicits students' ideas about Lesson C, while the second question looks forward to Lesson D. Ms. Pham is interested in whether any of her students have figured out that an object can be traveling in a direction other than that of the net force. She knows that students will need to figure out this idea in order to model the forces acting on the car as it crashes into the wall, and—from the learning progression—she anticipates this idea might be challenging for her students.

G. Conclusions from Both Examples

In this final section, we highlight some common themes across the elementary and high school examples, paying particular attention to discipline-specific features of science formative assessment.

Connection to Figuring Out

With its focus on students' figuring out phenomena, the new vision of science teaching and learning requires some reinterpretation of traditional components of formative assessment.

Implications for learning targets

Although it is generally desirable to provide students with clear learning targets, which they could use to engage in peer and self-assessment, learning targets cannot "give away" what students are trying to figure out. In addition, learning targets should not only include students' understanding of content (DCIs, CCCs) but also their ability to engage in SEPs. As distinct from inquiry "skills," SEPs require deep understanding of (and, thus, engagement in) "doing" science and engineering. This type of figuring out may involve students in developing the success criteria themselves, rather than receiving a model of proficient achievement from the teacher.

For example, learning targets for Ms. Pham's students entailed clearly and accurately modeling forces acting for different types of motion. Although Ms. Pham was explicit about the goal of clearly modeling forces (i.e., the SEP), students themselves determined criteria for doing so, and—when presenting the learning target—Ms. Pham did not identify the relationship between force and motion that students should be figuring out (i.e., the DCI). Similarly, as part of their design challenge, Ms. Chara's students will help to identify the criteria for evaluating their boxcar designs; she will not present them with an example of a "good" boxcar design.

Implications for formative feedback

As they figure out phenomena and solve design challenges, scientists and engineers use evidence to evaluate their ideas. As such, evidence is an important form of formative feedback for scientists and engineers. For students learning to "do" science and engineering, evidence is similarly a source of feedback. Like scientists and engineers, students can test their ideas against empirical evidence, using that evidence to determine where ideas may need to be revised (and how).

Thus, in science, feedback can come from people (i.e., teacher and other students) as well as from the results of investigations (such as the ones that Ms. Pham's students conducted). For example, later in the Boxcar unit, Ms. Chara's students will develop a plan to move their boxcars through an obstacle course using pushes, ramps, etc. If their plan does not work, they need to revisit their ideas and think about *why* the plan did not work and how they can alter their design to be successful.

Connection to SEPs

When students engage in SEPs as part of the process of figuring out phenomena or answering driving questions, they are inherently providing rich evidence of their current understanding. Teachers can use this evidence in order to provide feedback and make instructional decisions.

For example, when students asked questions about how the soap boxcars in the derby started moving, Ms. Chara knew that students needed support in making connections between their investigations and the overarching phenomenon. In the high school example, Ms. Pham used students' models to elicit their understandings about how forces cause motion and used this evidence to guide the activities that she did next. Embedded sensemaking opportunities such as these allow teachers to use students' work products to better understand how to support their learning.

In addition, when using SEPs for formative assessment in science, classroom discourse is important. Making sense of phenomena using SEPs often necessitates discussion, both in small groups and with the whole class. This discourse can be used as a means to elicit evidence of student understanding as well as a means for providing formative feedback.

For example, when Ms. Chara worked with a pair of students, she asked the students to "explain like scientists," which meant that she wanted them to use evidence to support their claims. She supported students in responding to her question with more complete descriptions than "we pushed it." If they had not been able to use evidence, Ms. Chara could have worked with the pair on the spot to help them make better sense of the findings from their investigation.

In addition, when using SEPs for formative assessment in science, classroom discourse is important.

Similarly, Ms. Pham asked students to support their ideas with evidence during a whole class discussion about their models. In this discussion, students worked together to come to a deeper understanding of the nature of forces at work in the car crash phenomenon. Sometimes Ms. Pham challenged students' ideas, and sometimes students challenged each other's ideas; in both cases, questions asked as part of the discussion provided formative feedback for students to revise their ideas. In addition, Ms. Pham used this evidence from discussion to make instructional decisions for the next day.

Connection to Learning Progressions

Finally, learning progressions have implications for formative assessment aligned with the new vision of science teaching and learning. The teachers in the examples above used two types of learning progressions. The first is evident when looking across grade levels at the PEs in a given DCI. Because the Michigan Science Standards are designed so that student learning builds over time, students will begin working on a big idea as early as kindergarten and gradually develop more sophisticated understandings throughout their K-12 science education. When designing learning targets, it can be helpful to consider the larger progression of ideas that students will be learning before and after a given grade level. For example, by paying careful attention to the ideas that her students will encounter in

middle school and beyond, Ms. Chara was able to fine-tune the language that she used to express learning targets for her students. Ms. Pham used the sequence of PEs to identify what her students may already have encountered in prior instruction and used that information to identify a learning target early in her unit.

The second type of learning progression is more specifically designed to support formative assessment practices. Teachers like Ms. Pham can use researcher-developed learning progressions to anticipate and plan, in advance, to elicit and address common student ideas. Of course, unexpected ideas may still arise, but teachers need to make fewer instructional decisions "on the spot" if they have already reasoned about how students are most likely to engage in figuring out. These learning progressions may also be used to sequence instruction so that students can build understanding across a series of lessons. Even without a formalized, research-based document, teachers can draw on awareness of common student ideas and practices (and the relative sophistication of what students know and can do) to engage in the same type of work. Although Ms. Pham's learning progression was provided by researchers, it reflected some knowledge that she had already developed based on her prior work with students.

Reflection Questions:

Considering the two vignettes and some of the "take-away" messages that were highlighted above, how might these ideas apply in your own context? Below we have posed some questions to help you connect ideas in this Guide to your own practice.

1. Think of an investigation that you and your students will conduct. How could students use evidence that they gather as feedback on their predictions or initial ideas? How might you support students in using evidence as feedback to deepen their science understandings?

2. Think about a learning target for an upcoming lesson. What parts make sense to share with students and what parts will they be figuring out? How can you phrase this learning target to support students in understanding the goal without giving away what they will be figuring out? (HINT: How can you focus students' attention on the SEPs and/or CCCs)?

3. Think about a PE that you will be teaching soon. What evidence of students' understanding could you get from their engagement in the SEP in the PE? How might you use other PEs to both support student learning and elicit evidence of their understanding?

4. How could you use discussions to support students in figuring out a phenomenon? How can you use SEPs as part of the discussion (e.g., asking for evidence to support claims) to elicit evidence of student understandings and provide feedback to support students in figuring out a phenomenon?

5. Think about a DCI that you and your students will be engaging with:
    a. According to the progression of DCIs in the Next Generation Science Standards[xxxi] (NGSS), what ideas might your students have encountered in prior instruction? What ideas will they learn after your instruction? How might these ideas influence how you engage students with the DCI?
    b. If you have experience engaging students with the content of the DCI, what ideas and experiences do your students typically have before your instruction? What ideas do they typically express as they engage with the content of the DCI? What aspects of the DCI are typically challenging for them?

NOTES

Like scientists and engineers, students can test their ideas against empirical evidence, using that evidence to determine where ideas may need to be revised (and how).

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What is Formative Assessment for Michigan Educators (FAME)?

FAME is an exciting professional learning initiative sponsored by the Michigan Department of Education (MDE) that promotes teacher collaboration and planning for effective formative assessment practice. A cadre of Michigan educators serves as coaches for site-based learning teams of teachers and administrators in Michigan schools.

Visit www.FAMEMichigan.org for more information and to access the extensive set of supports and resources available to FAME Coaches.

NOTE to readers of a print version of this document: URLs for all hyperlinks included in this text are included in the Endnotes (as retrieved at the date of publication). FAME Coaches or participants can access a digital copy (with active embedded hyperlinks) on the FAME website or by requesting a file from youngk1@michigan.gov.

Endnotes

i A printable version of the FAME Components and Elements table is available on the FAME website, with hyperlinks to documents that provide descriptive overviews of each element. https://famemichigan.org/wp-content/uploads/2017/08/FAME-Comps-and-Elements-Table-and-FA-Graphic.pdf

ii Next Generation Science Standards (NGSS; NGSS Lead States, 2013) https://www.nextgenscience.org/

iii Michigan Science Standards (MSS, 2015) https://www.michigan.gov/documents/mde/K-12_Science_Performance_Expectations_v5_496901_7.pdf

iv *Framework for K-12 Science Education* (National Research Council [NRC], 2012) https://www.nap.edu/read/13165/chapter/15

v Eight SEPs (Science and Engineering Practices) https://www.nap.edu/read/13165/chapter/7

vi practices work together http://stemteachingtools.org/brief/3

vii learning progressions for the SEPs https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

viii (1) Physical Sciences https://www.nap.edu/read/13165/chapter/9

ix (2) Life Sciences https://www.nap.edu/read/13165/chapter/10

x (3) Earth and Space Sciences https://www.nap.edu/read/13165/chapter/11

xi (4) Engineering, Technology, and Application of Science https://www.nap.edu/read/13165/chapter/12

xii learning progression https://www.nextgenscience.org/sites/default/files/resource/files/AppendixE-ProgressionswithinNGSS-061617.pdf

xiii examples of bundling PEs https://ngss.nsta.org/AccessStandardsByTopic.aspx

xiv CCCs (Cross Cutting Concepts) https://www.nap.edu/read/13165/chapter/8

xv learning progressions for the CCCs https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

xvi conceptual shifts https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20A%20-%204.11.13%20Conceptual%20Shifts%20in%20the%20Next%20Generation%20Science%20Standards.pdf

xvii instructional shifts https://www.nextgenscience.org/sites/default/files/resource/files/NewVision.pdf

xviii NRC, 2017 https://www.nap.edu/catalog/23548/seeing-students-learn-science-integrating-assessment-and-instruction-in-the

xix scientific phenomena https://www.nextgenscience.org/sites/default/files/Using%20Phenomena%20in%20NGSS.pdf

xx Driving questions http://www-personal.umich.edu/~krajcik/DQ.html

xxi STEM Teaching Tool #46 http://stemteachingtools.org/brief/46

xxii Learning progressions https://www.nap.edu/read/11625/chapter/10#213

xxiii NGSS learning progressions https://www.nap.edu/read/18290/chapter/11

xxiv K-PS2-1, K-PS2-2 https://www.nextgenscience.org/dci-arrangement/k-ps2-motion-and-stability-forces-and-interactions

xxv 3-PS2-1 https://www.nextgenscience.org/pe/3-ps2-2-motion-and-stability-forces-and-interactions

xxvi MS-PS2-2 https://www.nextgenscience.org/pe/ms-ps2-2-motion-and-stability-forces-and-interactions

xxvii HS-PS2-1 https://www.nextgenscience.org/pe/hs-ps2-1-motion-and-stability-forces-and-interactions

xviii Soapbox Derby Races in Lake County https://www.youtube.com/watch?v=j37meEX4rqk

xxix learning progression for PS2.A (Forces and Motion) https://www.nap.edu/read/18290/chapter/11#375

xxx Michigan Science Standards https://www.michigan.gov/documents/mde/K-12_Science_Performance_Expectations_v5_496901_7.pdf

xxxi progression of DCIs in the Next Generation Science Standards https://www.nextgenscience.org/sites/default/files/resource/files/AppendixE-ProgressionswithinNGSS-061617.pdf

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