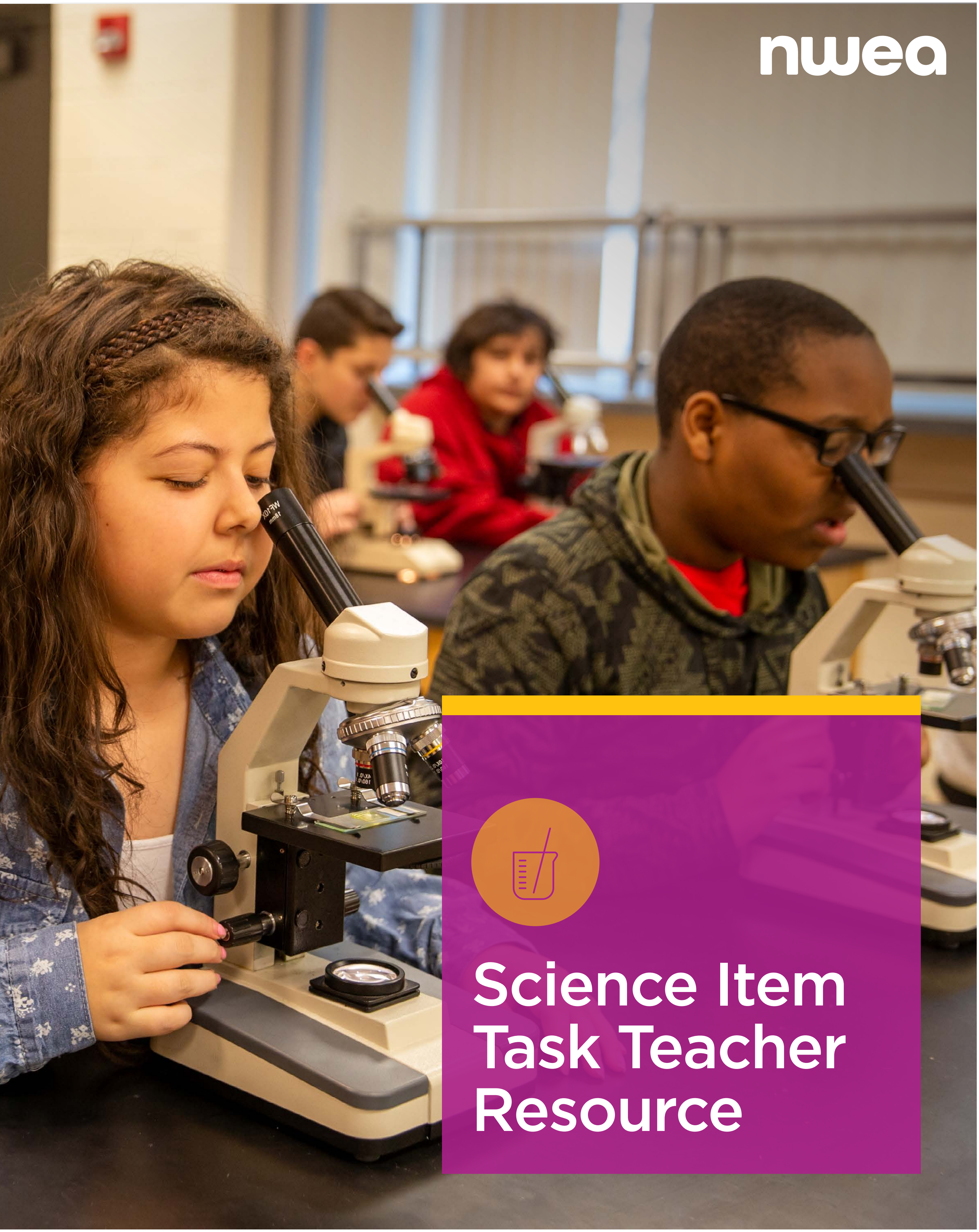


nwea

Science Item Task Teacher Resource

Contents

Purpose

The conceptual shifts of new multidimensional science standards encourage deep changes in teaching, learning, and assessment. NWEA® is excited to partner with educators to spur a national conversation about how to face the challenges presented by these new expectations. This document is for teachers and provides the following:

- a preview of what students will encounter in NWEA assessments and other high-quality assessments for multidimensional science standards in the coming years
- a commentary on how science assessment is interrelated with innovative classroom instruction

Two samples of high-quality sets of questions, or *item sets*, are provided to inform teachers about the direction assessment is moving. The document explains how each item set mirrors strong classroom instruction by requiring multidimensional problem-solving and sense-making within real-world contexts.

This document is *not* a manual for test preparation. Instead, it should encourage teachers to reflect on the classroom experiences that students should have in preparation for this sort of assessment:

- Are classroom experiences fair, equitable, and accessible?
- Will classroom experiences help students succeed in a college or career and as world citizens?
- Are classroom experiences designed to elicit multidimensional reasoning and problem-solving?
- Do classroom experiences engage students in relevant and meaningful contexts that potentially elicit wonder and lifelong learning?

NWEA and MAP Growth Science

NWEA is a research-based, not-for-profit organization that supports students and educators worldwide. For 40 years, NWEA has developed assessments and professional learning offerings for educators to help advance all students along their optimal learning paths.

MAP® Growth™ Science is a computer-adaptive interim assessment that allows educators to track growth in science through the school year and over multiple years. For states with multidimensional standards, MAP Growth Science is primarily composed of stand-alone multidimensional items. NWEA is actively working to build an assessment suite that honors the goals of multidimensional science standards. One step is to develop future assessments that will be largely composed of the type of sequenced item sets previewed in this document. Ultimately, NWEA's long-term vision is to provide assessments that depend less on items or items sets and more on authentic student experiences. Note that the assessment examples in this resource are selected-response items, to reflect the nature of NWEA's instantly scored computer-adaptive assessment. Teachers are encouraged to consider how they might design formative assessment classroom tasks that include open-ended responses.

NWEA's science assessment developers were teachers before they joined the organization. They still have strong relationships within the science education community, and they are always searching for opportunities to learn more from teachers, researchers, and the experts involved in crafting new science standards and curriculum. Through leadership roles and service in science education associations and through work with Achieve's Peer Review Panel, these developers have engaged with teachers across the country and have shared in the growing understanding of the shifts in science education.

Shifts in Science Standards

Most states, even those that have not directly adopted the Next Generation Science Standards (NGSS)*, have adopted (or are in the process of adopting) multidimensional standards that address foundational shifts in science education. Many of these state standards are based to some degree on *A Framework for K–12 Science Education* (National Research Council, 2012). The NGSS are an example of how some states use the framework to develop expectations of three-dimensional (3-D) performance.

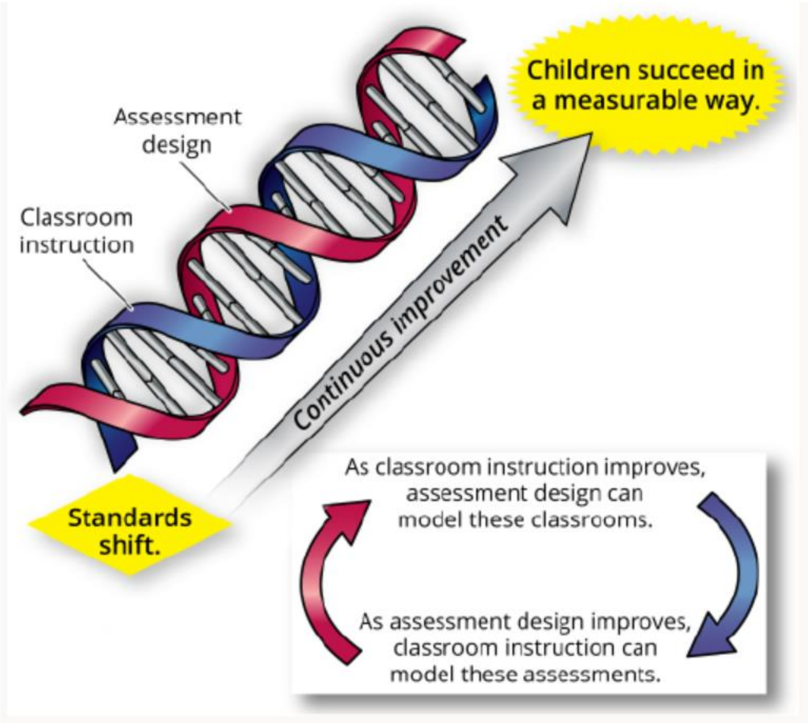
What does that mean for science education today and in the future?

Ideas Emphasized in *A Framework for K–12 Science Education* (NRC, 2012)
Phenomena are key: Phenomena—both natural and designed—are central, driving all instruction and assessment; they are more than "hooks." Making sense of phenomena includes explaining the natural and designed world as well as solving problems using engineering practices and content. Phenomena bring real-word applications to science classrooms.
Science is for everyone: Science instruction should ***not*** be designed to serve **only** future scientists. Equity should be at the forefront of all instructional and assessment design, to prepare ***all*** students for college, careers, and global citizenship.
Three dimensions are interconnected: The three dimensions—disciplinary core ideas (DCIs), science and engineering practices (SEPs), and crosscutting concepts (CCCs)—must be integrated to be effective in sense-making; they cannot be taught or assessed in isolation. They will be combined naturally in a variety of ways to address a particular phenomenon effectively.
Engineering design is essential: Engineering is an integral part of science standards and all science instruction. **Engineering is its own discipline, but it also can, and should, be embedded in every other science discipline.** When this document uses the terms ***phenomena*** and ***sense-making***, it **assumes that** engineering practices and content can and will be used to **solve problems that arise from phenomena**.
Concepts form a coherent progression: Concepts should build on one another. They should not be skipped, nor should they simply be repeated in subsequent years. Fewer concepts are identified in the framework than in many previous standards, but the concepts that are identified are essential content for ***all*** students to learn by the end of high school. This content represents underlying concepts that explain traditional topics.
Standards have connections beyond science: Each science standard includes direct references to related English language arts and math Common Core standards. Educators can provide a more cohesive and meaningful education experience by finding and leveraging natural connections among these content areas.

Relationship between Classroom Experience and Assessment Design

Science classrooms and assessments must both evolve to embody the shifts in science standards. NWEA is still on the road to an ideal science growth assessment, but its science team hopes that their assessment and the most effective science classrooms will mirror one another and continue to inspire one another to grow.

The model below demonstrates how teachers who incorporate multidimensional learning and formative classroom assessment can help students succeed on higher-stakes multidimensional assessments.

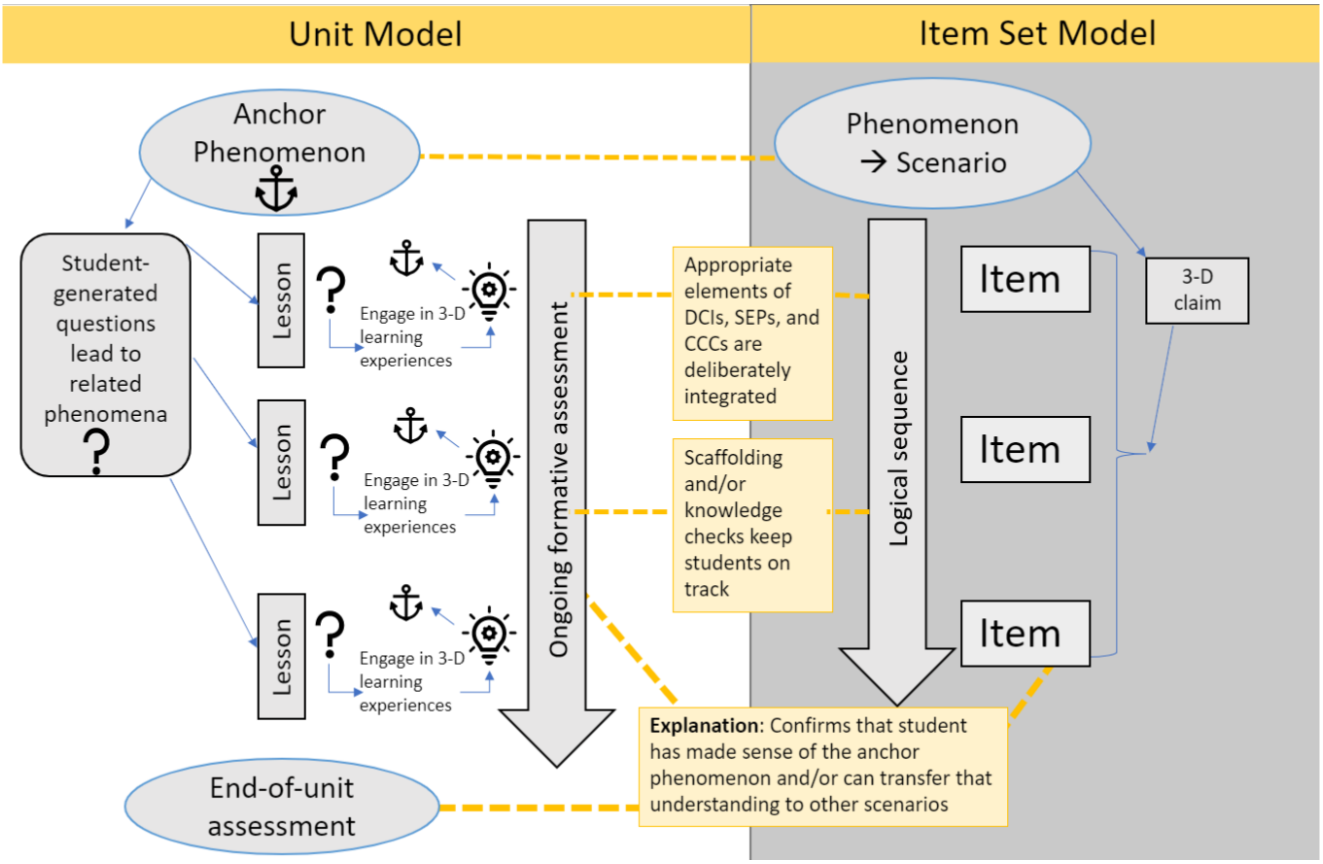


Integration of dimensions
The integration of many different DCIs, SEPs, and CCCs in the classroom should prepare students for the combinations of dimensions that they might encounter in any assessment. Likewise, the presence of cohesive, multidimensional item sets on an assessment should reflect similarly structured activities in the classroom.

Focus on phenomena
Sketching out an item set can overlap with the process of sketching out a phenomenon-based lesson or even an entire unit. Many teachers have had success with a unit model that starts with a very rich anchor phenomenon. As mentioned in the table above, a phenomenon can be focused on sense-making of a natural event and/or solving an engineering design problem. The anchor phenomenon leads to many student-generated questions, each of which can be explored through related phenomena in individual lessons. Each lesson moves students closer to making sense of the anchor phenomenon.

Educators and assessment developers can increase student engagement by *problematizing* a phenomenon. This is when the phenomenon conflicts with expectations, requiring students to figure something out in order to understand what they are observing. For example, students may have learned that an increase in humans in an area is often associated with an increase in negative environmental impacts. If these students encounter a phenomenon that displays a different relationship, such as an increase in human population coupled with positive effects on the environment, the students may be more motivated to make sense of the discrepancy and solve the puzzle.

Modeling a typical unit and assessment design process
This model shows where the unit design process overlaps with item set design.



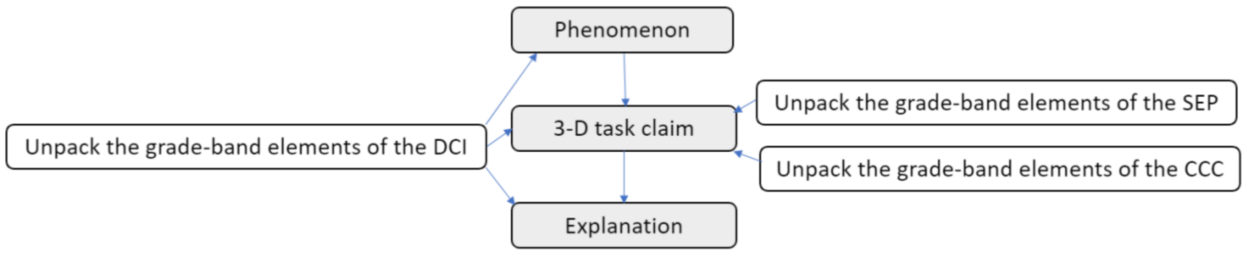
Development Process of an Item Set (General Overview)

The planning and development of an item set can be similar to the planning and development of a lesson or unit of instruction. This section provides a general overview of the process; specific examples will be shown later.

The process includes a review of all appropriate dimensions. Developers begin by identifying one or more DCIs that are most applicable to sense-making of a given phenomenon. They then analyze the DCI elements. Elements are the bulleted statements in the foundation boxes of the standards, also found in the NGSS appendices for each dimension. (See links in the Appendix of this document.) The DCI elements at the targeted grade band are compared to the elements one grade band below and one grade band above. This comparison can be called *unpacking*. It is the process of using the NGSS appendices to set parameters for which aspects of the targeted dimensions will be addressed in the item set.

Once the developers identify the parameters of the DCI, they can begin to define a phenomenon and its scenario. The scenario consists of a depiction of the phenomenon as well as supporting information or data to engage students and prepare them for their task. The developers continue to refine the scenario as they unpack the other dimensions.

In a similar way as the DCIs, developers unpack the SEPs and CCCs. Unpacking the dimensions is essential in pinpointing which grade-appropriate aspects of them will be taught and assessed. After all dimensions for the grade band have been unpacked and after the distinguishing features of the targeted content, practices, and crosscutting concepts have been identified, developers can establish a 3-D claim for the item set. This claim provides a summary of how students should integrate the three dimensions to make sense of the phenomenon. NGSS performance expectations (PEs) are examples of 3-D claims.



The explanation or solution statement describes the scientific explanation or solution for the phenomenon. The statement provides an end point—a target for keeping the items relevant and in a coherent sequence in the set. This is a helpful tool when designing a sequence of activities in a classroom lesson or a sequence of lessons in a unit of instruction. Note that by design some lessons or item sets might not arrive at a complete explanation or solution. Instead, educators may choose to focus on parts of the process that lead toward the explanation or solution. In such activities, it is still important for the educator to define the explanation or solution that students should be working toward.

Cognitive Complexity

The item sets in this document include cognitive complexity ratings based on *A Framework for Evaluating Cognitive Complexity in Science Assessments* (Achieve, 2019). This framework allows educators to consider student engagement in each science dimension separately. The framework also provides rating guidance for science scenarios and for the overall cognitive demand involved in completing a science task or item set.

Items within a set may intentionally have a range of complexity ratings because different items contribute to a set's overall purpose in different ways. While all items in a set should reflect the multidimensional nature of the standards, individual items may foreground one or two dimensions and place less emphasis on the other dimension(s). Providing some item sets with lower complexity levels within an assessment can allow students at all ability levels to demonstrate their science skills and knowledge. For detailed explanations of each rating, please refer to the framework.

Equity and Accessibility Considerations

A primary goal of NWEA is to develop assessments that are fair, equitable, and accessible. To promote equity in item sets, NWEA developers write sets with accessibility for all students in mind while also connecting to students' interests and maintaining alignment to grade-appropriate core ideas, practices, and crosscutting concepts.

In a classroom, potential biases can be addressed and leveled through media and pictures and by sharing stories. In large-scale assessments, however, it is impossible for every scenario to be familiar and relevant to every student. Therefore, NWEA developers carefully review scenarios to confirm that they do not rely on familiarity with specific circumstances. NWEA uses pictures and descriptions to ensure all students have the background information needed to understand each scenario.

Multidimensional science standards encourage more complex, data-rich scenarios than previous science standards have. This complexity often increases cognitive load, reading demand, and visual bias.

To address reading load, simple sentence structure and concise wording can help. Achieve recommends using an appropriate amount of words for the task (“Science Task Screener,” Achieve). Sometimes a rich scenario requires extended text in order to convey essential background information and establish the details necessary to meet sensitivity and fairness criteria. NWEA uses multiple readability measures to ensure grade-appropriate vocabulary. When difficult vocabulary is unavoidable, supports are used in the item sets. NWEA encourages teachers to use the scientific vocabulary found in grade-band dimensions with their students in the classroom.

To address visual bias, auditory bias, and cognitive load, assessment developers continue to collaborate with experts at NWEA, within partner schools, and throughout the wider community. These are challenges developers are aware of and embrace, in order to support students in accessing these item sets.

Jump & Tuck! Grade 3–5 Item Set

Item Set Development Process for "Jump & Tuck!"

The following item set development process can be used by educators to guide the development of classroom assessments, activities, lessons, and units.

Unpacking the DCIs: The design process begins by choosing at least one DCI, one SEP, and one CCC as the focus of the set. The elements of the DCI at the targeted grade band (3–5) are then unpacked by comparing them to the elements one grade band above (6–8) and one grade band below (K–2). Unpacking pinpoints the grade-appropriate content.

DCI: Conservation of Energy and Energy Transfer (PS3.B)			
Grade Band	**K–2**	**3–5**	**6–8**
Elements of the DCI	Sunlight warms Earth's surface.	Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.	When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
Identified Defining Content	Sunlight warms.	Energy is present when there are heat, light, moving objects, and sounds. Collisions transfer energy, causing changes in other energies.	Motion energy changes occur with changes in other energies.

DCI: Relationship Between Energy and Forces (PS3.C)			
Grade Band	**K–2**	**3–5**	**6–8**

Elements of the DCI	Bigger pushes and pulls cause bigger changes in an object's motion or shape.	When objects collide, contact forces transfer energy so as to change the objects' motions.	When two objects interact, each one exerts a force on the other, and these forces can transfer energy between them.
Identified Defining Content	Pushes or pulls change motion or shape.	In collisions, forces change motion and transfer energy.	Objects exert force and transfer energy between each other in collisions.

DCI: Wave Properties (PS4.A)			
Grade Band	**K–2**	**3–5**	**6–8**
Elements of the DCI	Sound can make matter vibrate, and vibrating matter can make sound.	Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach.	A simple wave model has a repeating pattern with a specific wavelength, frequency, and amplitude, and mechanical waves need a medium through which they are transmitted. This model can explain many phenomena including sound and light. Waves can transmit energy.
Identified Defining Content	Vibrations and sound cause each other.	Surface disturbances cause water waves. In deep water, waves and water move in different directions.	Waves transmit energy.

DCI: Optimizing the Design Solution (ETS1.C)			
Grade Band	**K–2**	**3–5**	**6–8**

Elements of the DCI	Because there is always more than one possible solution to a problem, it is useful to compare and test designs.	Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Identified Defining Content	Compare and test designs of solutions.	Test solutions to find which one best meets the criteria and constraints.	Test solutions and modify designs until the optimal solution is found.

Bundling the DCIs: In this set, several physical science DCIs are bundled with an engineering DCI. This bundling is purposeful. As with writing lessons or units, bundling DCIs helps determine whether students understand phenomena at a deeper level.

Developing the Problem and Scenario: Once the parameters of the DCIs are identified, the problem and its scenario are developed. For this item set, the content focuses on a problem that involves a collision between a person or rock and the water, the transfer of energy through water waves, the movement of matter in water waves, and the evaluation of solutions in terms of criteria and constraints. The scenario is set at a swimming pool. The problem is about two boys trying to find a way to move a floating ball away from the end of the diving board by jumping in from the side of the pool. The problem is based on the common misconception that the waves will move the ball to a different location. This problem can be solved and explained using the unpacked DCI elements listed above for grade 3–5.

The item set combines two interrelated ideas that are needed to understand the phenomenon. The DCI Relationship Between Energy and Forces (PS3.C) states in the 3–5 grade band, “When objects collide, contact forces transfer energy so as to change the objects’ motions.” The K–2 band states, “Bigger pushes and pulls cause bigger changes in an object’s motion or shape.” The waves are a result of the collision between the people or rocks with the water. Energy is transferred through the water, causing waves. Consequently, Relationship Between Energy and Forces (PS3.C) was bundled with Wave Properties (PS4.A) for this item set.

The bundling of DCIs also makes apparent that there is a gap the Energy and Matter CCC can fill: why moving waves do not move water (i.e., matter) in the direction of the wave. By looking at waves through the lens of “matter is made of particles,” students can understand how water particles move in a wave and make sense of why the ball does not change locations in the scenario.

Unpacking the SEPs and CCCs: The SEPs and CCCs are unpacked in a similar way as the DCIs, by comparing the elements at the targeted grade band to the elements one grade band above and one grade band below.

The diagram shows the unpacking of one of the main SEPs of the item set.

SEP: Developing and Using Models			
Grade Band	**K–2**	**3–5**	**6–8**
Elements of SEP	Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).	Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.	Develop and/or use a model to predict and/or describe phenomena. Develop a model to describe unobservable mechanisms.
Identified Defining Practice	Use models to show amounts, relationships, scales, and patterns.	Use models to test cause and effect relationships or interactions.	Use a model to show relationships between unobservable mechanisms and observable phenomena.

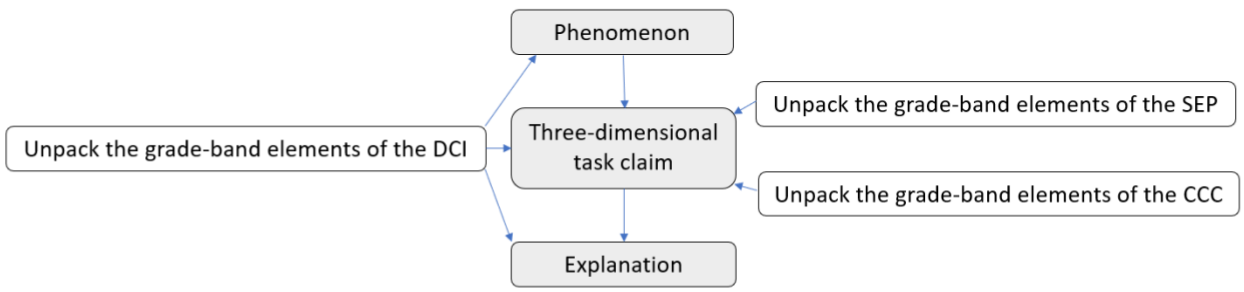
Choosing CCCs: For this item set, the Cause and Effect CCC element of "Cause and effect relationships are routinely identified, tested, and used to explain change" closely overlaps with the Developing and Using Models SEP element of "Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system." Using a closely associated CCC and SEP makes writing the item set, and likely writing lessons, much easier, but it also makes assessing the SEP and CCC more difficult. The SEP and CCC elements are too closely intertwined to assess them separately. Another approach is to include CCCs that are not as closely related to an SEP. In this item set, for example, the Energy and Matter CCC element of "Matter is made of particles" provides a distinctive lens for students to understand the relationship between waves and the motion of matter in them, without overlapping with an SEP.

The diagram shows the unpacking of one of the main CCCs of the item set.

CCC: Energy and Matter			
Grade Band	**K–2**	**3–5**	**6–8**
Elements of CCC	Objects may break into smaller pieces, be put together into larger pieces, or change shapes.	Matter is made of particles.	Matter is conserved because atoms are conserved in physical and chemical processes.

Identified Defining Crosscutting Concept	Objects are made of smaller pieces.	Matter is made of particles.	Matter is made of atoms that are conserved.

Three-Dimensional Task Claim: After the elements for the grade band are identified and unpacked, an overall, three-dimensional (3-D) claim for the item set is determined. This claim provides a summary statement of how students will use the dimensions in the item set. Again, this could also apply to developing a classroom lesson.



3-D Task Claim: Students use models to test cause and effect relationships between the size of an object disturbing the surface of water, the forces of the collisions with the water, and the energy transfer through waves and to test interactions between particles of matter, water, and waves to find the best solution to the problem.

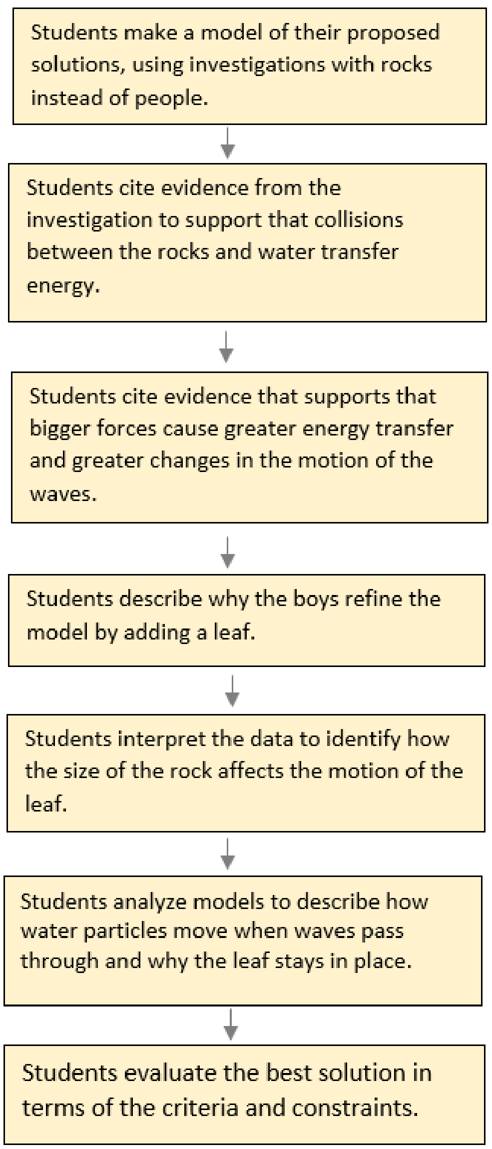
DCI	PS3.B: Conservation of Energy and Energy Transfer	Energy is present when there are heat, light, moving objects, and sounds. Collisions transfer energy, causing changes in other energies.
DCI	PS3.C: Relationship Between Energy and Forces	In collisions, forces change motion and transfer energy.
DCI	PS4.A: Wave Properties	Surface disturbances cause water waves. In deep water, waves and water move in different directions.
DCI	ETS1.C: Optimizing the Design Solution	Test solutions to find which one best meets the criteria and constraints.
SEP	Developing and Using Models	Use models to test cause and effect relationships or interactions.
CCC	Energy and Matter	Matter is made of particles.

What is the Explanation? After the 3-D task claim is developed, an explanation for that claim is written. The explanation describes the solution and its scientific explanation. The explanation is helpful when developing item sets and lessons because it provides an end target for the progression of the item set or lesson.

Explanation: By applying the rock models of the solutions to the actual problem, students should predict that the largest person, the lifeguard, will exert the most force in the collision with the water and transfer the most energy, resulting in the tallest waves, but that the ball will not move away from the diving board. The ball does not move away because the ball, like water and other matter, moves up and down in place as water waves pass by. Consequently, the main criterion of the solution—the ball moves away from the end of the diving board—is not met. The boys should not find a solution under the criteria and constraints that they set.

Coherent Sequence of Items: From the problem and 3-D task claim, a coherent sequence of assessment items can be mapped that allows students to determine the solution. The target for the sequence of items is the explanation.

Diagram of the Item Sequence



The problem of the item set is about two boys trying to find a way to move a floating ball away from the end of the diving board by doing jumps from the side of the pool. They claim that either a large person or small person can move the ball away, since a medium-sized boy cannot.

They cannot test their solutions directly without an adult, so they test using a model. Rocks of different sizes represent people of different sizes jumping into the pool. The boys realize rocks hitting the water are examples of collisions that transfer energy. Using their model, the boys connect the cause (interacting forces) with the effect (energy transfer) and the resulting motion of the waves.

The boys improve the model by adding a leaf to represent the ball. They discover that the size of the rock does not change the location of the leaf. To make sense of this result, they make a model of their observations. Then, they make a model of those observations from the water particle level. From the models, they see their observations can be explained if matter moves up and down in place.

Students apply scientific ideas about how energy transfers away from collisions with water and how matter moves in waves to find the best solution to the problem.

Classroom Connections: Possible Activities that Prepare Students for Multidimensional Assessments

To support learning of PS4.A, consider using classroom activities that capitalize on students' previous experiences with water waves, like in a bath, pool, lake, or ocean. Although students may have experienced water waves, they may not have carefully observed the motion of the water compared to the motion of objects floating on the water.

Here are some ways to explore the motion of water waves and the motion of matter in those waves:

- Use models to explore why old sailing vessels would get stuck at sea when there was no wind, even though the ships were in waves that seemed to push them along.
- Investigate why it is hard to maintain balance and avoid getting pushed over when wading out through breaking waves, but why it is effortless to bob up and down once past those breaking waves. This phenomenon may be relevant only to students near large bodies of water. Not all students may have played in large waves. With the addition of media and the sharing of experiences, more students can come to make sense of the phenomenon of moving against breaking waves.
- Investigate wave phenomena using ripples, or surface waves, in an aquarium. Students can explore how disturbing the surface of still water causes waves. From the sides of the tank, students can observe the changing shape of the surface line and the direction of waves, can mark the amplitude and wavelength, and can attempt to measure how far the waves move an object horizontally.

Equity and Accessibility

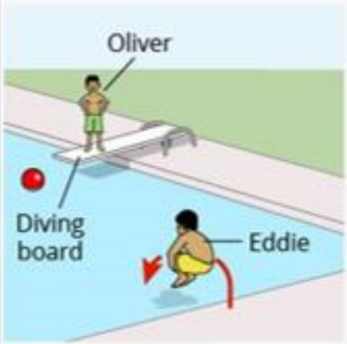
A major component of equity in assessment and instruction is accessibility. The "Jump & Tuck!" item set incorporates several accessibility strategies that have use in the classroom.

Checking for Bias: The scenario of the item set occurs at a swimming pool. Although this location may initially seem to have socioeconomic bias, many students attend free swims at community pools. In the classroom, potential biases can be addressed and leveled through media and pictures, digital or physical simulations, and sharing experiences as described previously in the Classroom Connections section.

Understandable Language: This item set follows NWEA's guidelines of using multiple readability measures to ensure grade-appropriate vocabulary. When difficult vocabulary is necessary, supports are included. In this set, there are pictures, diagrams, and descriptions for terms like *diving board* and *lifeguard*. Students also encounter scientific words in this item set like *cause*, *effect*, *problem*, *solution*, *criteria*, *constraints*, *model*, and *collision* without the aid of the supports described above. NWEA encourages teachers to use the scientific vocabulary found in the grade band's dimensions with their students in the classroom. The data and observations are presented using multiple modalities, including data tables, illustrations, and text descriptions. The sentence structure is simple, and the text is as direct and concrete as possible.

The difficulty with "Jump & Tuck!" was that the scenario must introduce the story line, the problem with its many parameters (e.g., the pool layout, the weather, water conditions), as well as the criteria, the constraints, and the possible solutions. Even using simple language, concise sentences, a picture, and a table, the reading load for the scenario was high for a grade 3–5 item set, as shown below.

Two brothers go to a pool with a grownup. The weather is hot with no wind. The lifeguards are the only other people there. The lifeguards will keep the swimmers safe. The water is not moving. Oliver wants to jump off the diving board for the first time. He is a little scared. A ball is in his way.



Eddie thinks he can move the ball for his brother by jumping into the water. He knows he cannot run at the pool, so he stands on the edge and jumps. He holds his knees to his chest. The splash does not reach the ball, but the waves do. The ball seems to move, but it stays in front of the diving board. Both boys think this is strange. Eddie jumps again. The ball does not move away.

The boys want to move the ball away by jumping into the pool.

They have two possible solutions:

- Solution 1: Oliver jumps. Oliver is smaller than Eddie.
- Solution 2: A grownup jumps. The grownup must be larger than Eddie.

Criteria	Constraints
The ball moves away from the end of the diving board.	No touching the ball
Each person jumps from the same spot where Eddie jumped.	No running
Each person holds both knees when jumping.	

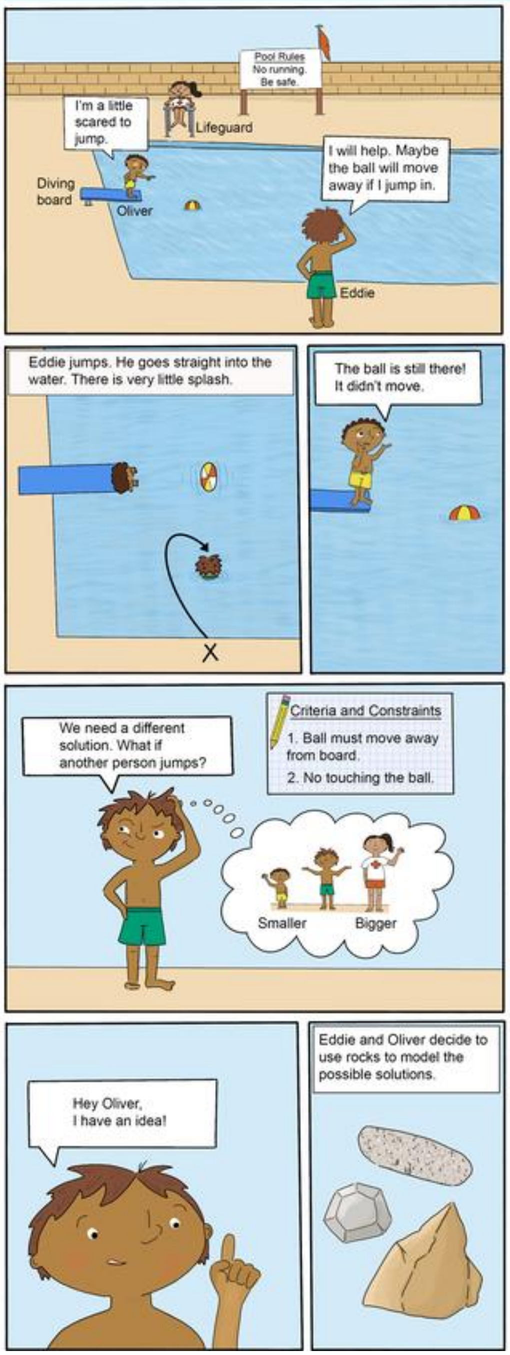
The boys want to test their solutions, but they cannot. The grownup with them does not swim, and the lifeguards are busy. The boys decide to test the solutions by using a model.

To alleviate these issues, one of NWEA's science content specialists created a graphic novel to present the same information in a more grade-appropriate way. As shown in the revised scenario in Item 1 below, the format is more visually appealing and engaging. The graphics provide language support to enhance comprehension while reducing the reading load.

Item-Level Annotations

Item 1

This question has two parts. Use the information to answer Part A and Part B. There may be similar information in other questions.



Part A

For the model, the boys will drop rocks into the water. The lifeguards will let them do this.

Which two properties should the rocks have in order to model both solutions?

- A. different sizes
- B. a rounded shape
- C. different textures
- D. a flat shape like a plate

Part B

Which variable should the boys control in the model?

- A. how they let go of the rocks
- B. what order they drop the rocks in
- C. which side of the pool they drop the rocks from
- D. how warm the water is when they drop the rocks

Key:

Which two properties should the rocks have in order to model both solutions?

- [x] A. different sizes
- [x] B. a rounded shape
- [ ] C. different textures
- [ ] D. a flat shape like a plate

Part B

Which variable should the boys control in the model?

- (●) A. how they let go of the rocks
- ( ) B. what order they drop the rocks in
- ( ) C. which side of the pool they drop the rocks from
- ( ) D. how warm the water is when they drop the rocks

Alignment:

Alignment to grade-band dimensions is based on the results of the unpacking process described earlier. Cognitive complexity ratings are based on *A Framework to Evaluate Cognitive Complexity in Science Assessments*.

Area of Alignment	Alignment	Text	Cognitive Complexity
PE	2-PS1-2	Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.	N/A
PE	3-5-EST1-3	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.	N/A
DCI	PS1.A: Structure and Properties of Matter (K–2)	Different properties are suited to different purposes.	Medium
DCI	ETS1.C Optimizing the Design Solution	Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	Low (The item is in the context of this DCI but is not assessing it.)

SEP	Developing and Using Models	Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.	Medium
SEP	Planning and Carrying Out Investigations	Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.	Medium
CCC	None	N/A	N/A

Item Narrative:

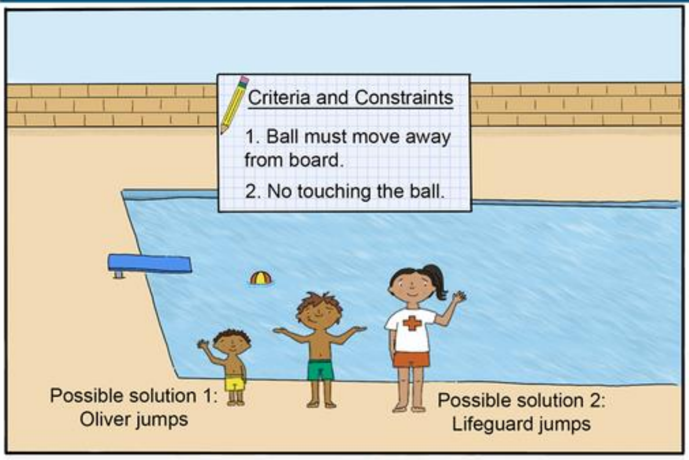
Item 1 is set in the context of the element of the Optimizing the Design Solution DCI (ETS1.C) of "Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints." The boys in the scenario develop a model to test their solutions because the actual solutions cannot be tested without a grownup participant.

In Part A, students use the properties of different rocks to represent Eddie, Oliver, and an adult (different sizes), doing tucked jumps (a rounded shape) into the pool. This item aligns to a DCI element at the lower, K–2 grade band, "Different properties are suited to different purposes." At the 3–5 grade band, students use "measurements of . . . properties . . . to identify materials," which does not apply in this context because the properties of shapes are not easily measurable. Teachers may consider using DCI elements that are below grade-band level in lessons as a review, as precursors to a deeper investigation into elements that are at grade-band level, or as a part of differentiation.

In Part B, students continue to develop the model of their solutions. This item focuses on the element of Planning and Carrying Out Investigations SEP of "using fair tests in which variables are controlled" by determining what variables the boys need to control in each test. This item reflects the thinking students do when setting up an investigation in the classroom.

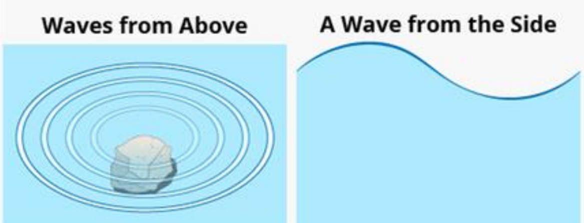
Item 2

Use the information to answer the question. There may be similar information in other questions.



The boys model the solutions with rocks of different sizes. They drop the rocks one at a time into the pool. They wait for the water to stop moving after they drop each rock.

The boys make observations about the waves.



	Small Rock	Medium Rock	Large Rock
Height of the Waves	Short	Medium	Tall
Direction the Waves Move	Toward the sides of the pool	Toward the sides of the pool	Toward the sides of the pool
Distance the Waves Move	Least	In between	Most
Height of Each Wave as It Moves toward the Sides of the Pool	Gets shorter	Gets shorter	Gets shorter

The boys realize that the rocks collide with the water. Collisions transfer energy.

Which two observations support their claim?

- [ ] A. The rocks sink.
- [ ] B. The water looks blue.
- [ ] C. There is a splash sound.
- [ ] D. The surface of the water changes shape.

Key:

The boys realize that the rocks collide with the water.
Collisions transfer energy.

Which two observations support their claim?

- [ ] A. The rocks sink.
- [ ] B. The water looks blue.
- [x] C. There is a splash sound.
- [x] D. The surface of the water changes shape.

Alignment:

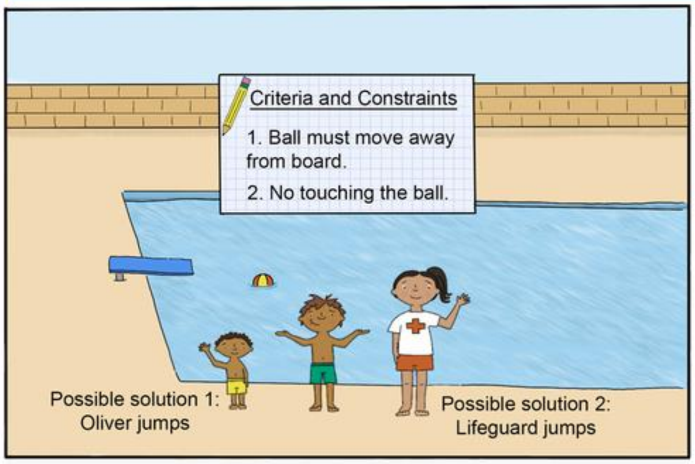
Area of Alignment	Alignment	Text	Cognitive Complexity
PE	4-PS3-3	Ask questions and predict outcomes about the changes in energy that occur when objects collide.	N/A
DCI	PS3.B	Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.	Medium
DCI	PS3.C	When objects collide, contact forces transfer energy so as to change the objects' motions.	Low (The item is in the context of this DCI but is not assessing it.)
SEP	Constructing Explanations and Designing Solutions	Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.	Low
CCC	Patterns	Patterns can be used as evidence to support an explanation.	Low

Item Narrative:
Items 2 and 3 both address misconceptions students have about waves because of an incomplete understanding of the connections between forces, energy transfer, and waves. The boys' solutions to the problem of moving the ball involve the relationship between the size of objects (rocks or people) and the degree of disturbance in the water. The reason the size of the object matters is because of the

interactions of force and energy. This item explores students' understanding of how collisions between the rocks and the water transfer energy to the water. Students cite evidence of that energy transfer—sound energy and motion energy.

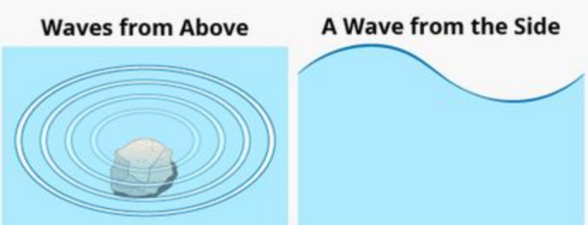
Item 3

This question has two parts. Use the information to answer Part A and Part B. There may be similar information in other questions.



The boys model the solutions with rocks of different sizes. They drop the rocks one at a time into the pool. They wait for the water to stop moving after they drop each rock.

The boys make observations about the waves.



	Small Rock	Medium Rock	Large Rock
Height of the Waves	Short	Medium	Tall
Direction the Waves Move	Toward the sides of the pool	Toward the sides of the pool	Toward the sides of the pool
Distance the Waves Move	Least	In between	Most
Height of Each Wave as It Moves toward the Sides of the Pool	Gets shorter	Gets shorter	Gets shorter

Part A

Which collision involves the most force between a rock and the water?

- A. the collision between the small rock and the water
- B. the collision between the medium rock and the water
- C. the collision between the large rock and the water

Part B

Which two pieces of evidence support the correct answer from Part A?

- A. the height of the waves
- B. the distance the waves move
- C. the direction the waves move
- D. the shape of the waves when looking from above

Key:

Part A

Which collision involves the most force between a rock and the water?

- ◯ A. the collision between the small rock and the water
- ◯ B. the collision between the medium rock and the water
- ◉ C. the collision between the large rock and the water

Part B

Which two pieces of evidence support the correct answer from Part A?

- ☑ A. the height of the waves
- ☑ B. the distance the waves move
- ☐ C. the direction the waves move
- ☐ D. the shape of the waves when looking from above

Alignment:

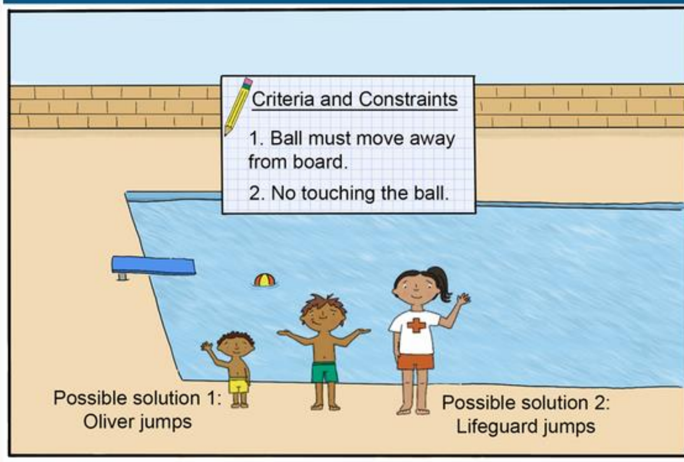
Area of Alignment	Alignment	Text	Cognitive Complexity
PE	4-PS3-3	Ask questions and predict outcomes about the changes in energy that occur when objects collide.	N/A
DCI	PS3.C	When objects collide, contact forces transfer energy so as to change the objects' motions. (3–5) Bigger pushes and pulls cause bigger changes in an object's motion or shape. (K–2)	Medium
SEP	Constructing Explanations and Designing Solutions	Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.	Low
CCC	Cause and Effect	Cause and effect relationships are routinely identified, tested, and used to explain change.	Low

Item Narrative:

In Item 3, students continue to explore how the sizes of the objects, the forces in the collisions, and the effects on the water due to energy transfer relate to one another. In Part A, using the observations provided, students make the claim that bigger objects collide with water with greater force. In Part B, students cite evidence to support that greater forces cause greater changes in the motion of the water waves.

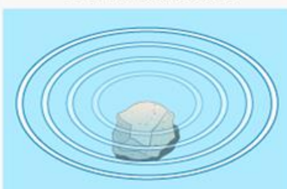
Item 4

Use the information to answer the question. There may be similar information in other questions.



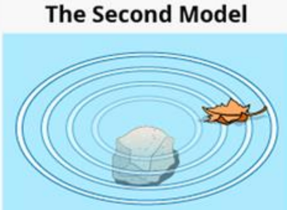
Eddie sees a problem with the model.

The First Model



He adds a leaf to the model to make it better.

The Second Model



How does the leaf make the model better for finding the solution?

- A. The leaf shows how the ball will move.
- B. The leaf shows the direction the waves will move.
- C. The leaf shows where the person will enter the water.
- D. The leaf shows how tall the waves will be as they move away from the rock.

Key:

How does the leaf make the model better for finding the solution?

- (selected) A. The leaf shows how the ball will move.
- B. The leaf shows the direction the waves will move.
- C. The leaf shows where the person will enter the water.
- D. The leaf shows how tall the waves will be as they move away from the rock.

Alignment:

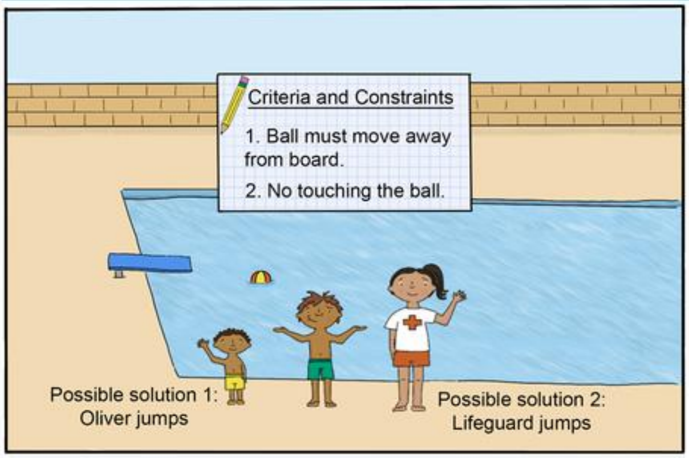
Area of Alignment	Alignment	Text	Cognitive Complexity
PE	4-PS4-1	Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.	N/A
DCI	PS4.A	Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach.	Low (The item is in the context of this DCI but is not assessing it.)
SEP	Developing and Using Models	Identify limitations of models.	Medium
CCC	None	N/A	N/A

Item Narrative:

In Item 4, students continue to develop the model. They identify the reason Eddie refines the model by adding a leaf. The addition of the leaf will help students track the movement of matter, specifically the ball in the scenario. This item focuses on the SEP of "identifying limitations of models" and exemplifies how refining models may be necessary during investigative processes done in the classroom.

Item 5

Use the information to answer the question. There may be similar information in other questions.



The boys model the solutions with rocks of different sizes. They drop the rocks one at a time into the pool. They wait for the water to stop moving after they drop each rock.

The boys make observations about the waves.

The Model with a Leaf

	Small Rock	Medium Rock	Large Rock
Height of the Waves	Short	Medium	Tall
Direction the Waves Move	Toward the sides of the pool	Toward the sides of the pool	Toward the sides of the pool
Distance the Waves Move	Least	In between	Most
Height of Each Wave as It Moves toward the Sides of the Pool	Gets shorter	Gets shorter	Gets shorter

	Small Rock	Medium Rock	Large Rock
Distance the Leaf Moves toward the Side of the Pool	Does not move toward the side of the pool	Does not move toward the side of the pool	Does not move toward the side of the pool

The data puzzles the boys.

How does the size of the rock affect how far the leaf moves toward the side of the pool?

- A. A larger rock causes the leaf to move closer to the side.
- B. A smaller rock causes the leaf to move closer to the side.
- C. The size of the rock does not change the amount the leaf moves toward the side.

Key:

The data puzzles the boys.

How does the size of the rock affect how far the leaf moves toward the side of the pool?

- A. A larger rock causes the leaf to move closer to the side.
- B. A smaller rock causes the leaf to move closer to the side.
- C. The size of the rock does not change the amount the leaf moves toward the side.

Alignment:

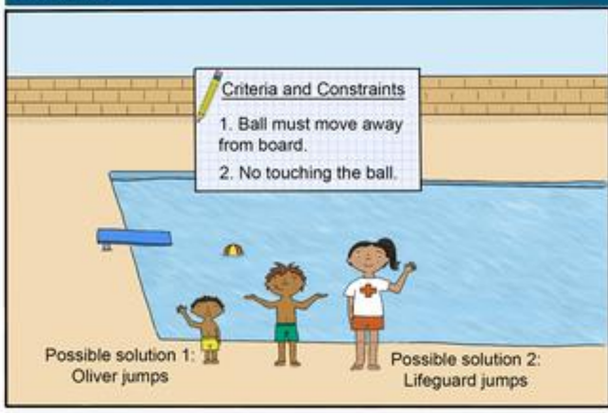
Area of Alignment	Alignment	Text	Cognitive Complexity
PE	4-PS4-1	Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.	N/A
DCI	PS4.A	Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach.	Low (The item is in the context of this DCI but is not assessing it.)
SEP	Developing and Using Models	Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.	Low
CCC	Cause and Effect	Cause and effect relationships are routinely identified, tested, and used to explain change.	Low

Item Narrative:

Item 5 is an item with low cognitive complexity that is purposely designed to focus students' attention on important data. It provides a moment for students to pause and notice a common misconception.

Item 6

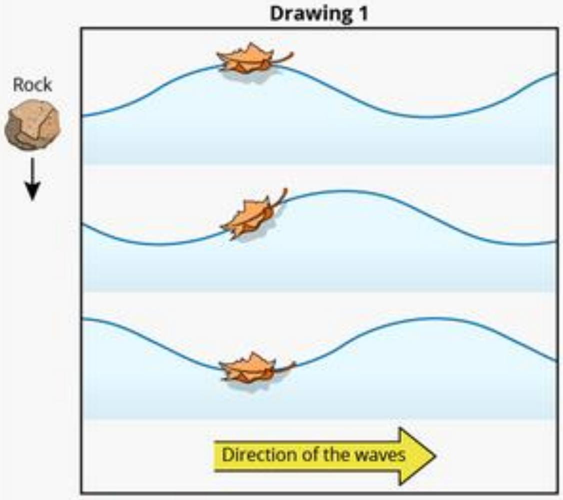
This question has two parts. Use the information to answer Part A and Part B. There may be similar information in other questions.



The boys want to understand why the leaf did not move closer to the side of the pool. They make two drawings.

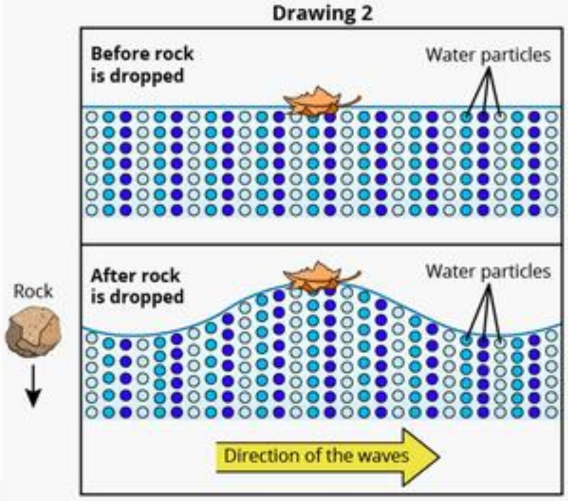
In Drawing 1, they show their observations.

Drawing 1



In Drawing 2, they show the water particles at the surface of the pool. The boys know water is made of particles too small to see.

Drawing 2



Part A

Based on the models, how do water particles most likely move in a wave in a pool?

- A. down toward the bottom
- B. across the top of the water
- C. up and down in the same place
- D. up and down in the direction of the wave

Part B

Why does the leaf most likely NOT move closer to the side of the pool when a wave goes by? Choose two reasons.

- A. because the leaf is too big to move away
- B. because the leaf moves like the water particles move
- C. because the wave moves too fast for the leaf to move with it
- D. because the wave goes past the leaf and water particles without moving them in the direction of the wave

Key:

Part A

Based on the models, how do water particles most likely move in a wave in a pool?

- A. down toward the bottom
- B. across the top of the water
- C. up and down in the same place (selected)
- D. up and down in the direction of the wave

Part B

Why does the leaf most likely NOT move closer to the side of the pool when a wave goes by? Choose two reasons.

- A. because the leaf is too big to move away
- B. because the leaf moves like the water particles move (selected)
- C. because the wave moves too fast for the leaf to move with it
- D. because the wave goes past the leaf and water particles without moving them in the direction of the wave (selected)

Alignment:

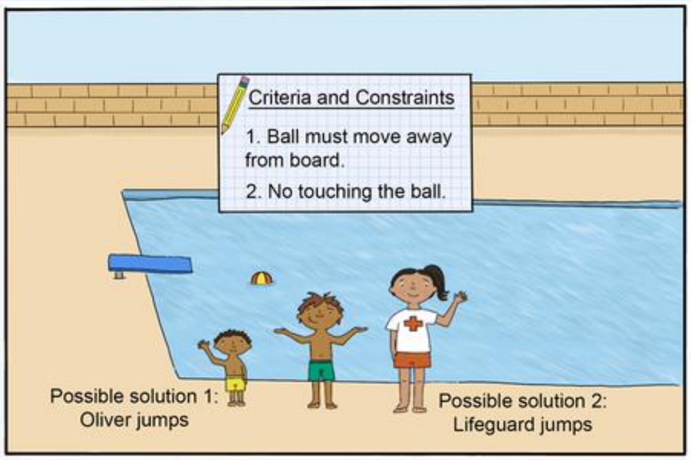
Area of Alignment	Alignment	Text	Cognitive Complexity
PE	4-PS4-1	Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.	N/A
DCI	PS4.A	Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach.	Medium
SEP	Developing and Using Models	Develop a model to describe unobservable mechanisms. (6–8)	Medium
CCC	Energy and Matter	Matter is made of particles.	Low

Item Narrative:

Looking at waves from the CCC lens of the particles of matter helps translate an abstract concept (wave motion through a medium) into a concrete representation: the particle model shows how water particles move up and down in place even though water itself appears to move across the pool with the waves. Students can use the model to relate the observable phenomenon of the leaf not changing locations to the unobservable movement of water particles moving up and down in place.

Item 7

Use the information to answer the question. There may be similar information in other questions.



The boys want to do the tests with people. They ask a grownup lifeguard for help. She is larger than both boys. Oliver will do three jumps. Then, the lifeguard will do three jumps. They will stand on the edge and jump straight into the water. There will not be much splash.

The Model with a Leaf

	Small Rock	Medium Rock	Large Rock
Height of the Waves	Short	Medium	Tall
Direction the Waves Move	Toward the sides of the pool	Toward the sides of the pool	Toward the sides of the pool
Distance the Waves Move	Least	In between	Most
Height of Each Wave as It Moves toward the Sides of the Pool	Gets shorter	Gets shorter	Gets shorter

	Small Rock	Medium Rock	Large Rock
Distance the Leaf Moves toward the Side of the Pool	Does not move toward the side of the pool	Does not move toward the side of the pool	Does not move toward the side of the pool

The boys use the rock model to predict what will happen.

Based on the models with rocks, what will most likely happen when the people do the jumps? Move the answers to the table.

Which jump will make the tallest waves?	
Which jump will have the most force and transfer the most energy?	
Which jump will move the ball toward the side of the pool?	
Which jump will meet all criteria and constraints?	

The lifeguard's jump   Oliver's jump   Neither jump

Key:

Based on the models with rocks, what will <u>most</u> likely happen when the people do the jumps? Move the answers to the table.

Which jump will make the tallest waves?	The lifeguard's jump
Which jump will have the most force and transfer the most energy?	The lifeguard's jump
Which jump will move the ball toward the side of the pool?	Neither jump
Which jump will meet all criteria and constraints?	Neither jump

The lifeguard's jump   Oliver's jump   Neither jump

Alignment:

Note: Because this item requires a synthesis of the entire sequence of problem-solving that came before it, the item has more alignment elements than the previous items.

Area of Alignment	Alignment	Text	Cognitive Complexity
PE	4-PS4-1	Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.	N/A
DCI	PS4.A	Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach.	Medium
DCI	ETS1.C	Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	Medium
DCI	PS3.B	Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.	Medium

DCI	PS3.C	When objects collide, contact forces transfer energy so as to change the objects' motions.	Medium
SEP	Constructing Explanations and Designing Solutions	Apply scientific ideas to solve design problems.	Medium
CCC	Cause and Effect	Cause and effect relationships are routinely identified, tested, and used to explain change.	Medium

Item Narrative:

In the previous item, students figure out that water particles, water, and the leaf move up and down as waves pass by. In this item, they apply those scientific ideas to the ball. Waves will not move the ball to the side of the pool no matter how large the person is who jumps. Note that the conditions stated in the scenario control for confounding factors that could move the ball, such as wind or an excessive splash—these could result in water traveling through the air (not as a wave) to push against the ball and move it. As stated in DCI PS4.A, the ball does not move because the ball, like the water, "goes up and down in place" and not "in the direction of the wave." Consequently, the ball will not move away from the diving board by people doing tucked jumps, so none of these solutions meets the main criterion.

This final item culminates in arguably the most important part of the investigative process—the explanation behind the outcomes. The item brings everything together, and students reach the target established in the explanation during the development process.

Holistic Cognitive Complexity Analysis

The holistic cognitive complexity rating for the item set is based on *A Framework to Evaluate Cognitive Complexity in Science Assessments*, found here: *A Framework to Evaluate Cognitive Complexity in Science Assessments*.

Rating: Low-Guided Integration (High Guidance)

Scenario: In the scenario, students are introduced to a simple and potentially unique problem of moving a ball using waves in a pool. The problem may or may not be immediately explainable by students recalling the DCI, as many students have misconceptions about how waves appear to move water in their direction when they actually only move water particles up and down. Multiple modalities convey data for students to interpret, although that interpretation is guided.

SEP: Emphasis is on using the Developing and Using Models SEP to test the solutions to the problem. Students represent the variables to be tested and apply the results to evaluating the solutions. While the set is three dimensional, this SEP is heavily foregrounded.

DCI: To determine that none of the solutions is viable based on the criteria and constraints (ETS1.C), students are required to use some sense-making as they apply the science content of contact forces transferring energy in collisions (PS3.C) and wave movement compared to water movement (PS4.A) to this particular problem.

CCC: Use of the Cause and Effect CCC is implicitly guided as questions ask students to apply cause and effect relationships in the data to support and scientifically explain their choice of solutions. However, for the most part, the terms *cause* and *effect* are not specifically stated. The Energy and Matter CCC is implicitly used to target specific understanding of how water particles move in waves.

Why “Jump & Tuck!” is an Exemplar

“Jump & Tuck!” Provides an Engaging Scenario

The “Jump & Tuck!” item set showcases a problem encountered during a fun day at the pool. Students may connect their own life experiences to the puzzling incongruity of waves not carrying floating objects with them. This personal connection can elicit interest and motivate problem-solving. The misconceptions that students—as well as adults—have about this content may add to the puzzling nature of the problem.

“Jump & Tuck!” Explores the Use of Models in Problem-Solving

The item set illustrates how models can be helpful in problem-solving when an actual solution cannot be tested. In this case, there is no grownup to participate in the boys’ tests. The boys resort to representing people of different sizes entering the water by using rocks of different sizes. In this item set, students do not learn the results from the smaller boy and the grownup lifeguard jumping into the pool—the students must instead rely on the outcomes from the model.

“Jump & Tuck!” Provides Explicit Cues and a Scaffolded Approach

As an interim growth measure, MAP Growth must assess all students at all ability levels. An item set like “Jump & Tuck!” embeds scaffolding, as classroom lessons do, to guide students through the problem-solving process. It allows them to show what they know and can do with the practices of science and engineering, crosscutting concepts, and disciplinary core ideas.

“Jump & Tuck!” Uses Dimensions Not Specified by the Standard

The “Jump & Tuck!” item set demonstrates how teachers do not need to be constrained by the dimensions specified by multidimensional standards when teaching and assessing science students. This item set deviates from Performance Expectation (PE) 4-PS4-1 by using different CCCs and several SEPs and by adding an ETS DCI. The item set also shows how using dimensions above or below grade-band level may be an appropriate and seamless addition to students’ problem-solving or sense-making.

“Jump & Tuck!” Bundles DCIs and Allows Students to Engage with the Problem More Deeply

The “Jump & Tuck!” item set bundles several physical science DCIs with an engineering DCI. By bundling DCIs, students engage with phenomenon deeply, connecting related concepts for a comprehensive understanding that helps dispel common misconceptions.

Grade 6–8 Item Set: Mayfly Mayhem

Item Set Development Process for "Mayfly Mayhem"

The following item set development process can be used by educators to guide the development of classroom assessments, activities, lessons, and units.

Unpacking the Dimensions

The design process begins by choosing at least one DCI, one SEP, and one CCC as the focus of the set. Each dimension is then examined to identify defining characteristics and progressions across grade levels and to ensure that each item elicits the target thought process from students. The following table shows the grade-band breakdown of the focus DCI, SEP, and CCC for the "Mayfly Mayhem" set. The element for the 6–8 grade band is the focus for each dimension.

DCI: Human Impacts on Earth Systems (ESS3.C)			
Grade Band	**3–5**	**6–8**	**9–12**
Elements of the DCI	Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.	Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.	Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.
Identified Defining Content	Human activities affect the environment, but people can do something about it.	Increased consumption has negative effects, but technology can help.	Technology can limit impacts in two main ways.

SEP: Asking Questions and Defining Problems			
Grade Band	**3–5**	**6–8**	**9–12**
Elements of the SEP	Ask questions that can be investigated based on patterns such as cause and effect relationships.	Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.	Same as 6–8 language

Identified Defining Content	Ask initial questions and predict outcomes that follow expected patterns.	Ask clarifying questions based on observations or outcomes that do not follow expected patterns.	Same as 6–8 language

CCC: Stability and Change			
Grade Band	**3–5**	**6–8**	**9–12**
Elements of the CCC	Change is measured in terms of differences over time and may occur at different rates.	Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales.	Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
Identified Defining Content	Change happens over time and at different rates.	Explaining stability and change requires looking at change over time and at interactions at different scales.	Change can be quantified and modeled, and it can be irreversible.

3-D Task Claim

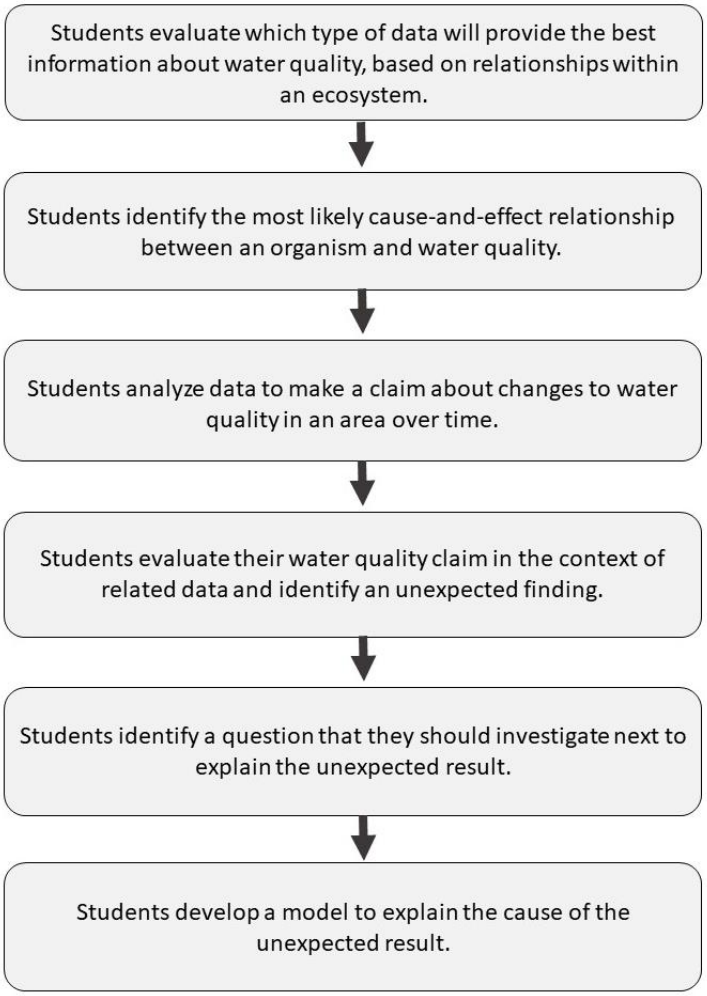
The 3-D claim for “Mayfly Mayhem” is:

> Students ask questions about changes over time related to human activities and consumption of natural resources to explain unexpected results within a natural or designed system.

This claim references the focus DCI, SEP, and CCC of the task in the following table.

DCI	ESS3.C: Human Impacts on Earth Systems	Increased consumption has negative effects, but technology can help.
SEP	Asking Questions and Defining Problems	Ask clarifying questions based on observations or outcomes that do not follow expected patterns.
CCC	Stability and Change	Explaining stability and change requires looking at change over time and at interactions at different scales.

Coherent Sequence of Items



In this set, students navigate the process of evaluating water quality changes in an area: from identifying appropriate data, to interpreting the data, and finally to asking questions to help explain the results. Students begin by determining a way to evaluate water quality over time using a bioindicator. Students make a claim about water quality changes over time in the area using data about mayflies. Then, students start to explain this change using related data but discover something unexpected—the water quality has improved during a time in which resource use and human population has increased. This finding should be surprising to students, based on their science content knowledge. To explain this result, students must use their content knowledge further to determine that they must investigate how advances in technology have changed the environmental impact of human activities. Finally, students use their understanding to develop a model that explains the cause of the unexpected result.

Classroom Connections: Possible Activities That Prepare Students for Multidimensional Assessments

For this DCI, consider classroom activities that contrast instances in which the expected negative environmental impacts occurred with examples in which increased consumption of natural resources did not result in negative impacts. This contrast helps illustrate a discrepancy between what normally happens (negative impacts) and what *can* happen (mitigation of negative impacts), and it has the potential for some very rich phenomena. Consider also how other DCIs can support understanding of ESS3.C. For example, LS2.A (Interdependent Relationships in Ecosystems) and LS2.C (Ecosystem Dynamics, Functioning, and Resilience) offer opportunities to deepen students' understanding about why human activities affect the environment. Examine ways in which the relationship between population growth, consumption, and environmental impacts could be investigated. For example:

- Compare per capita resource use in a suburban setting to that in an urban setting or in an eco-community that uses green engineering (e.g., LEED certification for a neighborhood development). How can students translate lessons from the urban setting and the eco-community to reduce the impact of the suburban setting?

- Design a future Mars colony constrained by availability of a variety of natural resources. What systems need to be designed to support a given population? If that population increases, what changes need to happen to avoid negative impacts on the environment in the colony? How could people monitor the colony environment, and what data would that require?

Equity and Accessibility

A major component of equity in assessment and instruction is accessibility. The “Mayfly Mayhem” item set incorporates several strategies that are applicable to the classroom.

Checking for Bias: “Mayfly Mayhem” avoids bias that could result from specific knowledge about agricultural practices by closely adhering to the DCI and focusing on the *general* ways in which negative environmental impacts are typically addressed. An item set focused on *specific* farming practices could potentially exhibit a regional bias that favors students with more exposure to agricultural practices. In addition, critical terms are defined for students to provide language support and limit the role of prior knowledge.

Providing Scaffolding: “Mayfly Mayhem” incorporates items to scaffold student thinking toward particularly important or challenging targets. For example, Item 2 requires students to identify the relationship they should expect to see between an organism and water quality before the students need to apply that relationship in Item 3. Item 3 leads students toward the crucial discovery that water quality improved during the target time period. Students who do not notice this trend are less likely to be able to engage effectively with the remainder of the set, so it is important to utilize supports for that specific component.

Item-Level Annotations

Item 1

Use the information to answer the question. There may be similar information in other questions.

Maya likes to swim in a lake. Sometimes she cannot swim because the water is too polluted. Maya wonders why the water quality changes from year to year. She wants to track the water quality in the lake so she can predict when it is safe to go swimming.

Photo Credit: Paul Cole. creativecommons.org/licenses/by/2.0

Maya finds a lot of data about the water quality in the lake, but the information is confusing. There is information about chemicals and temperature. She doesn't know how these relate to water quality. She wants a simpler way to estimate water quality.

Which question will best help Maya estimate water quality in the area?

- A. How many total plants and animals live in the lake?
- B. How many activities do people want to do using the water in the lake?
- C. How does the speed of the water in the lake change throughout the year?
- D. How has the population of a plant or animal that lives in the lake changed over time?

Key

Which question will best help Maya estimate water quality in the area?

- A. How many total plants and animals live in the lake?
- B. How many activities do people want to do using the water in the lake?
- C. How does the speed of the water in the lake change throughout the year?
- ◉ D. How has the population of a plant or animal that lives in the lake changed over time?

Item-Level Alignment

Area of Alignment	Alignment	Text	Cognitive Complexity
PE	MS-LS2-1	Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.	N/A
DCI	LS2.A (6–8)	Organisms and populations are dependent on their environmental interactions both with other	Medium

		living things and with nonliving factors, any of which can limit their growth.	
SEP	Asking Questions and Defining Problems (6–8)	Ask questions to identify and clarify evidence of an argument.	Low
CCC	Stability and Change (6–8)	Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales.	Low

Item Narrative

In this item, students deal with the real problem that some data require more background knowledge to understand than other data do. Water quality is a complicated combination of factors that can be easier to understand through a proxy, like an indicator species. In this item, students must evaluate the possible data options to determine which data will be most closely related to water quality. Through their DCI knowledge, students should understand that organisms in an area depend on the nonliving factors within that ecosystem, including water quality. Students also must recognize that the change to a single population of organisms over time will likely provide more useful information than the total number of organisms at a single point in time will reveal. By completing this item, students should have identified that examining changes to the population of an aquatic organism may be a possible way to estimate water quality. While this conclusion oversimplifies the selection of an appropriate organism to study, it ensures that students understand why the remainder of the set refers to the population of mayflies.

Item 2

This question has two parts. Use the information to answer Part A and Part B. There may be similar information in other questions.

Maya likes to swim in a lake. Sometimes she cannot swim because the water is too polluted. Maya wonders why the water quality changes from year to year. She wants to track the water quality in the lake so she can predict when it is safe to go swimming.

Photo Credit: Paul Cole, creativecommons.org/licenses/by/2.0

Maya decides to study the population of an animal that lives in and depends on the water in the lake. She does not know which animal to choose yet, but for now she calls it Animal X.

Part A

Which relationship will Maya most likely observe between water quality and Animal X?

- A. Better water quality causes an increase in the number of Animal X.
- B. Better water quality causes a decrease in the number of Animal X.
- C. Better water quality causes no change in the number of Animal X.

Part B

Which reasoning supports the correct answer from Part A?

- A. Living things use clean water as a resource.
- B. Many factors affect the quality of the water.
- C. Water is a nonliving part of the environment.

Key

Part A

Which relationship will Maya most likely observe between water quality and Animal X?

- (selected) A. Better water quality causes an increase in the number of Animal X.
- B. Better water quality causes a decrease in the number of Animal X.
- C. Better water quality causes no change in the number of Animal X.

Part B

Which reasoning supports the correct answer from Part A?

- (selected) A. Living things use clean water as a resource.
- B. Many factors affect the quality of the water.
- C. Water is a nonliving part of the environment.

Item-Level Alignment

Area of Alignment	Alignment	Text	Cognitive Complexity

PE	MS-LS2-1	Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.	N/A
DCI	LS2.A (6–8)	Organisms and populations are dependent on their environmental interactions both with other living things and with nonliving factors, any of which can limit their growth.	Medium
SEP	Constructing Explanations and Designing Solutions (6–8)	Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.	Low
CCC	Cause and Effect (6–8)	Cause and effect relationships may be used to predict phenomena in natural or designed systems.	Medium

Item Narrative

This item progresses from the first item by assuming that students know that people can use the relationship between organisms and organisms' nonliving environment to understand changes within that environment. Now students must go one step further to specify the expected relationship between a population of organisms and a given resource—in this case, clean water. In this item, students must recognize how water quality is likely to affect an organism in the water (higher-quality water causes a larger population). This combines DCI, SEP, and CCC knowledge to scaffold students toward the relationship they will use to evaluate water quality in the rest of the set.

Item 3

This question has two parts. Use the information to answer Part A and Part B. There may be similar information in other questions.

Maya likes to swim in a lake. Sometimes she cannot swim because the water is too polluted. Maya wonders why the water quality changes from year to year. She wants to track the water quality in the lake so she can predict when it is safe to go swimming.

Maya decides to use the population of an insect called a mayfly to estimate water quality in the lake. Mayflies grow in the water during an early stage of their life cycle. Maya learns that the population of mayflies in an area becomes more dense when water quality improves.

Photo Credit: gailhampshire, creativecommons.org/licenses/by/2.0

Mayfly Population Density

Year	1935	1945	1955	1965	1975	1985	1995	2000
Average Mayfly Population Density (flies /m^2)	300–500; 1,000 in some places	300–500; 1,000 in some places	About 0	About 0	About 0	About 0	30	400; 1,000 in some places

Source: Great Lakes Fishery Commission; Ohio Sea Grant

Words to Know

Mayfly Population Density the number of mayflies in a specific area

Part A

Which claim about the overall trend in water quality during the 1990s does the mayfly data best support?

- A. The water quality improved.
- B. The water quality worsened.
- C. The water quality stayed the same.

Part B

Which pattern in the mayfly population density best supports the correct answer from Part A?

- A. The population density remained about 0 from 1955 to 1985.
- B. The population density increased from about 0 in 1985 to 400 in 2000.
- C. The population density increased most rapidly between 1995 and 2000.
- D. The population density decreased significantly between 1945 and 1955.
- E. The population density was around 1,000 in some places in both 1935 and 2000.

Key

Part A

Which claim about the overall trend in water quality during the 1990s does the mayfly data best support?

- (●) A. The water quality improved.
- ( ) B. The water quality worsened.
- ( ) C. The water quality stayed the same.

Part B

Which pattern in the mayfly population density best supports the correct answer from Part A?

- ( ) A. The population density remained about 0 from 1955 to 1985.
- (●) B. The population density increased from about 0 in 1985 to 400 in 2000.
- ( ) C. The population density increased most rapidly between 1995 and 2000.
- ( ) D. The population density decreased significantly between 1945 and 1955.
- ( ) E. The population density was around 1,000 in some places in both 1935 and 2000.

Item-Level Alignment

Area of Alignment	Alignment	Text	Cognitive Complexity
PE	MS-ESS3-4	Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	N/A
DCI	ESS3.C (6–8)	Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.	Low; DCI provides item context but is not directly assessed.
SEP	Constructing Explanations and Designing Solutions (6–8)	Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena.	Medium
CCC	Patterns (6–8)	Patterns in rates of change and other numerical relationships can provide information about natural and human-designed systems.	Medium

Item Narrative

This item guides students to recognize that the water quality for the area improved during the targeted time period. This is a more heavily scaffolded item because it is essential for students to recognize the change in water quality to evaluate the rest of the item set effectively. The item is multidimensional, although the cognitive complexity ratings for each dimension are low. This is appropriate and intentional, given the purpose of the item as a scaffold for student thinking. Even in this scaffolded item, students must analyze data accurately, identify relevant patterns, and explicitly connect the key data to their claim. In addition, students use their CCC knowledge to make an informed inference about the specified time period (the 1990s) rather than to perform a direct translation of data. This reflects real-world science because data are often not available for the exact time in question, but patterns can be inferred by looking at data for surrounding time periods.

Item 4

This question has two parts. Use the information to answer Part A and Part B. There may be similar information in other questions.

Maya likes to swim in a lake. Sometimes she cannot swim because the water is too polluted. Maya wonders why the water quality changes from year to year. She wants to track the water quality in the lake so she can predict when it is safe to go swimming.

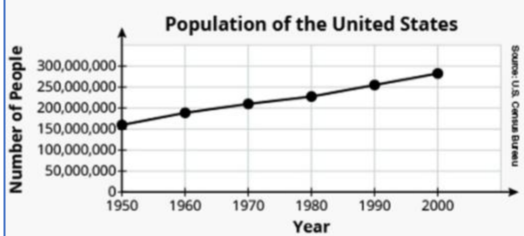
Maya decides to use the population of an insect called a mayfly to estimate water quality for the lake. Mayflies grow in the water during an early stage of their life cycle. Maya learns that the population of mayflies in an area becomes more dense when water quality improves.

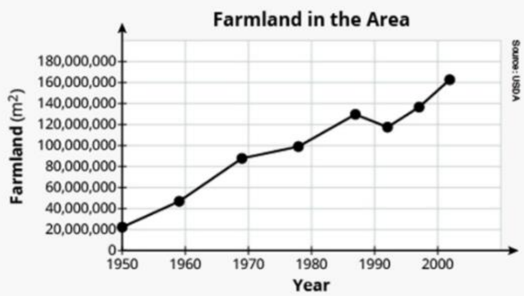
Mayfly Population Density

Year	1935	1945	1955	1965	1975	1985	1995	2000
Average Mayfly Population Density (flies /m^2)	300–500; 1,000 in some places	300–500; 1,000 in some places	About 0	About 0	About 0	About 0	30	400; 1,000 in some places

Source: Great Lakes Fishery Commission; Ohio Sea Grant

There are many large farms near the lake. The farms grow food for people across the United States. Storm water carries fertilizers and pesticides from the farms into the lake. Maya wonders how farming might affect the lake. She finds more data to analyze with the mayfly data.





Part A

Maya reviewed all the data. The data surprised her.

Based on knowledge of relationships between human populations and the environment, what is unexpected about the data?

- A. The rate of growth for human population and farmland was fastest from 1990 to 2000.
- B. The amount of farmland increased rapidly during a time when human population showed rapid growth.
- C. The mayfly population density increased during a time when human population and resource use increased.
- D. The rate of growth for the mayfly population was slower from 1985 to 1995 but increased more quickly from 1995 to 2000.

Part B

Which question should Maya investigate next to best explain the data?

- A. How has the number of farmworkers changed over time?
- B. How will natural cycles affect water quality in the next 1,000 years?
- C. How much food can people produce without affecting the water quality?
- D. How does the importance of having clean water compare to the need to produce enough food for people?
- E. How do the water quality impacts of newer farming methods compare to the impacts of older farming methods?

Key

Part A
Maya reviewed all the data. The data surprised her.

Based on knowledge of relationships between human populations and the environment, what is unexpected about the data?

- ○ A. The rate of growth for human population and farmland was fastest from 1990 to 2000.
- ○ B. The amount of farmland increased rapidly during a time when human population showed rapid growth.
- ● C. The mayfly population density increased during a time when human population and resource use increased.
- ○ D. The rate of growth for the mayfly population was slower from 1985 to 1995 but increased more quickly from 1995 to 2000.

Part B
Which question should Maya investigate next to best explain the data?

- ○ A. How has the number of farmworkers changed over time?
- ○ B. How will natural cycles affect water quality in the next 1,000 years?
- ○ C. How much food can people produce without affecting the water quality?
- ○ D. How does the importance of having clean water compare to the need to produce enough food for people?
- ● E. How do the water quality impacts of newer farming methods compare to the impacts of older farming methods?

Item-Level Alignment

Area of Alignment	Alignment	Text	Cognitive Complexity
PE	MS-ESS3-4	Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	N/A
DCI	ESS3.C (6–8)	Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.	Medium
SEP	Asking Questions and Defining Problems (6–8)	Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.	Medium
CCC	Stability and Change (6–8)	Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales.	Medium

Item Narrative

In this item, students must engage and integrate their DCI knowledge with the SEP and the CCC. It is not enough to understand in isolation any one of the dimensions assessed in this item; students must use the dimensions together in order to evaluate the questions. Students must be able to analyze and interpret data to identify trends and patterns, use content knowledge to understand when those patterns are surprising, and combine content knowledge with a general understanding of why systems change and what information is relevant in this scenario. For example, students may know that natural systems change over time, but they must also understand what time scale is relevant to eliminate answer choice option B in Part B. Students must also distinguish between questions that are testable and questions that are not. This incorporates an additional layer of SEP knowledge from the 3–5 grade band “Asking Questions” practice. As discussed in the introduction to the set, students must demonstrate understanding of the DCI and are not assessed on prior knowledge of a specific agricultural technology.

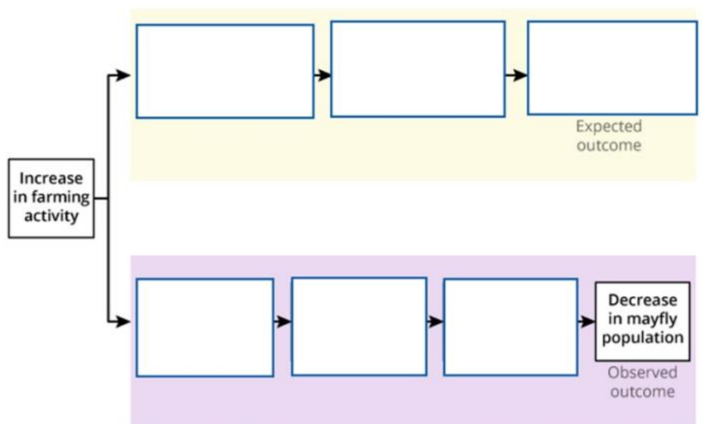
Item 5

Use the information to answer the question. There may be similar information in other questions.

Maya likes to swim in a lake. Sometimes she cannot swim because the water is too polluted. Maya wonders why the water quality changes from year to year. She wants to track the water quality in the lake so she can predict when it is safe to go swimming.

The increase in the mayfly population during a time in which farming also increased surprises Maya. She researches changes to farming methods to explain this pattern. She wants to make a model to show her explanation.

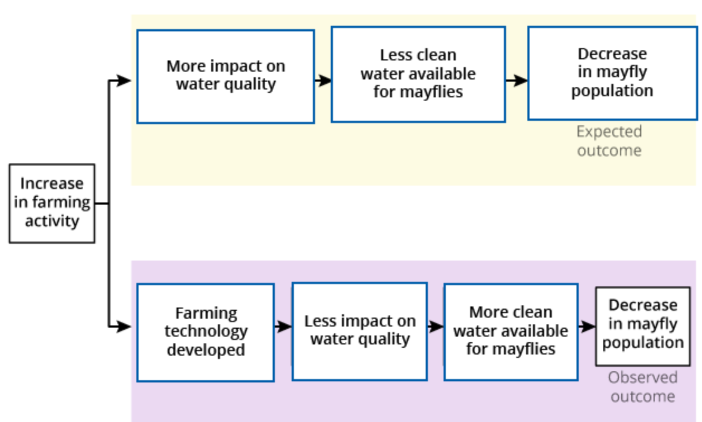
How can Maya model the causes of the unexpected relationship between farming activity and mayflies? Move one change to each empty box to complete the model.



More impact on water quality | **Less impact on water quality** | **More clean water available for mayflies** | **Less clean water available for mayflies** | **Decrease in mayfly population** | **Farming technology developed**

Key

How can Maya model the causes of the unexpected relationship between farming activity and mayflies? Move one change to each empty box to complete the model.



Item-Level Alignment

Area of Alignment	Alignment	Text	Cognitive Complexity
PE	MS-LS2-1	Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.	N/A
DCI	LS2.A (6–8)	Organisms and populations are dependent on their environmental interactions both with other living things and with nonliving factors, any of which can limit their growth.	Low
	ESS3.C (6–8)	Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.	Low
SEP	Developing and Using Models (6–8)	Develop a model to predict and/or describe phenomena.	Medium
CCC	Cause and Effect (6–8)	Cause and effect relationships may be used to predict phenomena in natural or designed systems.	Medium

Item Narrative

In the final item of the set, students combine their understanding that organisms rely on the nonliving components of an ecosystem with their understanding of how human activity typically affects the environment and the analysis of the given scenario. Students must develop a model to show the chain of cause-and-effect relationships expected in the given scenario compared to the relationships that are likely happening based on the observations from the data. This item gives students an opportunity to compose a full explanation of the unexpected result in the form of a model, combining DCI, SEP, and CCC knowledge.

Holistic Cognitive Complexity Analysis

The holistic cognitive complexity rating for the item set is based on "The Framework to Evaluate Cognitive Complexity" found here: Cognitive Complexity Framework.

Rating: high-guided integration (low guidance) with elements of low-guided integration (high guidance)

This set employs an engaging phenomenon (changes to water quality in a local lake) through an authentic lens (the complexity of water quality and the need for a simpler measure). Students must use all three dimensions to explain changes in the data. The set combines cognitive complexity levels to scaffold students toward success in lessons and assessments that involve more complex activities.

SEP: Students must use multiple SEPs throughout the set to engage fully with the phenomenon, a characteristic of high-guided integration. For example, students need to analyze and interpret data to identify patterns in the water quality data. Then they need to apply their findings from the data to ask relevant questions that will further explain the identified patterns. However, in some items, the use of the SEP is more scaffolded—a characteristic of low-guided integration.

DCI: Students must combine DCI knowledge from Life Science and Earth Science to address the phenomenon fully. While students may have examined related scenarios in the classroom, this specific phenomenon is likely to be new to most students. These are characteristics of high-guided integration.

CCC: The CCCs are involved in sense-making of the phenomenon but are not explicitly and deeply addressed in the items. For example, students need to understand cause-and-effect relationships to identify the best proxy for water quality, but the items do not probe the way that students employ cause and effect to determine the answer.

Why “Mayfly Mayhem” Is an Exemplar

“Mayfly Mayhem” Uses a Challenging SEP in an Unusual Way

“Mayfly Mayhem” explores an unexpected finding from a data set. This series of items works toward “Asking Questions and Defining Problems” as one of the culminating Science and Engineering Practices (SEP) of the set. This is important and unusual because this SEP is often the first step in an investigation but is also a mechanism through which students should reevaluate results, models, and explanations. “Mayfly Mayhem” showcases that, at the middle school level, students’ questions are grounded not just in curiosity (why does this happen?) but also in science content knowledge and data (based on what I know about X, why did I get this result?).

“Mayfly Mayhem” Is a Short but Rich and Engaging Set of Items

“Mayfly Mayhem” demonstrates how students can engage in and demonstrate multidimensional thinking with just a few questions. While answering these few questions, students must engage in several SEPs and CCCs, in addition to the target DCIs. These dimensions are not the same as those paired in the PE. Students analyze a multifaceted collection of data that includes tables and graphs. The data are adapted from real sources, such as scientific studies, and include the *messiness* from the original data sets. Students must deal with patterns that are not perfectly clean or consistent but that still support valid claims, which allows students to demonstrate higher levels of cognitive complexity in their thinking. Finally, students combine DCIs from different content areas to deepen their understanding and explanation of the phenomenon.

“Mayfly Mayhem” Targets a DCI That Is Difficult to Assess

“Mayfly Mayhem” targets a component of ESS3.C: “Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.” This DCI is challenging because it seems more like a broad concept than a discrete piece of content. In “Mayfly Mayhem,” students do not need to know any specifics about how agricultural practices may impact the environment or how practices and technologies have changed to avoid negative impacts. Students need only to recognize that a decrease in environmental impacts is unusual when the human activity of farming has increased. Students conclude that a technological development or process change is likely responsible for the discrepancy. This is an example of how students could effectively interact with other broad DCIs as well. Specific activities and technological advances make engaging phenomena but will differ from classroom to classroom and student to student. The broad DCI is the common thread that connects the understanding and learning of all students, regardless of the phenomena.

In Summary

Achieving success in teaching, learning, and assessing multidimensional science standards is a team effort involving educators and the education industry. NWEA hopes that this vision of high-quality assessment has highlighted several key areas of assessment design that are invaluable for instructional design:

- equitability as a consideration in all aspects of design
- relevant, high-interest phenomena using elements of the three dimensions to inform alignment
- coherent sequences that lead to evidence-based explanations or solutions
- varying degrees of cognitive engagement required to make sense of phenomena

By continuing to keep these key areas at the forefront of instruction and assessment, the education community can move closer to achieving the vision of science for all.

Appendix: Resources and References

Glossary

- **3-D claim:** description of a task that integrates three dimensions
- **Dimension:** an essential aspect of scientific and engineering education; for standards based on *A Framework for K–12 Science Education*, there are three named dimensions: disciplinary core ideas, scientific and engineering practices, and crosscutting concepts
- **Elements:** statements that provide more detail about the concepts within each dimension that students are expected to understand by the end of each grade level or grade band.
- **Item:** an assessment unit consisting of a stem, answer choice options or interactive manipulatives, and any supplementary information used by students to select a response
- **Item set:** a group of related items; in this document, the term refers to a sequenced set of items that guides students toward making sense of a given phenomenon
- **Key:** correct response in an assessment item
- **Multidimensional:** involves the integration of scientific and engineering content, practices, and crosscutting concepts (or overarching themes), rather than teaching or assessing each dimension in isolation
- **Performance expectations:** examples of what all students should be able to do after instruction; these statements describe tasks that integrate multiple dimensions
- **Problematization:** framing a phenomenon in a way that highlights a puzzling or discrepant feature
- **Scenario:** part of an item that includes a depiction of the phenomenon, as well as other supporting information or data to engage students and prepare them for their task.
- **Stem:** question or directive in an assessment item
- **Task:** this term is used in a general sense in this document to refer to activities or objectives presented to students; it can refer to an item set or a more general classroom or assessment experience
- **Unpacking:** the process of using the NGSS appendices to set parameters for which aspects of the targeted dimensions will be addressed in the item set

Acronyms

- **2-D, 3-D:** two-dimensional, three-dimensional; uses two or three dimensions
- **CCC:** crosscutting concept

- **DCI:** disciplinary core idea
- **NGSS:** Next Generation Science Standards
- **PE:** performance expectation
- **SEP:** scientific and engineering practice

Resources for Phenomena-Based Instruction

1. Sense-Making
2. Phenomena
3. EQuIP Rubric
4. Quality Examples of Science Lessons and Units (based on EQuIP rubric)
5. OpenSciEd Instructional Model
6. OpenSciEd Instructional Materials
7. NSTA Storylines: An educator collaborative that provides NGSS tools
8. NextGenScience at WestEd: Provides support for science programs
9. Instruction and Assessment Resources from NGSS
10. *Preparing Teachers for Three-Dimensional Instruction*. Jack Rhoton, Editor. NSTA Press, 2018.

Accessibility Resources

1. Equity in Three-Dimensional Science Assessments
2. Features of Classroom Culture that Support Equitable Sensemaking (OpenSciEd worksheet for teachers)
3. NGSS Appendix D: All Standards, All Students
4. NGSS For All Students (a book from NSTA Press)
5. STEM Teaching Tools

References

1. NGSS Appendix A: Conceptual Shifts in the Next Generation Science Standards
2. Achieve's Science Assessment Criteria
3. NGSS: An Overview for Principals
4. NGSS Lesson Screener (criteria A–C)
5. NGSS Appendix F: Scientific and Engineering Practices in the NGSS
6. NGSS Appendix G: Crosscutting Concepts
7. NGSS Appendix E: Progressions Within the Next Generation Science Standards
8. NSTA Dimension Element Matrices: DCIs, SEPs, CCCs
9. Compare NGSS to Existing State Standards
10. A Framework to Evaluate Cognitive Complexity in Science Assessments
11. Task Annotation Project in Science: Non-negotiables
12. Achieve's Task Annotation Project in Science
13. Developing Assessments for the Next Generation Science Standards, NRC
14. CCSSO SAIC Assessment Framework for the NGSS
15. A Framework for K–12 Science Education, NRC