MICHIGAN STATE UNIVERSITY College of Education

C2. Next Generation Science Formative Assessment

Michigan School Testing Conference
February 13, 2019

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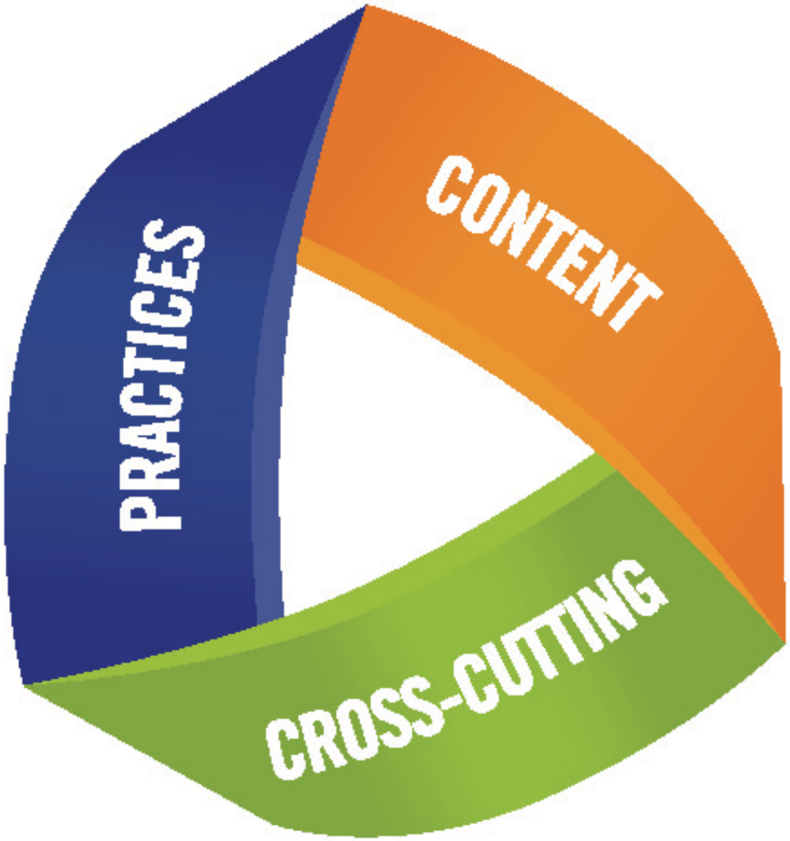
This material is based upon work supported by the National Science Foundation under Grant No. DRL-1253036 and Grant No. DRL-1620580. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Session Outline

- Brief overview of NGSS and formative assessment
- Prioritizing Science & Engineering Practices (SEPs)
- Considering students' learning pathways
- Next steps for next generation science formative assessment practices

Next Generation Science Standards



Content and Practice Work together to Build Understanding

- Scientific ideas are best learned when students engage in practices
- To form useable understanding, knowing and doing cannot be separated, but rather must be learned together
- Allows for problem-solving, decisions making, explaining real-world phenomena, and integrating new ideas

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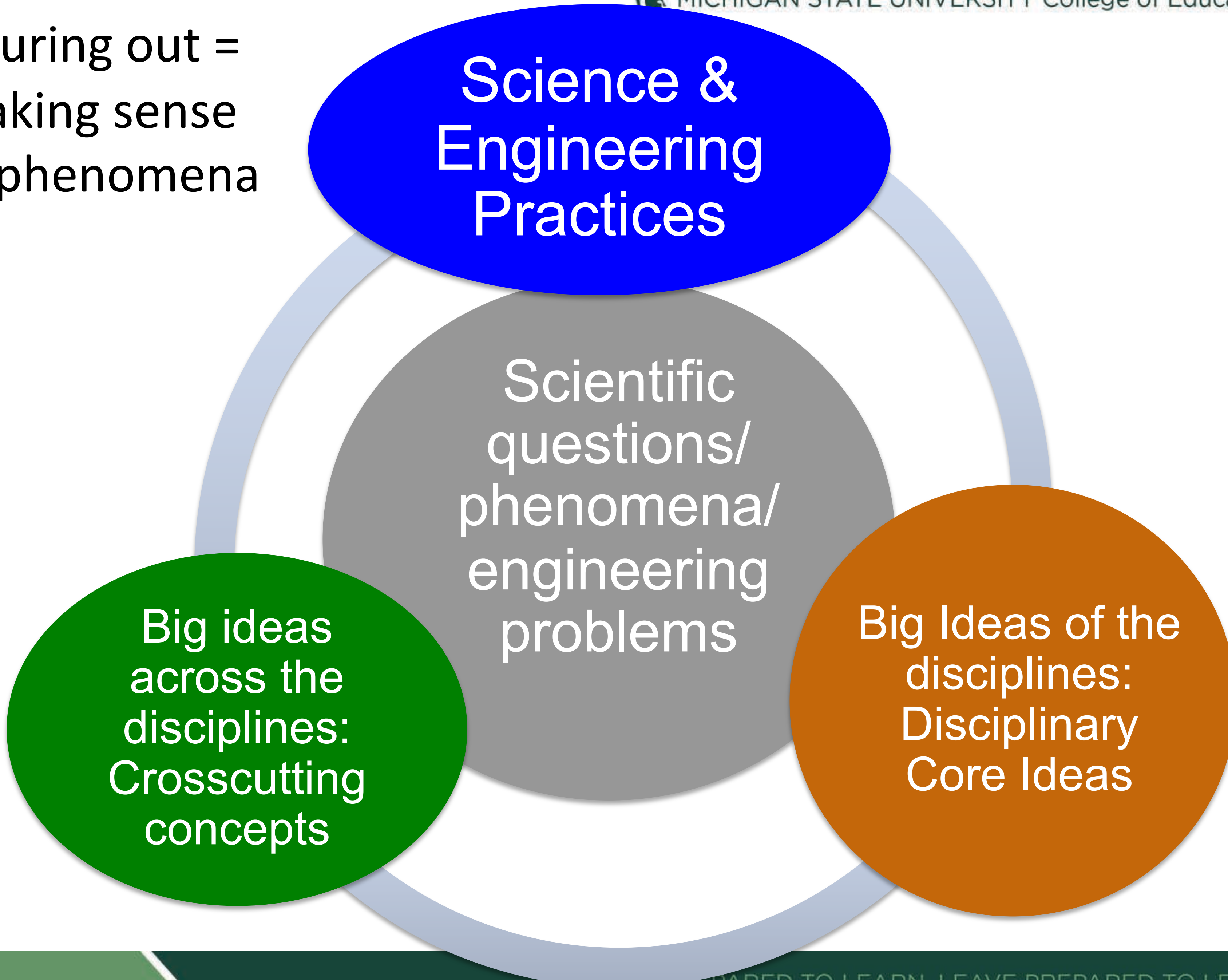
Learning About → Figuring Out

Figuring out =
Making sense
of phenomena



Phenomenon

Natural phenomena are observable events that occur in the universe and that we can use our science knowledge to explain or predict. https://www.nextgenscience.org/sites/default/files/Using%20Phenomena%20in%20NGSS.pdf

Everyday: Frost on the INSIDE when its cold OUTSIDE

Novel: Crushed tanker car

A New Vision for Science Education

Implications of the Vision of the Framework for K-12 Science Education and the Next Generation Science Standards

SCIENCE EDUCATION WILL INVOLVE LESS:	SCIENCE EDUCATION WILL INVOLVE MORE:
Rote memorization of facts and terminology	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning.
Learning of ideas disconnected from questions about phenomena	Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned
Teachers providing information to the whole class	Students conducting investigations, solving problems, and engaging in discussions with teachers' guidance
Teachers posing questions with only one right answer	Students discussing open-ended questions that focus on the strength of the evidence used to generate claims
Students reading textbooks and answering questions at the end of the chapter	Students reading multiple sources, including science-related magazine and journal articles and web-based resources; students developing summaries of information.
Pre-planned outcome for "cookbook" laboratories or hands-on activities	Multiple investigations driven by students' questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas
Worksheets	Student writing of journals, reports, posters, and media presentations that explain and argue
Oversimplification of activities for students who are perceived to be less able to do science and engineering	Provision of supports so that all students can engage in sophisticated science and engineering practices

Source: National Research Council. (2015). *Guide to Implementing the Next Generation Science Standards* (pp. 8-9). Washington, DC: National Academies Press. http://www.nap.edu/catalog/18802/guide-to-implementing-the-next-generation-science-standards

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Teachers posing questions with only one right answer

Students discussing open-ended questions that focus on the strength of evidence used to generate claims

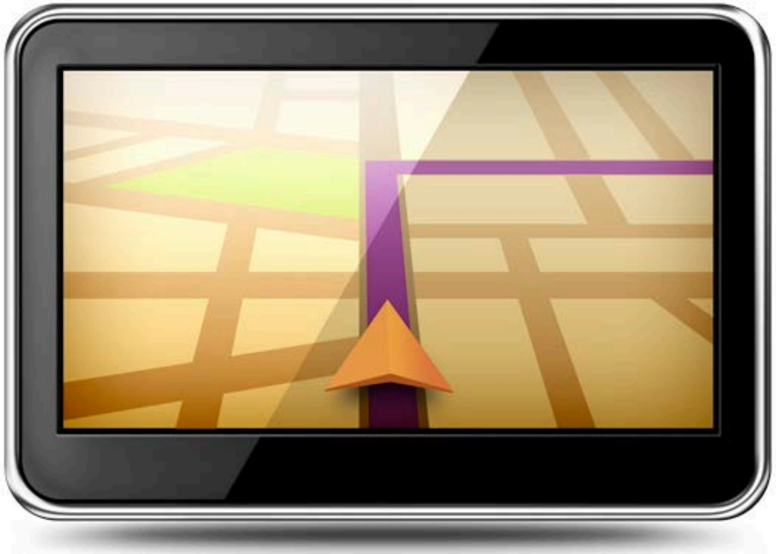
What is Formative Assessment?

Formative assessment is a "... a planned, ongoing process used by all students and teachers during learning and teaching to improve student understanding of intended disciplinary learning outcomes, supporting students becoming more self-directed learners."

(CCSSO, 2017).

Overview of Formative Assessment

- **Where are we going?**
  Setting learning targets and goals
- **Where are we now?**
  Collecting evidence of current student understanding
- **How do we get there?**
  Closing the gap and responding to students



Range of Formative Assessment Strategies

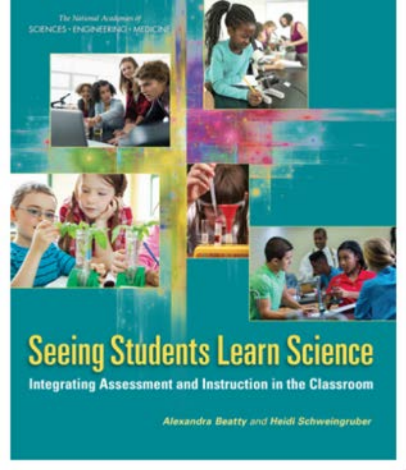
On-the-fly | **Planned for interaction** | **Embedded assessment** | **Separate assessment**

Informal Practice | **Formal Practice**

Adapted from Shavelson (2003)

Turn and Talk

- In what ways do you and your colleagues use formative assessment when teaching science (e.g., what strategies are you using? what tools are you using?)



Shifts for NGSS-Aligned Formative Assessment

To measure three-dimensional learning that develops over time, assessments need to:

- examine how students use science and engineering practices in the context of crosscutting concepts and disciplinary core ideas;
- focus on students' progress along a learning pathway rather than what is correct or incorrect at a particular time.

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

How can we…

…examine how students use science and engineering practices in the context of crosscutting concepts and disciplinary core ideas?

Science and Engineering Practices

- The multiple ways of knowing and doing that scientists and engineers use to study the natural and design world
- "Practices" as distinct from "skills" to emphasize knowledge that is specific to each practice
- Practices wok together – they are not separate

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

Organizational schema for interrelating knowledge from various science fields

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

Disciplinary Core Ideas

- Have **broad importance** & are a **key organizing concept** of a single discipline
- Provide a **key tool** for understanding / investigating complex ideas and solving problems
- Relate to the **interests and life experiences of students** or be connected to **societal issues** that require scientific knowledge
- Be **teachable** and **learnable** over multiple grades at increasing levels of depth and sophistication

Physical Sciences
PS1: Matter and its interactions
PS2: Motion and stability: Forces and interactions
PS3: Energy
PS4: Waves and their applications in technologies for information transfer

Life Sciences
LS1: From molecules to organisms: Structures and processes
LS2: Ecosystems: Interactions, energy, and dynamics
LS3: Heredity: Inheritance and variation of traits
LS4: Biological evolution: Unity and diversity

Earth and Space Sciences
ESS1: Earth's place in the universe
ESS2: Earth's systems
ESS3: Earth and human activity

Engineering, Technology, and Applications of Science
ETS1: Engineering design
ETS2: Links among engineering, technology, science, and society

Examples of 3D Formative Assessment

- High School Biology: Using a phenomenon to elicit student ideas
- Elementary Weather: Using student ideas to guide discussion

Example HS Biology

Students who demonstrate understanding can:

Performance Expectations

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. HS-LS1-4

Clarification Statement and Assessment Boundary

Clarification Statement: none

Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).

- Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-4)

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4)

Crosscutting Concepts

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS1-4)

Planning the Cancer Unit

Choose a Phenomenon to guide instruction:

- Cancer

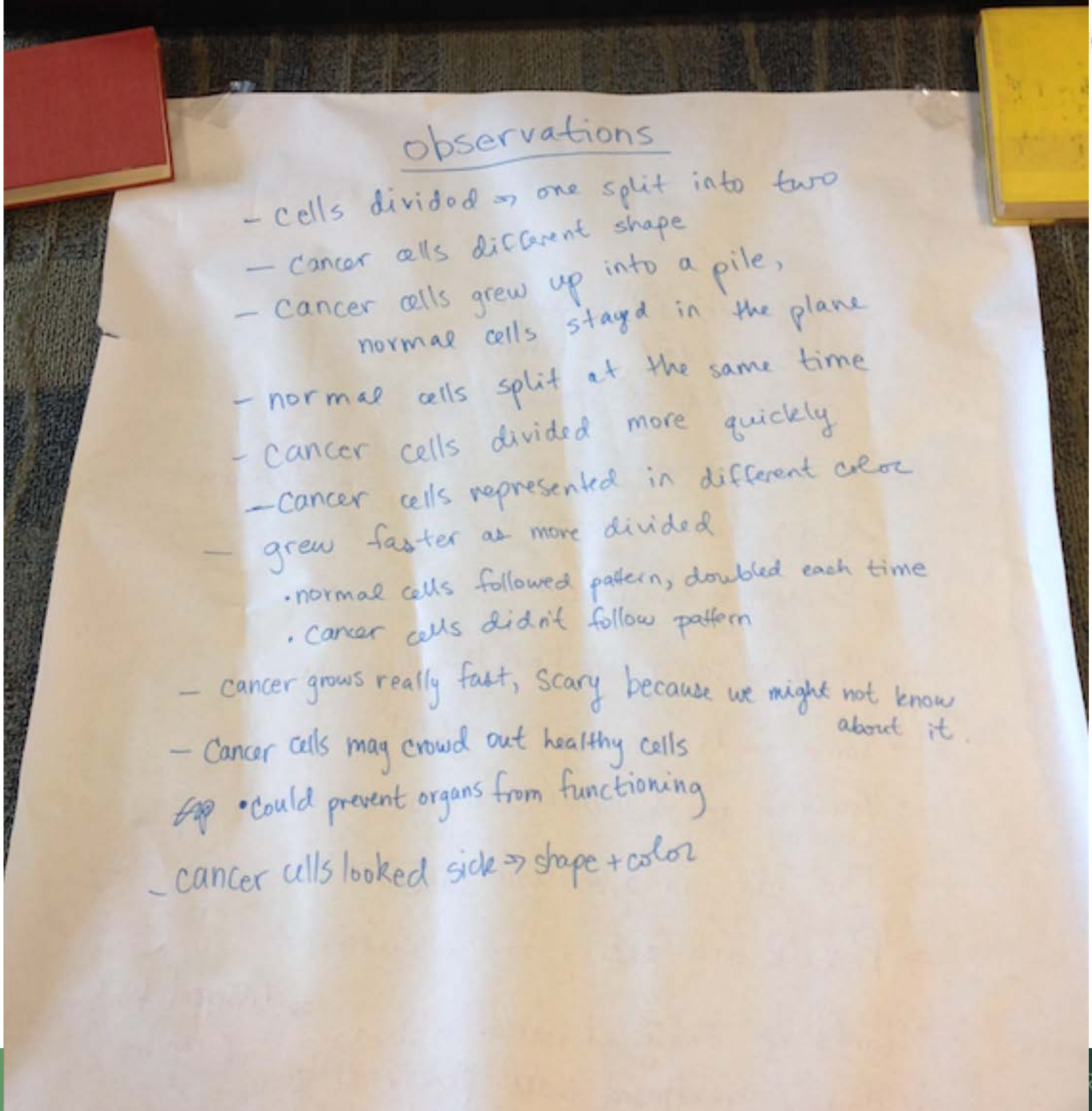
Choose a driving question based on the phenomenon:

- What is cancer? How might we find a cure for cancer?

How to Elicit Students' Ideas

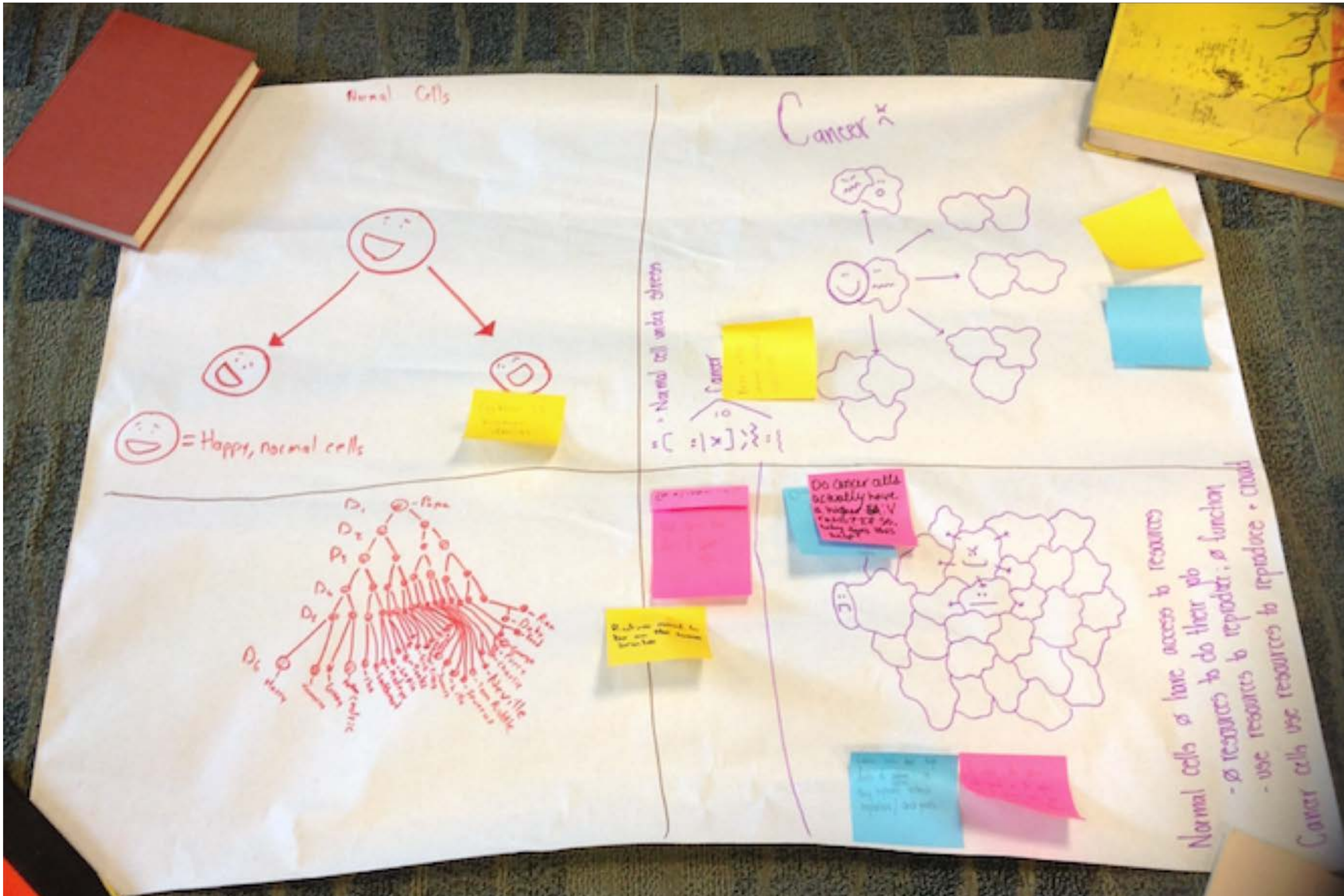
- Common experience to support ALL students
  - Engaging and peaks students' interest
  - Equitable starting point
- Rich task that presents an entry point for ALL students
  - Accessibility: students know enough about the task or question to hypothesize about it
  - Power to reveal consequential ideas: get students talking about facets of understandings

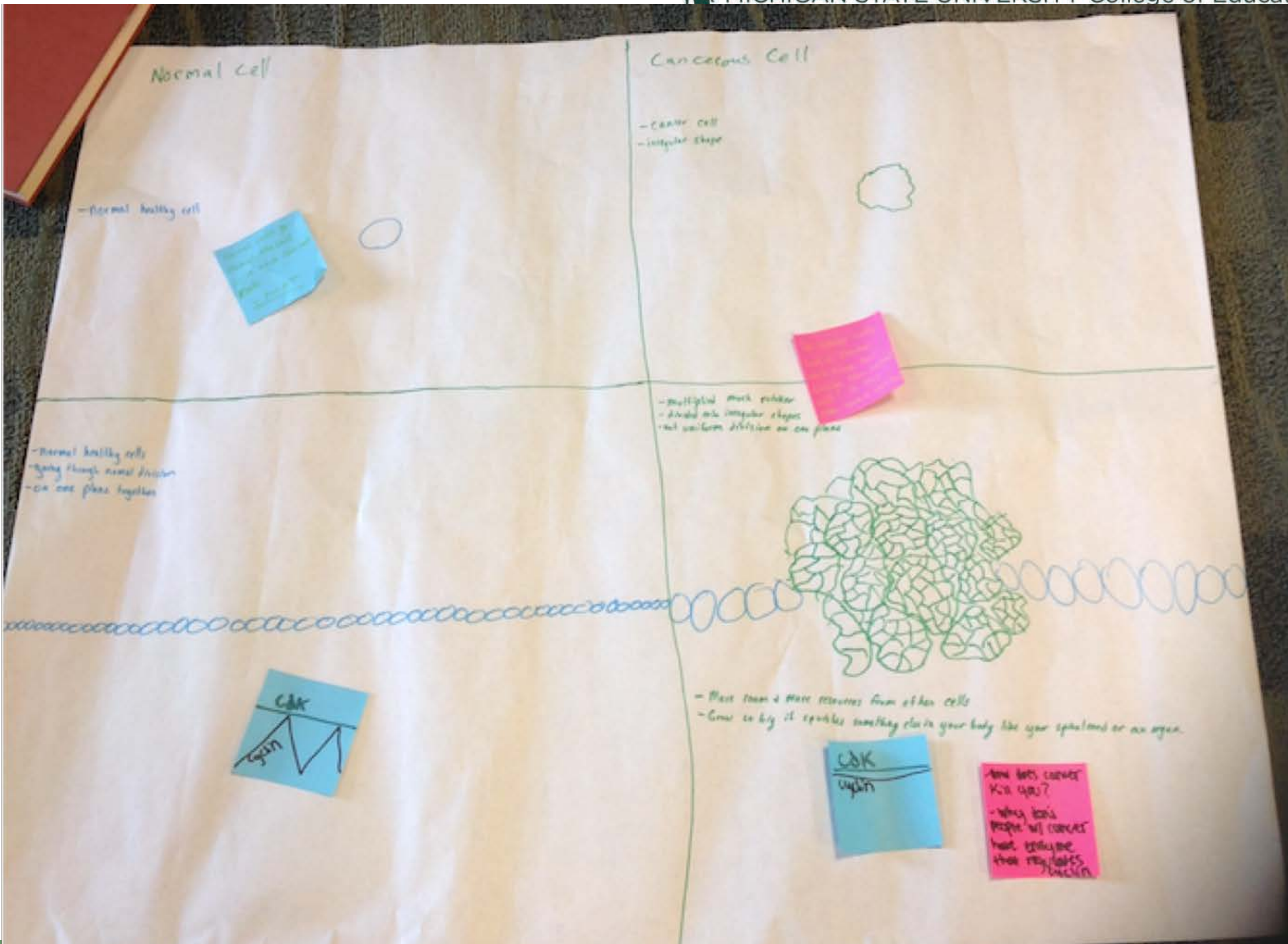
Cancer Unit



observations

- cells divided ⇒ one split into two
- cancer cells different shape
- cancer cells grew up into a pile, normal cells stayed in the plane
- normal cells split at the same time
- cancer cells divided more quickly
- cancer cells represented in different color
- grew faster as more divided
  - normal cells followed pattern, doubled each time
  - cancer cells didn't follow pattern
- cancer grows really fast, scary because we might not know about it.
- Cancer cells may crowd out healthy cells
  - could prevent organs from functioning
- cancer cells looked sick ⇒ shape + color


Normal Cells
= Happy, normal cells
Cancer
Normal cell under stress
Do cancer cells actually have
Normal cells ø have access to resources
- ø resources to do their job
- use resources to reproduce; ø function
- use resources to reproduce + crowd
Cancer cells use resources to reproduce


Normal cell
Cancerous Cell
- cancer cell
- irregular shape
- normal healthy cell
- normal healthy cells
- going through normal division
- on one plane together
CDK
cyclin
CDK
cyclin

What questions do you still have?

- Why did the cancer cells look bumpy/ different from the regular cells?
- Why did the cancer cells grow more quickly?
- Why were there so many more cancer cells?
- How can you slow down the cancer cells?

Kindergarten Weather

Students who demonstrate understanding can:

Performance Expectations

Ask questions to obtain information about the purpose of weather forecasting to prepare for, and respond to, severe weather. K-ESS3-2

Clarification Statement and Assessment Boundary

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in K–2 builds on prior experiences and progresses to simple descriptive questions.

- Ask questions based on observations to find more information about the designed world. (K-ESS3-2)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.

- Read grade-appropriate texts and/or use media to obtain scientific information to describe patterns in the natural world. (K-ESS3-2)

Disciplinary Core Ideas

ESS3.B: Natural Hazards

- Some kinds of severe weather are more likely than others in a given region. Weather scientists forecast severe weather so that the communities can prepare for and respond to these events. (K-ESS3-2)

ETS1.A: Defining and Delimiting Engineering Problems

- Asking questions, making observations, and gathering information are helpful in thinking about problems. *(secondary to K-ESS3-2)*

Crosscutting Concepts

Cause and Effect

- Events have causes that generate observable patterns. (K-ESS3-2)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- People depend on various technologies in their lives; human life would be very different without technology. (K-ESS3-2)

Interdependence of Science, Engineering, and Technology

- People encounter questions about the natural world every day. (K-ESS3-2)

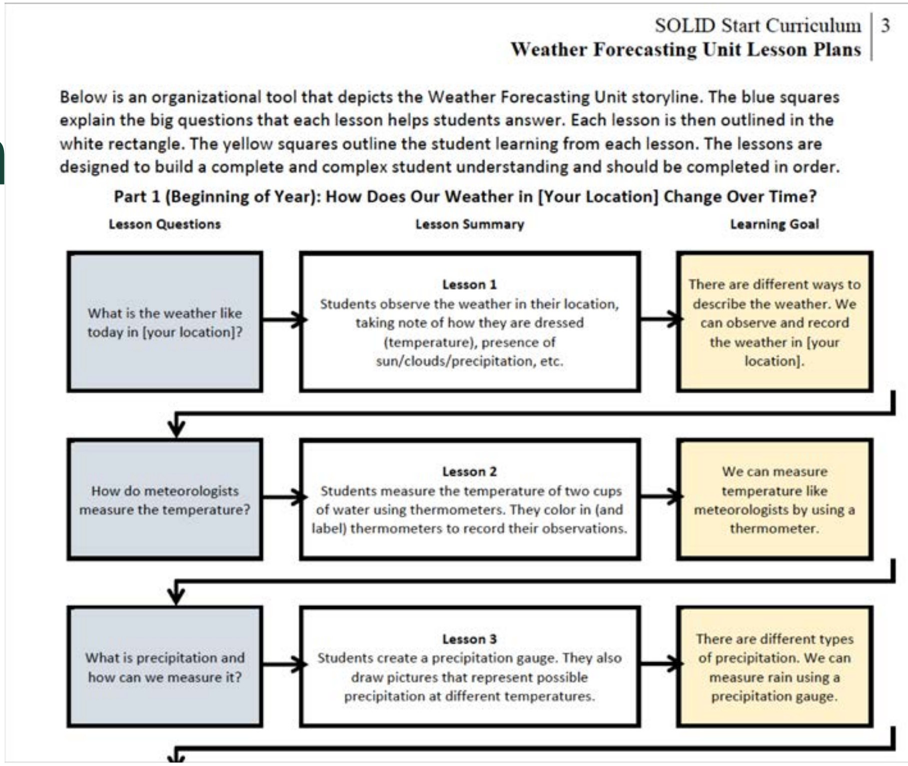
Planning the Weather Unit

Choose a Phenomenon to guide instruction:

- Local weather

Choose a driving question based on phenomenon:

- How does the weather in your location change over time?


SOLID Start Curriculum | 3
Weather Forecasting Unit Lesson Plans

Below is an organizational tool that depicts the Weather Forecasting Unit storyline. The blue squares explain the big questions that each lesson helps students answer. Each lesson is then outlined in the white rectangle. The yellow squares outline the student learning from each lesson. The lessons are designed to build a complete and complex student understanding and should be completed in order.

Part 1 (Beginning of Year): How Does Our Weather in [Your Location] Change Over Time?

Lesson Questions	Lesson Summary	Learning Goal
What is the weather like today in [your location]?	Lesson 1 Students observe the weather in their location, taking note of how they are dressed (temperature), presence of sun/clouds/precipitation, etc.	There are different ways to describe the weather. We can observe and record the weather in [your location].
How do meteorologists measure the temperature?	Lesson 2 Students measure the temperature of two cups of water using thermometers. They color in (and label) thermometers to record their observations.	We can measure temperature like meteorologists by using a thermometer.
What is precipitation and how can we measure it?	Lesson 3 Students create a precipitation gauge. They also draw pictures that represent possible precipitation at different temperatures.	There are different types of precipitation. We can measure rain using a precipitation gauge.

Throughout the unit

- Activities that include a cascade of practices
- Gathering evidence of students' ideas
  - Discourse: whole class discussions & small group discussions
  - Written work: models, explanations, investigation plans…

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Classroom Discourse

Jordan: Are we going to have indoor recess?

Teacher: When do we have indoor recess?

Jordan: When it is rainy or snowy

Shayanne: or really really cold

Teacher: Is it any of those things today?

Students: No…

Jordan: But it is gray outside

Teacher: Okay, so how would a meteorologist talk about “gray outside”?

(Wright & Gotwals, 2017)

Jordan: Partly cloudy

Shayanne: No, Cloudy

Teacher → Shayanne:

Why do you say cloudy? Do you have evidence?

Shayanne: There no blue sky, no sun at all, no shadows on the ground

Jordan: But its not rainy, so how is it all the way cloudy?

Teacher: Do clouds always mean rain?

Students: No…

Turn and Talk

What is one (additional) thing that you could do to adapt an existing formative assessment strategy or task to be more NGSS-aligned/3-dimensional?

How can we…

…focus on students' progress along a learning pathway rather than what is correct or incorrect at a particular time?

Learning Progressions

"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…"

Taking Science to School
National Research Council (2007)

Learning Progressions

"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…"

- Different from a progression of content (i.e., ordering of concepts)

Taking Science to School
National Research Council (2007)

Learning Progressions

"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…"

- Focus on how students think and represent ideas
- Include partial and even incorrect understandings

Taking Science to School
National Research Council (2007)

Learning Progressions

"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…"

- Not developmentally inevitable
- Depend on instruction, other individual and contextual factors

Taking Science to School
National Research Council (2007)

Simplified Learning Progression for Scientific Explanations

(Songer, Kelcey, & Gotwals, 2009; Gotwals & Songer, 2010)

Level 4: Student constructs scientific explanation.
Level 3: Student makes a claim and backs it up with sufficient and appropriate evidence but does not use reasoning to tie the evidence to the claim.
Level 2: Student makes a claim and backs it up with evidence, but the evidence is insufficient or inappropriate.
Level 1: Student makes a claim but does not back it up with evidence.
Level 0: Student does not make a claim or makes an incorrect claim.

Part of a Learning Progression for Construction and Use of Scientific Models

(adapted from Schwarz et al., 2009)

Level 3: Students view models as tools that can support their thinking about existing and new phenomena.
Level 2: Students view models as a means of communicating their understanding, rather than as tools to support their own thinking.
Level 1: Students view models as a means of showing others what the phenomenon looks like.

Simplified Learning Progression for Force & Motion

(adapted from Alonzo & Steedle, 2009)

Level 4: Acceleration (change in speed and/or direction) is proportional to applied net force (which may not be in the direction of motion).
Level 3: Velocity is proportional to applied net force.*
Level 2: Motion is directly associated with applied force.* (Force implies motion; motion implies force; non-motion implies no force; no force implies no motion.)
Level 1: No general relationship between force and motion. Forces and their effects depend on properties of objects such as mass.

**A subset of Levels 2 and 3 represents an alternative conception of force as impetus (that a moving object carries a force with it, proportional to its speed).*

Simplified Learning Progression for Matter & Energy in Carbon-Transforming Processes

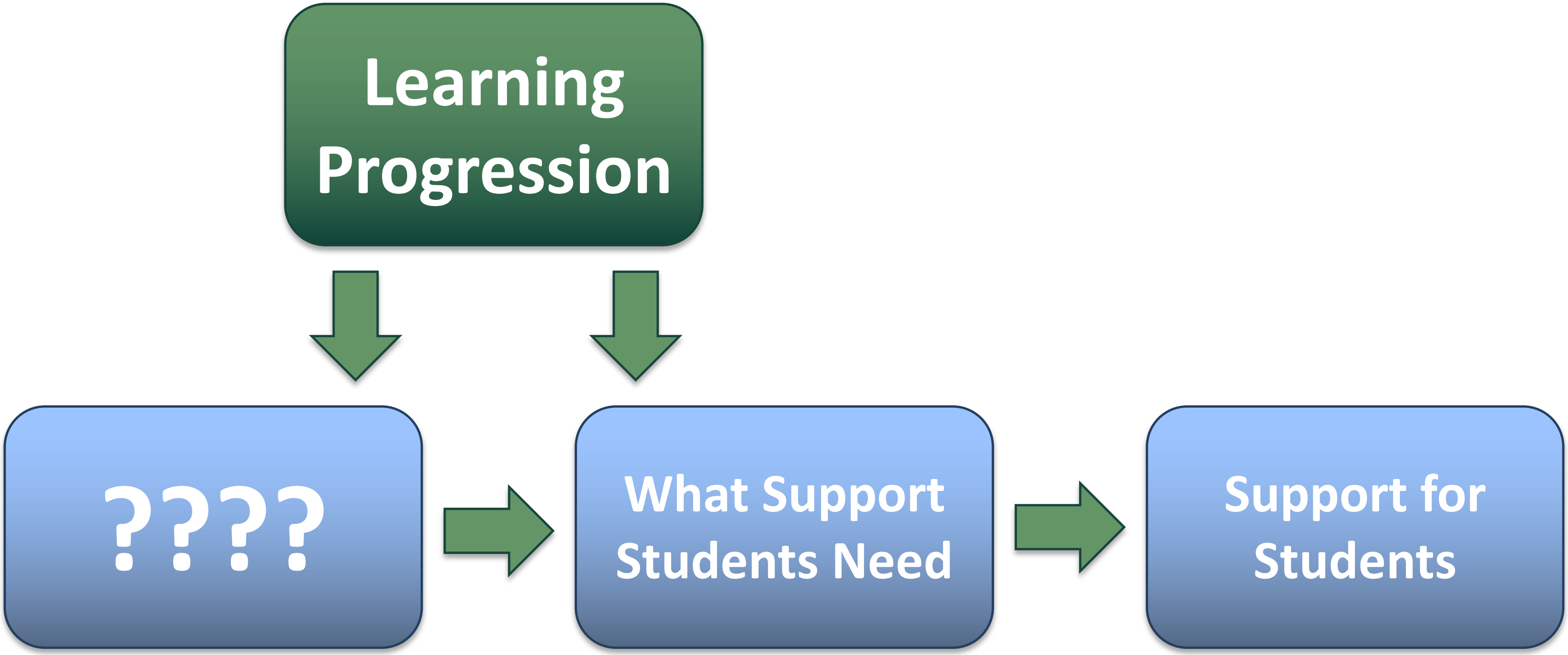
(adapted from Parker, de los Santos, & Anderson, 2015)

Level 4: Accounts reflect a *sense of necessity* for use of conservation rules as tools for analyzing processes, tracing matter and energy across scales without confounding the two.
Level 3: Accounts trace matter and energy intermittently, inconsistently, inaccurately, or incompletely, reflecting knowledge of laws of conservation of matter and energy without following these rules. The accounts describe key subsystems, rather than actors and enablers.
Level 2: Accounts recognize cycles, in which specific processes have specific needs. The material inputs and outputs involved are typically restricted to what is visible and a few specific gases and are not transformed following scientific rules such as conservation of matter.
Level 1: Accounts focus on visible elements and involve *actors* that use *enablers* to fulfill their needs. Materials may appear or disappear, or the fate of materials may not be part of the story at all.

Role of Classroom Experience

- Research-based learning progressions don't exist for many topics in the curriculum
- But… experience with students tells us a lot about what learning progressions are designed to represent:
  - How students' knowledge/practices change over time
    - Including learning difficulties
    - Including learning resources
  - How students are likely to display knowledge/practices

How Can Learning Progressions Help?



FORMATIVE INFORMATION

ACTIONABLE FEEDBACK

ACTION

How Can Learning Progressions Help?

How students' knowledge/ practices change over time	Learning difficulties	Learning resources
????	????	????
FORMATIVE INFORMATION	FORMATIVE INFORMATION	FORMATIVE INFORMATION

How Can Learning Progressions Help?

How students' knowledge/ practices change over time

Learning difficulties

Learning resources

Where are students' current knowledge/ practices relative to a model of how learning progresses?

Are students experiencing known learning difficulties?

Do students have known learning resources?

FORMATIVE INFORMATION

FORMATIVE INFORMATION

How Is This Useful?

Learning Progression

????

What Support Students Need

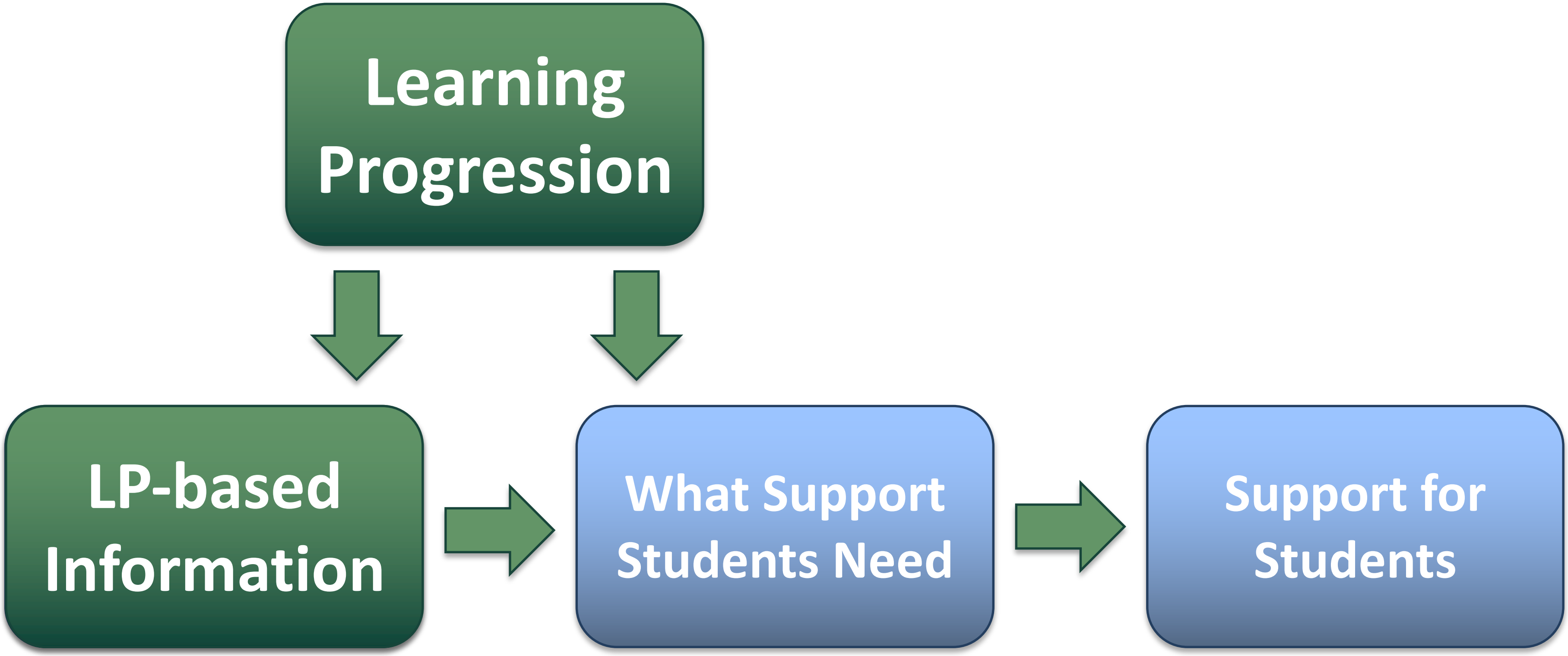
Support for Students

FORMATIVE INFORMATION

ACTIONABLE FEEDBACK

ACTION

How Is This Useful?



FORMATIVE INFORMATION

ACTIONABLE FEEDBACK

ACTION

How Is This Useful?

Where are students' current knowledge/ practices relative to a model of how learning progresses?

→

Students need to take the next step in the model of cognition

→

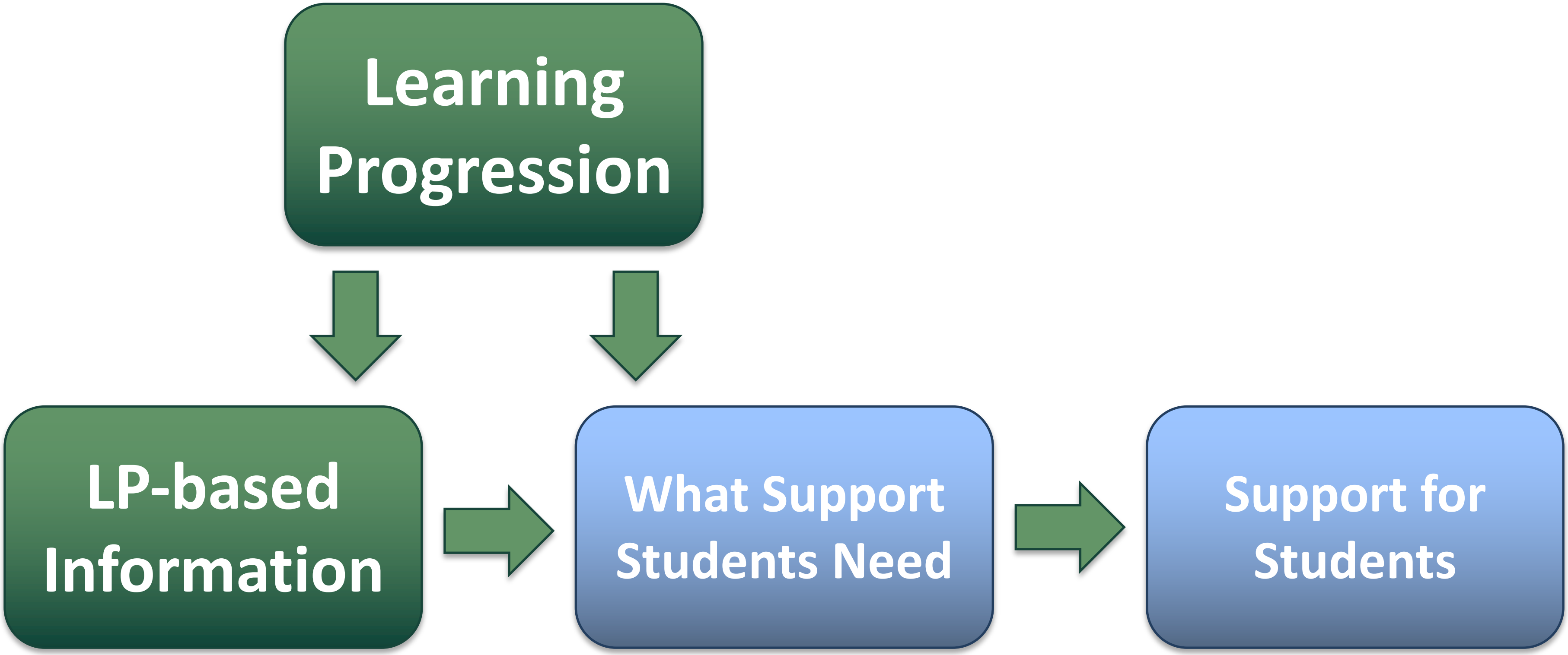
Support the next step in the model of cognition

FORMATIVE INFORMATION

ACTIONABLE FEEDBACK

ACTION

How Is This Useful?



FORMATIVE INFORMATION

ACTIONABLE FEEDBACK

ACTION

How Is This Useful?

Are students experiencing known learning difficulties?

→

Students need to overcome the specific learning difficulty

→

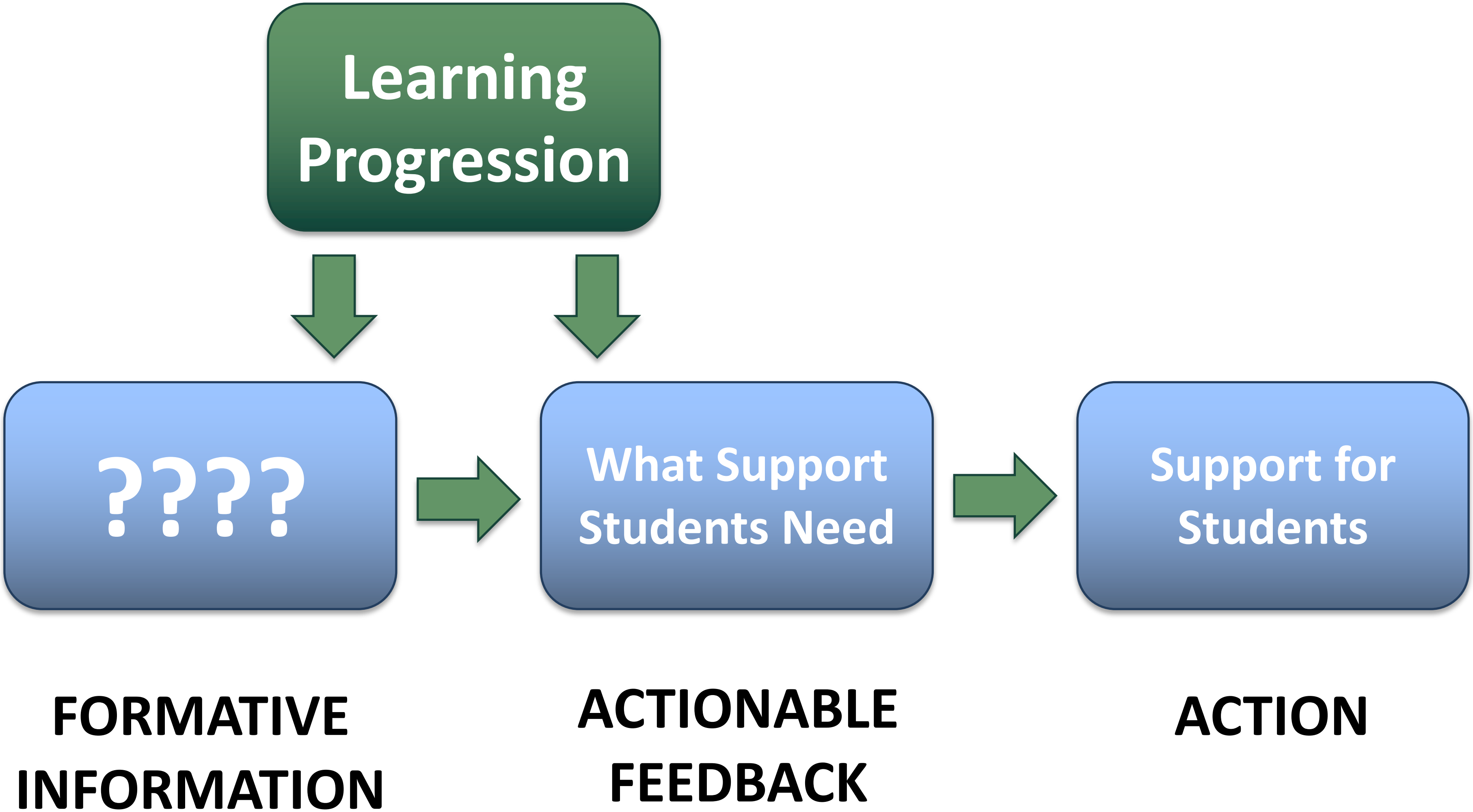
Support students in overcoming the specific learning difficulty

FORMATIVE INFORMATION

ACTIONABLE FEEDBACK

ACTION

How Is This Useful? (A Contrast)



How Is This Useful? (A Contrast)

Right/Wrong Information → Students need to know X → Teach/re-teach X

FORMATIVE INFORMATION

ACTIONABLE FEEDBACK

ACTION

Middle School Force and Motion

Students who demonstrate understanding can:

Performance Expectations

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. MS-PS2-2

▸ Clarification Statement and Assessment Boundary

Science and Engineering Practices

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (MS-PS2-2)

Connections to Nature of Science

Science Knowledge Is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS2-2)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

Crosscutting Concepts

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-PS2-2)

Force & Motion Example

Level 4: Acceleration (change in speed and/or direction) is proportional to applied net force (which may not be in the direction of motion).
Level 3: Velocity is proportional to applied net force.*
Level 2: Motion is directly associated with applied force.* (Force implies motion; motion implies force; non-motion implies no force; no force implies no motion.)
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****A subset of Levels 2 and 3 represents an alternative conception of force as impetus (that a moving object carries a force with it, proportional to its speed).***

Force & Motion Example

Where are students' current knowledge/ practices relative to a model of how learning progresses?

Level 4: Acceleration (change in speed and/or direction) is proportional to applied net force (which may not be in the direction of motion).	
Level 3: Velocity is proportional to applied net force.*	
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A subset of Levels 2 and 3 represents an* ***alternative conception of force as impetus* *(that a moving object carries a force with it, proportional to its speed).*

Are students experiencing known learning difficulties?

Force & Motion Example

What are students' current models of the relationship between force and motion?

learning progresses?

Level 4: Acceleration (change in speed and/or direction) is proportional to applied net force (which may not be in the direction of motion).
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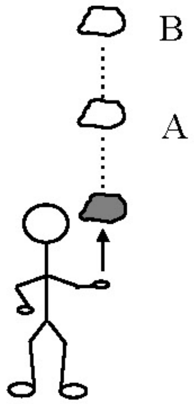
Do students have the impetus conception?

difficulties?

Force & Motion Example

Formative information:

- What are students' current models of the relationship between the force acting on an object and its motion?
- Do students have the impetus conception?

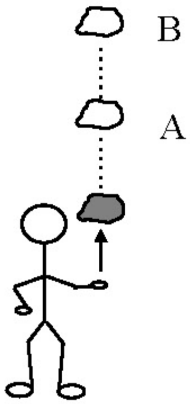


Derek throws a stone straight up into the air. It leaves his hand, goes up through point A, gets as high as point B and then comes back down through A again.

Ignoring air resistance, what force(s) are acting on the stone when it is moving <u>up</u> through point A?

Below, draw the force(s)(acting on the stone. Be sure to label each force.

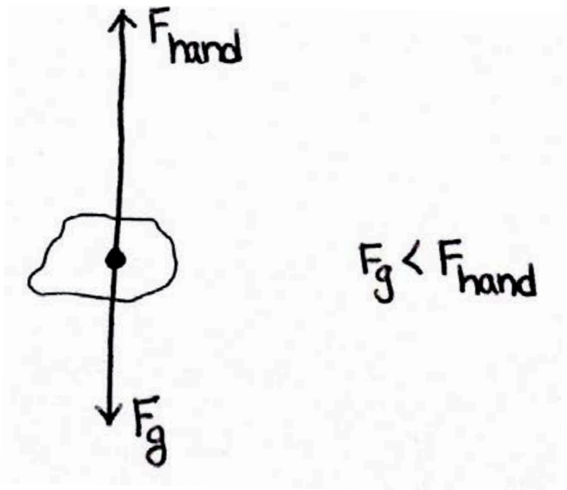
Force & Motion Example: Sample Response



Derek throws a stone straight up into the air. It leaves his hand, goes up through point A, gets as high as point B and then comes back down through A again.

Ignoring air resistance, what force(s) are acting on the stone when it is moving <u>up</u> through point A?

Below, draw the force(s)(acting on the stone. Be sure to label each force.



Force & Motion Example: Sample Response

Level 4: Acceleration (change in speed and/or direction) is proportional to applied net force (which may not be in the direction of motion).

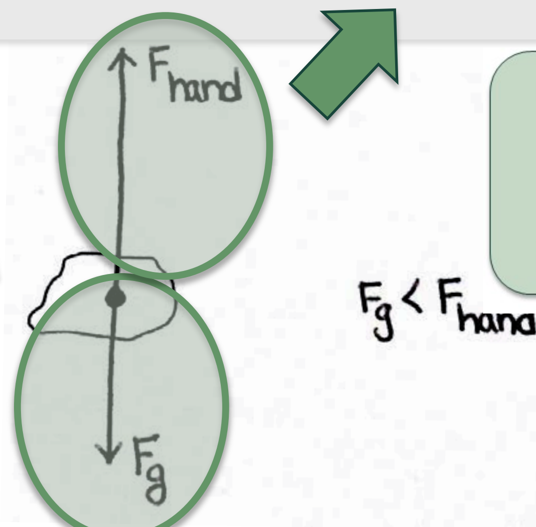
Level 3: Velocity is proportional to applied net force.*

Level 2: Motion is directly associated with applied force.* (Force implies motion; motion implies force; non-motion implies no force; no force implies no motion.)

Level 1: No general relationship between force and motion. Forces and their effects depend on properties of objects such as mass.

A subset of Levels 2 and 3 represents an **alternative conception of force as impetus (that a moving object carries a force with it, proportional to its speed).*

What are students' current models of the relationship between force and motion?



Do students have the impetus conception?

Force & Motion Example: Support for Students

Where are students' current knowledge/ practices relative to a model of how learning progresses? → Students need to take the next step in the model of cognition → Support the next step in the model of cognition

Are students experiencing known learning difficulties? → Students need to overcome the specific learning difficulty → Support students in overcoming the specific learning difficulty

FORMATIVE INFORMATION | **ACTIONABLE FEEDBACK** | **ACTION**

Force & Motion Example: Support for Students

What are students' current models of the relationship between force and motion?

Students need to progress from Level 3 to Level 3

Do students have the impetus conception?

Students need to overcome the impetus conception

Decouple direction of net force from direction of motion.

FORMATIVE INFORMATION

ACTIONABLE FEEDBACK

ACTION

Force and Motion Example: Support for Students

- ACTION:
  - Decouple direction of net force from direction of motion
- Provide feedback to students
  - “Look at your model. If you applied the same net force to a cart, how would it move?”
- Adapt instruction to meet identified learning needs
  - Investigate: Can an object move in a direction that is <u>opposite</u> to the direction of its net force?

Taking a "Learning Progressions Approach"

- What knowledge/practices do you want students to develop?
- How do your most struggling students typically display these before instruction?
- What knowledge/practices/experiences do students bring that help them to learn this topic?
- What difficulties do students experience with this topic?
- What do students' efforts look like as they begin to learn the knowledge/practice? As they learn a bit more?
- What stumbling blocks do students typically encounter as they move from their initial to targeted knowledge/practices?

Thank you!

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